JeL: Connecting Through Breath in Virtual Reality

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ABSTRACT

We present *JeL*—a bio-responsive, immersive installation for interpersonal synchronization through breathing. In *JeL*, two users are immersed in a virtual underwater environment, where their individual breathing controls the movement of a jellyfish. As users synchronize their breathing patterns, a virtual glass sponge-like structure starts to grow, representing the level of physiological synchrony between the users. *JeL* explores a novel form of interpersonal interaction in virtual reality that aims to connect immersants to their physiological state through biofeedback, to each other through physiological synchronization, and to nature through connecting with a jellyfish and collaboratively growing a glass sponge-inspired sculpture. We propose that this form of immersive, bio-responsive interaction could ultimately be used to encourage self-awareness, a feeling of connectedness, and consequently pro-social and pro-environmental attitudes. In this late breaking work, we describe the motivation, inspiration, design elements, and future work involved in bringing this system to fruition.

Figure 1: The two jellyfish agents and growing Glass Sponge in *JeL*. The jellyfish respond directly to each user's breathing while the sponge reflects the synchronization of their breath. As the two users progressively synchronize the sponge glows more brightly and grows more quickly.

KEYWORDS

Virtual Reality; Physiological Synchronization; Breath Biofeedback; Social Connectedness; Computational Creativity; Generative Systems

CHI 2019, May 4-9, 2019, Glasgow, Scotland, UK

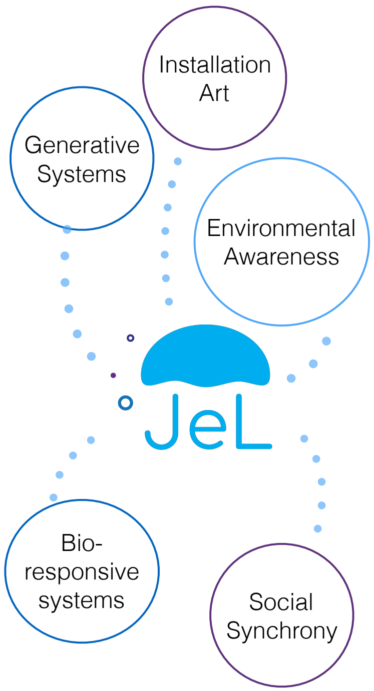

Figure 2: The Fields JeL Builds Upon

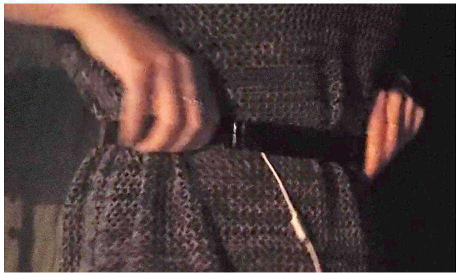

Figure 3: Breathing Sensor being fitted

INTRODUCTION

JeL is an interactive, breath-responsive virtual reality (VR) installation that subtly and playfully encourages users to synchronize their breath to grow a glass sponge-inspired sculpture together (Figure 1). *JeL* builds on work from several areas: bio-responsive systems, interpersonal synchronization, generative systems, and interactive art for environmental protection (Figure 2). While there are many notable works in each of these fields, few examples bring all of these concepts together. *JeL* gives users a unique experience, providing them with access to a physiological dimension of interpersonal interaction that we are not normally aware of. It simultaneously delivers an aesthetically compelling, meditative experience and facilitates the feeling of connection to their bodies, each other, and nature. This work explores how emerging technology and installation art can present a novel approach for tackling social isolation and disconnectedness in our society.

Connecting through Synchronization. When engaging in rhythmic group activities, such as dancing, yoga, choral singing, or marching, people naturally synchronize with each other in an enjoyable and sometimes even euphoric experience that supports bonding between participants. Research in psychology has shown that synchronizing movement and physiological functions can lead to an increased feeling of connection, pro-social behaviour, cooperation, empathy, compassion, and self-esteem [4, 8]; however, few interactive systems have been designed to promote social connection through synchronization. Tarr et al. [14] conducted a study validating that movement synchronization in VR with avatars leads to increased perceived social connection. But, breathing synchronization has not yet been used in VR as a form of interpersonal interaction and collaborative creation.

Interaction through Breath. Breathing has been used as a form of interaction to bring individuals' attention to their own body, to relieve anxiety, and to encourage mindfulness. Some examples of breath-based interaction in VR include *Osmose* [3], *Respire* [11], *DEEP* [16] and *Life Tree* [10]. These applications are designed for a single user and focus on mindfulness and stress reduction rather than collaboration and synchronization. Interactive breath-synchronization has been proposed in *Breeze* [5] (a mobile app) and *Exopranayama* [9] (a tent with reactive projection); however, multi-user interaction in VR through breath synchronization in public setting has not been explored yet.

Connecting with Nature. VR installations can deliver powerful experiences capable of influencing pro-environmental attitudes and behaviour [1, 7]. *Unexpected Growth* [15] is an augmented reality application visualizing the negative effects of humanity on coral reefs. In *JeL*, instead of imposing guilt for the negative impact of humanity on environment, we want to give users a more positive and intrinsically rewarding experience. In *JeL*, immersants connect to jellyfish by controlling the creature with their breath and by synchronizing their breath with a partner, fueling the growth of a glass sponge reef, a metaphor for the collaborative task of environmental stewardship.

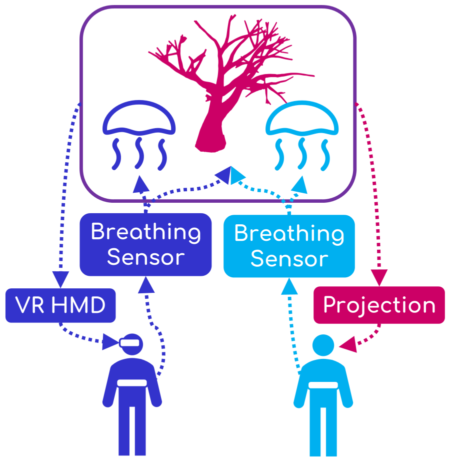

Figure 4: System Diagram. *JeL* is implemented in Unity and uses an HTC Vive, BioSignalsPLUX Breathing Sensor and large-scale projection (6.5 x 3.66 m).

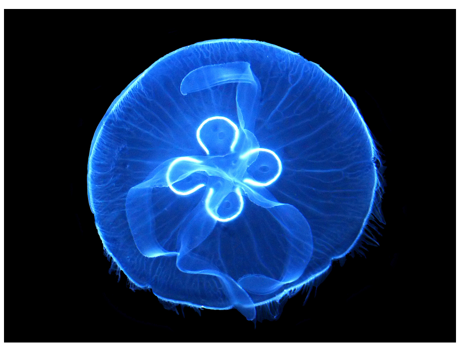

Figure 5: Moon jellyfish ©2008 Hans Hillewaert (licensed under 🅭🅯🄎)

Generative Systems. Computationally generated content allows for unique personalized experiences in virtual worlds. While generative systems are implemented widely for asset and level generation in video games, their use in bio-responsive, immersive environments is still in its infancy [13]. Bio-responsive generative systems can produce complex and intriguing forms of feedback reacting to the user's internal state to drive the creation of the virtual world around them. In *JeL*, we use parametric L-Systems to generate glass sponge sculptures that are created through users' collaboration. The form produced is unique to each interaction and serves as a form of aesthetically satisfying visual biofeedback and a virtual embodiment of the synchronization process between two users.

SYSTEM DESCRIPTION

JeL consists of a virtual environment (VE), viewed by two users through a Head-Mounted Display (HMD) or projection while wearing breathing sensors that are used as input (Figure 3). Within the VE, users see an underwater world with two jellyfish and a growing glass sponge. The projection enables a first step into the VE through the familiar metaphor of looking into an aquarium while the VR HMD lets the user become fully immersed, joining the creatures underwater. Each jellyfish pulses with the breath of the user, moving and glowing in direct response to provide users with clear feedback. As users breathe more in sync, an emerging generative glass sponge structure starts growing and emitting light, indicating progress towards the shared goal of creating a new glass sponge and populating the initially empty reef (Figure 4). *JeL* gamifies synchronization through collaborative production, encouraging physiological synchronization, and enabling a shared experience of internal states.

Inspiration from Nature

Moon Jellyfish (Aurelia Aurita), shown in Figure 5, were chosen as the user's virtual agent for their simple and recognizable form as well as their meditative aesthetic. Moon Jellyfish have previously been used to promote relaxation in *The Meditation Chamber* [12]. While Moon Jellyfish are not bioluminescent, we gave our virtual jellyfish this trait to provide clear feedback of breathing. Unique to British Columbia, Canada, **Glass Sponge Reefs** are formed as new glass sponges grow upon the remaining skeletal structure of older generations [2]. These sponges and the reefs they form are an important habitat for many creatures including those seen in Figure 6 [2]. Not only do glass sponges provide an aesthetic basis for our system, but, by producing these little-known organisms, users can be introduced to the rarely seen deep ocean environment while also potentially gaining a feeling of shared responsibility for its continued sustainability through their collaborative interaction.

Virtual Environment and Mapping

Developing the VE and system interaction followed an iterative design process. Parameter mappings were rapidly prototyped and experimented with to make design decisions. In many cases we found

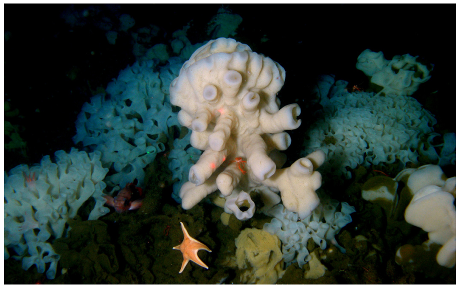

Figure 6: Glass sponges (center: Aphrocallistes vastus; background: Farrera occa) and their inhabitants. Image courtesy of Sally Leys, University of Alberta, and Fisheries and Oceans Canada.

Synchronization Score

$$S = Ae^{\frac{-\Delta fr}{frmax}} + Be^{\frac{-\Delta a}{amax}} + C\frac{cos(\varphi) + 1}{2} \quad (1)$$

$$A, B, C = constants\ A + B + C = 1$$
$$f_r = respiration\ frequency,$$
$$a = normalized\ amplitude,$$
$$\varphi = phase$$

The L-system follows a variable set of rules taken from the following alphabet:

- "F" Move forward a step of length d.
- "[" Save current position
- "]" Resume from previous position
- "-" Rotate θ clockwise from vertical axis
- "+" Rotate θ counterclockwise from vertical axis
- ">" Rotate ω clockwise around vertical axis
- "<" Rotate ω counterclockwise around vertical axis

that producing a cyclic visual and then trying to match our breathing with that visual was useful for quickly identifying parameters for intuitive mappings. Many VR breathing applications map the breathing to the vertical position of the user in VR [3] and place the user in a seated position [11, 16]. We opted instead to externalize the representation, similar to *Life Tree* [10], to make the interaction more apparent and discoverable while inviting a connection between the user and the creature whom they control. Additionally, the two similar jellyfish provide a common identity for users, facilitating the feeling of affiliation. This interaction paradigm works well as a projection while minimizing vestibular conflict in VR, as the virtual character position and visuals align with the actual physical position, rather than diaphragm expansion.

The breathing sensor data is directly mapped to the scale, vertical position, and biolumniescence of the jellyfish. The derivative, breathing rate, is mapped to the jellyfish's animation and a bubble particle system. The jellyfish expands and contracts in sync with the user's diaphragm and floats up while expanded and down while contracted. The jellyfish's swimming animation progresses relative to the breathing rate so that the jellyfish's own movements correspond to those of the user's diaphragm. While jellyfish themselves do not naturally exhale bubbles, we included this to link the jellyfish's actions to breathing, as though the user's breath was being exhaled out of this creature. In all, this results in the virtual creature seemingly breathing in sync with the user.

Visualization of Synchronization. The frequency, phase, and amplitude of each user's breathing is calculated by taking the Fast Fourier Transform (FFT) of each signal. These parameters are then used to compute an overall breath Synchronization Score, S. The frequency and amplitude scores are calculated from the exponential of the difference between the pairs, while phase synchronization is calculated by taking the cosine of the difference between the phases when the dominant frequencies align. The combined Synchronization Score is calculated as a weighted sum normalized between 0 and 1 (Equation 1). The Synchronization Score controls the growth of an L-system based glass sponge. As the users become more synchronized, the glass sponge grows exponentially more quickly and glows more brightly, maximizing when the frequencies, amplitudes and phases are matched. The interaction is designed to last approximately 5 minutes to provide sufficient time for a meaningful experience while making the growth rate noticeable. The resulting structure populates the virtual reef as more people continue to interact with the system. Each time a glass sponge is completed, a new structure is started, allowing users to come and go or to interact as long as they like.

EARLY OBSERVATIONS

A formal study to evaluate the system's capacity to encourage synchronization is planned in the near future. Thus far, we have made some initial observations through our colleagues' and our own interaction with the system during development. There are a number of limitations to overcome in

Anticipated User Journey and Interaction

Initial investigation: Unsure of its interactive nature, users initially approach *JeL* with tentative curiosity. A facilitator offers to help put on a breathing sensor and optional HMD, suggesting that they try to affect the system with their breathing.

Breathing Exploration: The users experiment with their breathing. After a few moments they notice a relation and begin to feel some control. This introspective interaction inspires wonder and further curiosity.

Sponge Growth: Confidently controlling their respective jellyfish, the users play with it. Occasionally they notice an unknown form that begins to light up and grow. As they experiment, they notice it only seems to occur when conditions are just right.

Aha Moment: At some point, the users will have an "aha moment" where the connection between their breathing and the sponge's growth becomes apparent. The users begin to try to breathe together.

Collaboration: Now aware of the capacity of their collaborative actions to stimulate the sponge's growth, the users are motivated to breathe in sync. The sponge grows faster, producing forms that reflect their synchronization and inspiring a feeling of togetherness through collaboration.

End or Repeat: After about 5 minutes, one sponge's growth is complete and a new one begins. The users can continue to grow a new sponge or end their experience.

continuing to develop the system; however, the design decisions made so far have led towards a coherent interaction paradigm which promises to successfully encourage synchronized breathing.

Successes. We have observed a number of important positive outcomes which suggest that the system is functioning as expected. *JeL* works well as a projection and most of the parameter mapping is understandable. The interaction especially suggested the importance of the animation synchronization as users often focus on trying to control this aspect. The visuals seemed to be compelling both in the VR headset and as a projection. The synchronization feedback seems sufficiently clear. The system activates easily enough to encourage investigation without false positives where synchronization is not actually happening. The exponential function gives a progressively better reward for incremental improvements and makes minute differences more apparent as synchronization improves.

Limitations. At the current stage the primary limitation is that the system requires careful attention to the sensor placement and clear instructions to encourage successful interaction. It was difficult to demonstrate the system to a group without being able to go through a rehearsed procedure explaining what to do and what to expect. As a result there is some variance in the success of interacting with *JeL*. In addition, while the public projection seems to work, public VR use is problematic without showing some virtual representation of others in the space, both for safety reasons and for user comfort and enjoyment. To resolve this, we will use an abstract representation of the users' surroundings using the depth map from a Kinect. The current FFT implementation, while fully functional, is a limitation compared to other methods of low frequency detection. We intend to instead implement a wavelet transform which will provide higher resolution at low frequencies without requiring a larger window size. Finally, the current appearance of the L-system needs to be improved to better match the appearance of glass sponges. We will revise the L-system to combine Kaandorp and Kübler's work on producing sponges [6] with Kim Conway's extensive documentation of Glass Sponges [2]

FUTURE WORK

We are continuously and iteratively improving the system to enhance aesthetics and the user experience. Furthermore, we plan to conduct a series of **formal studies** to evaluate the potential and effects of the system. We will formally assess the system's capacity to increase synchronization during and after interaction, as well as its effects on social connectedness and connectedness to nature. JeL will also be made into a **telepresent VR installation**, allowing immersants around the globe to collaborate through multiple concurrent public installations and in private spaces, together populating a large glass sponge reef. We will use a **genetic algorithm** to evolve the rules of the L-System using the synchronization score as a fitness function, allowing the system to adapt and produce aesthetic results which best lead to synchronization. Finally, we will add **other forms of synchronization** such as movement, heart rate and brainwaves to evaluate which are the most effective.

With continued development, *JeL* can be used as an interactive VR installation that enables the collaborative production of a virtual artifact through physiological synchronization. *JeL* is a multi-disciplinary investigation contributing to the intersection of design, art, technology, and psychology. This investigation will expand our understanding of the role of mediated physiological synchrony for social connection and could lead to the development of VR experiences which facilitate the feeling of connection to oneself, to each other, and to nature, ultimately inviting experiences that can contribute to improvements in well-being and pro-social and pro-environmental attitudes.

ACKNOWLEDGEMENTS

This research was supported in part by the Social Sciences and Humanities Research Council of Canada.

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