Where Is The Quiet: Immersive Experience Design Using the Brain, Mechatronics, and Machine Learning

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ABSTRACT

Where Is The Quiet? is a mixed-media installation that utilizes immersive experience design, mechatronics, and machine learning in order to enhance wellness and increase connectivity to the natural world. Individuals interact with the installation by wearing a brainwave interface that measures the strength of the alpha wave signal. The interface then transmits the data to a computer that uses it in order to determine the individual's overall state of relaxation. As the individual achieves higher states of relaxation, mechatronic instruments respond and provide feedback. This feedback not only encourages self-awareness but also it motivates the individual to relax further. Visitors without the headset experience the installation by watching a film and listening to an original musical score. Through the novel arrangement of technologies and features, *Where Is The Quiet?* demonstrates that mediated technological experiences are capable of evoking meditative states of consciousness, facilitating individual and group connectivity, and deepening awareness of the natural world. As such, this installation opens the door to future research regarding the possibility of immersive experiences supporting humanitarian needs.

Author Keywords

Installation, Immersive Experience Design, Machine Learning, Wekinator, Mechatronics, Brain Interface, Feedback, Sound-Art, Interactivity, Wellness, Musical Score, Solenoid

CCS Concepts

•**Applied computing** → **Media arts;** •**Computing methodologies** → *Machine learning;* •**Hardware** → Sensor devices and platforms;

1. INTRODUCTION

One of the pitfalls of living in the twenty-first century, a time defined by the rise of technology and hyperconnectivity, is that there is a shortage of quiet spaces. That is, spaces that are free of distractions. Highway billboards lure eyes towards commercial displays. Phones and computers constantly advertise to users. Social media demands attention and activity. *Where Is The Quiet* (*WITQ*), an immersive mixed-media installation, is intended as a meaningful escape from these distractions.

This installation invites participants to consider the notion of quiet places, both internal and external, as it relates to the individual, the community, and the surrounding world. As such, the primary goal of this experience is twofold: first, to evaluate the potential for technology to improve individual and communal wellness; second, to increase connectivity to the natural world. An individual interacts with the installation by using a brain-computer interface (BCI) that measures relaxation as determined by the strength of alpha wave activity in the brain. Other visitors without the interface take part in the installation by experiencing the accompanying spatialized sound elements and film, which includes footage of landscapes in California, The Adirondack Park, and Vermont. The use of environmental footage is deliberate; it suggests that it is possible to experience the natural quiet of nature through technology.

The installation was exhibited on October 29, 2018 in the WaveCave[1] gallery at California Institute of the Arts (CalArts) for one week. It was composed of film, musical score, brain interface, mechatronic singing bowls, carpet, and meditation cushions. The film and musical score are accessible online on Vimeo[2] and Soundcloud.[3]

2. REVIEW OF RELEVANT WORK

WITQ was motivated by several works in the areas of biofeedback, mechatronics, machine learning, and immersive experience design. With regards to biofeedback, Yoichi Nagashima's exploration of biosensors within the context of interactive performances served as a primer on exploiting this type of data for artistic purposes [11]. Another influential work was Tomohiro Tokunaga and Michael J. Lyons' experiments using brain signals to alter sound and visuals in real-time [14]. Javier Jaimovich was also involved in two notable projects that used biosignals for research and artistic purposes [5, 6]. Lastly, Ryan McGee, et al. produced an audio-visual installation that changed form based on data from the cardiovascular system [10].

Two papers inspired the installation's solenoid-based instrument system. First, a team of artists and researchers at University of Victoria in British Columbia wrote about solenoid implementations for musical expression with a specific focus on robotic drumming [7]. This paper was especially useful for its discussion on how to handle certain issues that arise while using solenoids within a musical context such as timing and reducing mechanical noise. Second, A. Blokkum Flø and H. Wilmers' paper on their sound installation *Doppelgänger* described a methodology for designing networks of solenoid-based sound objects [3].

[1]http://wavecave.calarts.edu/
[2]https://vimeo.com/299370692
[3]https://soundcloud.com/mjmmusique/sets/where-is-the-quiet

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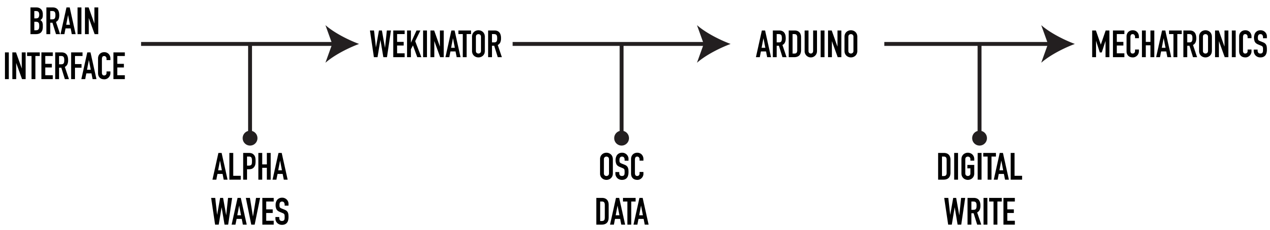

Figure 1: Flow of data throughout the installation.

In the area of machine learning, research in gesture recognition was helpful in devising the installation's interactive system. One such paper by Baptiste Caramiaux and Atau Tanaka presented several implementations of classification and regression models within the context of musical performance and interface design [2]. Another paper by Margaret Schedel, et al. described how a band used machine learning during live performances [13]. Furthermore, Cornelius Pöepel, et al. introduced a neural network system for tracking singing gestures to afford non-vocalists the experience of singing without actually vocalizing [12].

Many papers published in the NIME community on interactive installations were helpful in designing *WITQ*'s user experience. Brennon Bortz, et al. produced a public installation called *Luminous Kite Lanterns* that responded to participants' movement [1]. Benjamin Knichel, et al. also produced a public installation that invited users to engage with sound objects within a space [8]. Another installation by Anthony T. Marasco scraped critiques of musical compositions from the web and used the content of these reviews as the basis for sound modification [9]. Lastly, Georg Hajdu, et al. described how installation art within hospitals might improve patient recovery time and well-being [4].

Finally, several artistic works outside of academia motivated the design and functionality of this installation: Olafur Eliasson's *Reality Projector* (2018), Céleste Boursier-Mougenot's *clinamen v.3* (2012-ongoing), Pipilotti Rist's *Worry Will Vanish* (2016), Fidelia O. Lam's *LMNSCNCE* (2017-2018), and the Gamelatron.

3. SPATIAL DESIGN

The WaveCave gallery includes several features that made implementing the installation's spatial design possible: a square shape with four walls measuring approximately 18 ft. across, two hanging projectors, four speakers located inside a ceiling grid, and a control room containing a computer and an audio mixer.

To prepare the space for the installation, the projectors were arranged in such a way that their images were directed towards two perpendicular walls with the corner acting as a point of symmetry. A seating area, designated by a carpet and several meditation cushions, was subsequently placed in the center of the room. It was intended that the participants sit in the seating area so that their field of vision was consumed by the projected images thereby creating an immersive visual experience.

Adding to the immersive quality were two spatialized audio components. First, an original musical score was played through each of the four speakers located in the ceiling. Second, three self-playing singing bowls controlled by a series of devices and sensors were placed surrounding the seating area. Figure 1 shows the flow of media and data information throughout the installation and Figure 2 shows the assembled space.

Figure 2: Completed installation in the WaveCave gallery.

4. MECHATRONICS

A mechatronic system designed to play three Tibetan singing bowls functioned as the core spatialized audio component of the installation. This system emulated an experience known as a sound bath. In a sound bath, a group of participants lies down in a room and a facilitator plays an assortment of instruments such as gongs, wind chimes, and singing bowls. The diffusion of sound washes over the group and evokes deeper states of consciousness.

However, there are two notable issues with sound baths such as the one previously described. First, facilitators are often localized within a corner of the space. This means that participants are subject to a varying sound experience depending on where they choose to lie down. Second, the number of instruments playing at any given moment is limited by the physical capabilities of the facilitator(s). *WITQ*'s mechatronic system addresses these issues by distributing the sound-objects equally throughout the space and assigning the performance to a system capable of supporting multiple instruments simultaneously.

Each singing bowl was placed on top of a custom laser cut plywood structure. A large push-pull 12V solenoid,[4] which was responsible for striking the instrument, was also mounted to the structure. Figure 3 shows a three-dimensional rendering of the plywood structure while Figure 4 shows the completed instrument.

The system's timing was dictated by the BCI, in this case a Muse[5] brain sensing headband, and an Arduino[6] microcontroller located in the control room. The Muse device includes seven calibrated electroencephalography (EEG) sen-

[4]https://www.adafruit.com/product/413
[5]https://choosemuse.com/
[6]https://www.arduino.cc/

Figure 3: 3D rendering of the solenoid instrument structure.

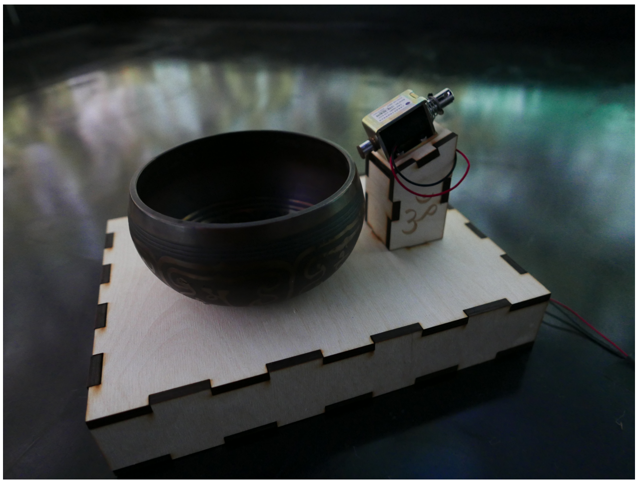

Figure 4: Realized solenoid structure.

sors and a gel-free electrode system that record information about the wearer's brainwave activity in real-time. There are several reasons that this device was chosen for the installation. First, Muse devices are affordable and accessible. Second, they transmit data as Open Sound Control[7] (OSC) messages via Bluetooth, which simplifies the process of connecting this device to other software. Third, they produce an extensive list of data streams including several that concern an individual's sense of calm. Finally, they internally handle noise and supply a reference signal in order to improve the accuracy of the reading. While a review of these processes is outside the scope of this paper, further information is available in the manufacturer's documentation.[8]

After the BCI registered a high enough level of alpha waves, which loosely correspond to states of relaxation, the microcontroller triggered a digital-on message to an L298N motor drive controller board. The board then passed the necessary power to the solenoid via a 220V power supply hooked up to a wall outlet. This resulted in the solenoid armature extending outward to meet the surface of the singing bowl. A digital-off message ended the flow of power to the solenoid causing the armature to retract to its resting position. This series of messages was sent to each instrument sequentially with a 15 second interval between each series. The long interval time allowed the sound of each singing bowl to naturally come to silence before the next singing bowl was struck. Figure 5 shows a schematic for the mechatronic system.

5. MACHINE LEARNING

Wekinator,[9] an open-source machine learning program, analyzed, averaged, and interpreted the data from the BCI. The software then provided real-time feedback to the user about their mental state. Muse Monitor,[10] an iOS application, was responsible for forwarding OSC messages to Wekinator from the BCI. Once Wekinator received the messages, the values were averaged using a short time window to smooth the output. By training Wekinator to identify and respond to calm states based on the strength of the user's alpha waves, the installation was able to provide feedback by triggering the singing bowls.

[7]http://opensoundcontrol.org/introduction-osc
[8]http://developer.choosemuse.com/tools/available-data
[9]http://www.wekinator.org/
[10]https://musemonitor.com/

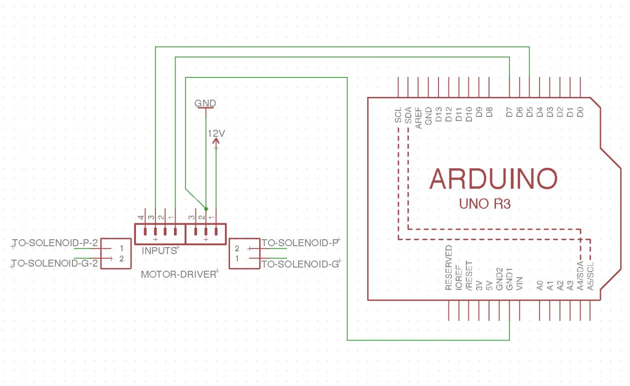

Figure 5: Mechatronic instrument system schematic.

The feedback signaled to the user the arrival of meditative states of consciousness as reflected by the sensor data. This signal was intended to motivate the user to further increase their level of relaxation in order to the sustain the activity from the singing bowls. Figure 6 shows a diagram outlining the installation's feedback loop.

6. USER RESPONSE

The feedback from visitors was generally favorable. During two critiques, participants described the space as tranquil and inviting. Additionally, they expressed feeling peaceful upon exiting the experience. In some cases, individuals admitted to spending several hours in the space due to its overall energy, despite the film and musical score being on a 15 minute loop. However, several visitors expressed discontent while in the space noting that the film's cinematographic style, which was entirely static except for scene changes, was distressing.

With regards to the BCI and feedback system, most participants found the system easy to use. To better assist visitors, a series of instructions on how to interact with the installation was posted outside the gallery entrance. The instructions described how to use the BCI as well as how to enjoy the space without the headband. Several users also stated that the feedback from the singing bowls was helpful in deepening their state of relaxation. Others, however, described the opposite effect; the sound and noise from the mechatronic system distracted them.

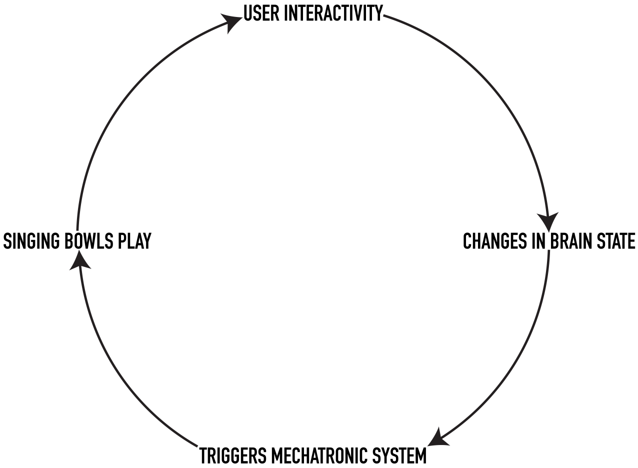

Figure 6: Feedback loop.

7. CHALLENGES AND LIMITATIONS

The mechatronic system was the most challenging aspect of implementing this installation. A great deal of time and attention was required to develop a system that produced a particular tonal characteristic with as little mechanical noise as possible. To address this issue, each solenoid was fitted with several thin layers of felt; one at the solenoid's tip and another between the armature and its body. Not only did the fitting reduce the amount of perceptible noise resulting from the solenoid's motion but also it softened the attack of each note.

Two further enhancements to the mechatronic system optimized its sound and playability. First, the timing of each digital-on message from the Arduino was adjusted to suit the desired tonal characteristics. For this particular system, 25 milliseconds produced a quick transient followed by a long resonant decay. As a juxtaposition, a slow digital-on message extended the armature excessively and diminished the decay after the strike while a fast message restrained the arm from reaching the singing bowl at all.

8. CONCLUSIONS

WITQ is a space for individuals and groups to experience quiet contemplation. To this end, this installation demonstrates that technology is capable of connecting individuals, not only to themselves and others but also to the surrounding world. The feedback element of the installation supports the intended experience by encouraging mindfulness.

Human and environmental awareness will remain at the heart of this experience during future iterations. The power of technology as a tool for improving well-being and facilitating group connectivity is a growing area of interest for artists and researchers. Further exploration may yield deeper truths about the human condition and how technology might go about serving humanitarian needs in the future.

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