Resonant Waves: Immersed in Geometry

Richard Grillotti, Andy DiLallo and Angus G. Forbes

ABSTRACT

This article introduces *Resonant Waves*, a work of interactive new media art that incorporates cymatic patterns into an immersive installation. The authors describe their research and design process in creating *Resonant Waves*, and they discuss technical details about the installation, highlighting innovative aspects of the project and contextualizing the project in terms of previous cymatics research and related artistic explorations of complex phenomena. Finally, the authors discuss audience reaction to different installations of the project and identify directions for future research in immersive cymatics.

Richard Grillotti
Artist
Digital Arts and New Media
University of California,
Santa Cruz
1156 High St
Santa Cruz, CA 95064, U.S.A.
rgrillot@ucsc.edu.

Andy DiLallo
Artist
Digital Arts and New Media
University of California
Santa Cruz
1156 High St
Santa Cruz, CA 95064, U.S.A.
adilallo@ucsc.edu

Angus G. Forbes
Researcher
Department of Computational
Media
University of California
Santa Cruz
1156 High St
Santa Cruz, CA 95064, U.S.A.
angus@ucsc.edu

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Resonant Waves is an art-science project that reveals and celebrates how sounds can form complex symmetrical shapes and patterns. This multisensory artwork generates and processes wave interference patterns that are translated into dynamic geometries across different modalities. Participants simultaneously *hear*, *feel* and *see* the patterns created when a carefully selected range of sound frequencies generate motion in water. While sitting inside the installation—which consists of a projector, an armchair with attached bass transducers, colored ring lights and a camera aimed at a dish of vibrating water—participants see visual images of the motions projected onto a screen and feel vibrations that are amplified to create a somatic representation of the sounds that resonate throughout participants' bodies. By adjusting various sonic parameters, participants interactively explore the connection between sound and shape and are encouraged to observe how these immersive patterns affect them physically, mentally and emotionally. Figure 1 shows an image of the *Resonant Waves* installation.

Fig. 1. Photo from a recent exhibition of the *Resonant Waves* project. The three main elements of the piece are the sounds created through user interaction, the visualization of the cymatic process projected in front of the participant and the somatic vibrations within the chair that the sounds produce. (Photo © Richard Grillotti)

Background and Related Work

The visualization of sound vibrations is commonly referred to as *cymatics*, a term originally coined by Hans Jenny in 1967, derived from the Latin words *kyma* (wave) and *matic* (matter). Cymatics explores how sound waves demonstrate visible physical structures when they vibrate within fluid and particle mediums, such as water or sand [1].

As noted by Hans Jenny and John Stuart Reid, the ability of sound vibrations to form patterns in materials has been observed by many investigators, including, notably, Leonardo Da Vinci, Galileo, Robert Hooke and Michael Faraday [2,3]. Ernst Chladni's book *Discoveries in the Theory of Sound* (1787) presents a thorough taxonomy of these patterns, now known as Chladni figures [4]. Chladni's figures were transcribed from experiments using sand placed on top of resonant brass plates of various shapes and sizes, which he then "played" with a violin bow, causing the sand to form different geometric patterns depending on where on the edge of the plates the bow was drawn.

An early example of creative work made using a cymatic process was presented in 1891 by the singer Margaret Watts Hughes, who created a series of "Voice-Figures" using an apparatus she invented called an *eidophone*. Consisting of an elastic membrane stretched over a tube, pipe or drum, with various materials placed on the membrane, including sand, lycopodium powder, water, milk and colored glycerin, the eidophone is played by a person singing into a small tube, causing the material to rearrange into pleasing patterns [5].

Hans Jenny describes numerous cymatics experiments using different frequencies and media, exploring a wide range of vibrational behaviors and noting the fascinating relationships between sounds and images: "In attempting to observe the phenomena of vibration, one repeatedly feels a spontaneous urge to make the processes visible and to provide ocular evidence of their nature" [6]. Moreover, Jenny finds that these geometric wave interference patterns occur even at microscopic scales: "Cymatic effects [. . .] can be clearly recognized even after the original has been magnified several hundred times. We realize that these figures and processes appear in every dimension" [7]. A main goal of our project is to highlight the subtleties of these patterns by enlarging them using digital projections and to translate the patterns into multiple modalities simultaneously [8].

Recent work by Linden Gledhill uses high-resolution microscope photography to capture the beauty of various materials including ferrofluids, prismatic liquids, crystals, snowflakes and butterfly scales. In his work on cymatics, Gledhill makes use of high-speed cameras and custom macro rails that can record several thousand frames per second to visualize these patterns. Through this work, Gledhill finds that the temperature of water affects how the wave formations appear, even when producing vibrations at the same exact frequency and using the same container size [9]. Rather than capturing physical manifestations of cymatic vibrations, researchers John McGowan, Grégory Leplâtre and Iain McGregor have developed a tool called CymaSense that uses computational models of cymatic behavior to generate visualizations; they propose that cymatic patterns may have a therapeutic effect [10]. Musician Nigel Stanford has also produced performative compositions with cymatic accompaniments, using mediums including salt, water, fire, electricity and ferrofluid [11].

In addition to drawing inspiration from early and contemporary experiments in cymatics, our design of *Resonant Waves* builds on previous artistic research by Richard Grillotti, in which he investigates energy and magnetism and reveals physical processes and perspectives that are ordinarily unseen or invisible. Grillotti's earlier projects include *Magnetic Attraction* (1996), which reveals magnetic fields using iron filings and visualizes magnetism used to levitate magnets in mid-air, and *You Are Here (Sort Of)* (2018), which uses virtual reality to "shrink" the viewer into a range of unusual spaces, such as inside children's toys or inside appliances, allowing the viewer to gain normally unattainable perspectives of the world.

More broadly, *Resonant Waves* is thematically related to creative projects that translate science into spectacle [12]. For example, artists Mark Boyle and Joan Hills began working in the 1960s with performative psychedelic light projections displaying chemical reactions; their 1966 piece, *Son et Lumiere for Fire and Water*, features "chemical reactions including evaporation, corrosion, combustion and effervescence" [13]. Similarly, artists Evelina Domnitch and Dmitry Gelfand think of their work as "phenomenological investigations" into potential relationships between perception and consciousness; their 2003 installation *Camera Lucida (light chamber)* features visual patterns of light released inside of imploding gas bubbles [14]. In a series of ferrofluid works from 2001 to the present, Sachiko Kodama and Minako Takeno manipulate magnetic fields in surreal and hypnotic ways, encouraging the audience to interact with the work, such as in *Protrude, Flow*, where sound influences the magnetic fields that create the sculptural forms [15].

Project Details and Design Process

Resonant Waves—a collaborative artwork by Richard Grillotti and Andy DiLallo—is an interactive installation that consists of an armchair with two powerful vibrating bass transducers attached, a projection screen, two speakers, a camera, two RGB ring lights and a water dish. The installation provides a multisensory display of cymatics generated in real time through user interactions. Participants are invited to sit down in a comfortable cushioned armchair and interact with the installation via controls—buttons, a slider, a trackpad and a touchscreen color wheel—that change various sound and color parameters. These controls, made from preexisting commercially available products, are set strategically within the custom-made arms of the armchair. Two larger speakers are mounted closely to the left and the right of the chair, aimed directly at one another. The chair faces a circular projection screen, which displays a live video feed of the wave activity in a water dish. The dish is secured to a smaller horizontal speaker on a stand, about 4 ft off the ground. Two different-sized colored ring lights are mounted directly above and perpendicular to the water dish to illuminate the wave patterns from the camera's point of view; the ring lights also cast ambient light around the water dish, ensuring the cymatics capture can be easily seen by the audience and encouraging viewers to enter the installation and investigate how the patterns are created. A primary goal of *Resonant Waves* is to prominently display the live generation of cymatics in water in real time, allowing visitors to see that this is the source of the visuals appearing on the projection screen and make clear the connection between the sound tones they hear and the patterns in the water. Figures 2 and 3 show examples of different configurations of the installation.

Fig. 2. A young participant explores the cymatic connection between sonic parameters and visual output in the *Resonant Waves* installation. (Photo © Zoe Sandoval)

We carefully considered the arrangement of all the elements of the installation in the 16 × 16 ft space. First, we knew the space would need to be relatively dark to enhance the brightness and saturation of the projected cymatic visuals. The colored ring lights provide sufficient ambient light for the visitor to navigate their way around the installation. The 4 ft white circular projection screen displaying the colorful, dancing, fluid geometries draws the visitor in. The vibrating chair faces the screen from a few feet away. Two speakers mounted on 4 ft tall stands are directed at the participant sitting in the chair from the left and right sides at a distance of around 2–3 ft. The audio is played at a moderate volume but is loud enough for those nearby to hear in any size room. The audio experience does, however, improve for both the bystanders and the participants when the project is installed on its own in a smaller enclosed space, becoming more of a sound chamber containing and reflecting the sound around the room.

Mounted directly behind the chair, a small water dish on a speaker is on display, standing about 4 ft off the ground, along with adjustable colored ring lights placed 2 ft directly above the dish. The colored lights make the live generated wave patterns in the water dish visible as

Fig. 3. Close-up of a participant engaged with the *Resonant Waves* installation. (Photo © Richard Grillotti)

a secondary focal point for the installation. By setting the water dish behind the chair, we allow bystanders who are not in the chair to directly witness this natural phenomena of sound generating complex symmetrical, geometric, mandala-like patterns live; when we eventually exhibited *Resonant Waves*, we found that many bystanders were amazed to discover that sound vibrations can produce physical shapes in this way. At first, many participants believed that the visuals were computer-generated; they were surprised to learn that the visual projections were made by sound passing through water.

Resonant Waves thus functions as an immersive experience for the individual sitting in the chair controlling the frequency parameters, and it also serves as a sound-and-light-projecting instrument that can be appreciated by a larger audience. The (sitting) participant can influence the sound being produced, which also generates the projected visuals and the deep vibrations that can be felt when sitting in the chair. The participant can become familiar with how to "play" the artwork and can learn to produce their own patterns in the water, according to their mood and preferences. The artwork becomes a feedback loop, with the user making adjustments to the sound, changing the patterns and vibrations in their body, further affecting how they interact with the installation.

Resonant Waves was created over a yearlong period, and the creative process included substantial research and engineering related to generating, controlling, capturing and translating cymatics behavior. Moreover, considerable effort went into designing the immersive multisensory experience, and many of the original concepts turned out not to be effective in practice, forcing us to change direction. For example, some of the original prototypes used virtual reality or augmented reality to immerse participants visually within the cymatic patterns. While the visual outputs of these initial experiments were quite appealing, it became clear that something was missing and that the work would be more immersive if it incorporated a somatic representation of cymatics. Following this realization, we took the project in a new direction by incorporating physical vibration into the experience, and we investigated how vibrational patterns affect the whole body, not just the eyes and ears. The armchair became a central focus of the installation, and we began to think of the piece as a synesthetic space in which a participant would experience the vibrational patterns across multiple domains in an integrated way [16]. Figure 4 shows examples of an initial concept design for the project.

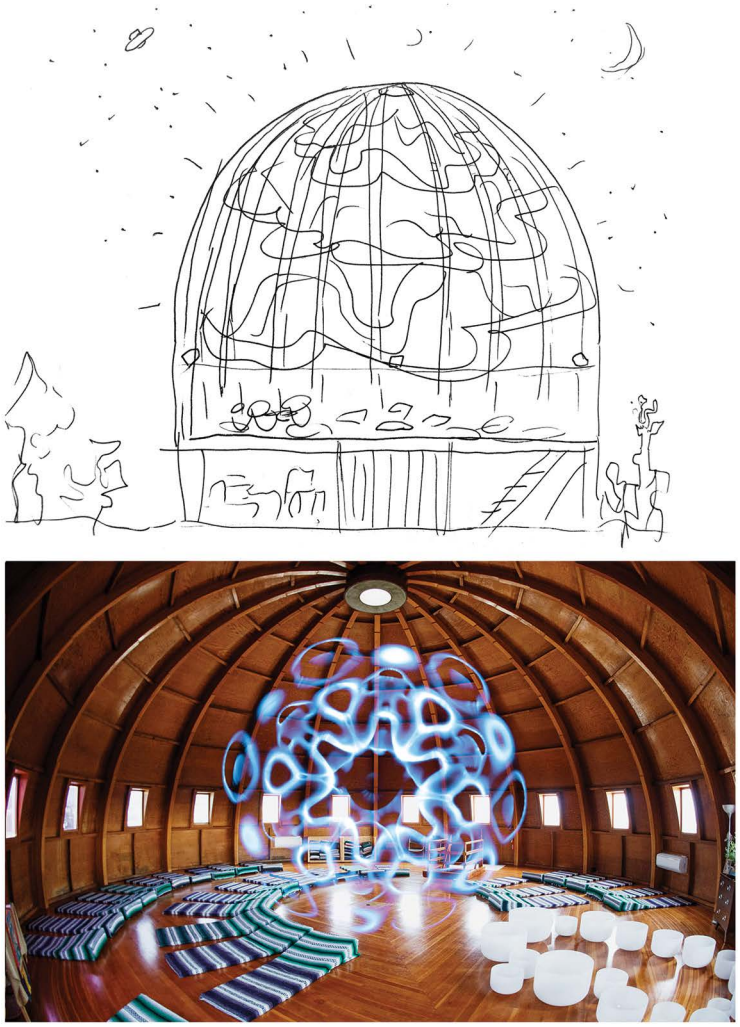

Fig. 4. Sketch and mock-up of an initial prototype created during the design process for the *Resonant Waves* installation. This version was ultimately not used since it did not incorporate a somatic component. (Sketch © Richard Grillotti. Photo © integratron.com and Richard Grillotti.)

Sounds—The sounds that the piece produces are created using a custom Max Audio patch, which is controlled by the participant using physical inputs. These sounds are pure sine waves ranging from 30 Hz–60 Hz, which the user adjusts freely with the slider that is embedded in the armchair. Using these controls, the participant can blend together harmonics of the major third, major fifth and upper octave of the current frequency, which is selected via a trackpad. Additionally, an arcade-style button adds in a 0.5 Hz frequency offset, which generates a natural pulse using binaural beats. We carefully considered these sounds

and refined and simplified the control options over many months of testing and feedback, so that the piece was easy to engage with and did not require prior information or instruction. Ultimately, we were able to design a comfortable experience for the participants, in which the pitch of the sine waves did not become grating (we set the maximum pitch to 120 Hz) and sounds did not become overly discordant, dark or chaotic when users controlled the harmonics via the trackpad. Figure 5 shows a close-up of the controllers embedded in the armchair.

Visuals—The cymatic patterns generated in the water dish are captured by a camera suspended directly above and perpendicular to the water dish and are output to the circular white projection screen that is directly in front of the participant sitting in the armchair. The smaller ring light, mounted directly on the lens of the camera, always remains a warm orange color, while the larger variable RGB bluetooth ring light can be controlled using a touchscreen color wheel interface that is built into the left arm of the chair. The participant can adjust the color combinations to influence the overall mood of the experience. Figure 6 shows a photo of the installation with different colors but using similar vibrational settings. Figure 7 shows a close-up of the wave patterns in the vibrated water dish.

Somatics—The inclusion of vibrations in the installation helped to create a compelling, immersive cymatic experience. By providing the means for the participant to deeply *feel* the sound that they are simultaneously hearing and seeing, we were able to cultivate a potent and compelling experience of sound and cymatics and provide a new form of agency to the participant [17]. During the design phase, we decided to cap the low Hz range to 30 Hz, to create a powerful yet comfortable vibration in the chair, as anything below that range caused a few participants to comment negatively on the intensity of the vibrations. Specifically, the deep vibrations are generated by passing the audio signal—which have the same frequency as those that are simultaneously sent to the water dish speaker and the room speakers—through two powerful ButtKicker bass transducers attached to the bottom and back of the armchair.

Audience Feedback and Future Work

Resonant Waves was recently exhibited at *Receivership*, UC Santa Cruz's Digital Art and New Media program MFA thesis exhibition, as well as at the *UCSC 2019 Games Showcase*, where it received two awards, one for originality and one for excellence in audio. It was also featured in *Binary Salon 13* (www.binary.salon) in San Francisco at *Botanica* (www.botanicasf.org), organized by Jeff Whitmore and John Mitchell in collaboration with the artist Marpi (www.marpi.studio). The project is currently installed

Fig. 5. Close-ups of the sonic controllers used to generate the cymatic outputs built into the customized armchair in the *Resonant Waves* installation. (Photo © Matthew Ragan)

Fig. 6. Stills of the visual cymatic outputs from the *Resonant Waves* installation, at different frequencies and with different light color combinations. (Photo © Richard Grillotti)

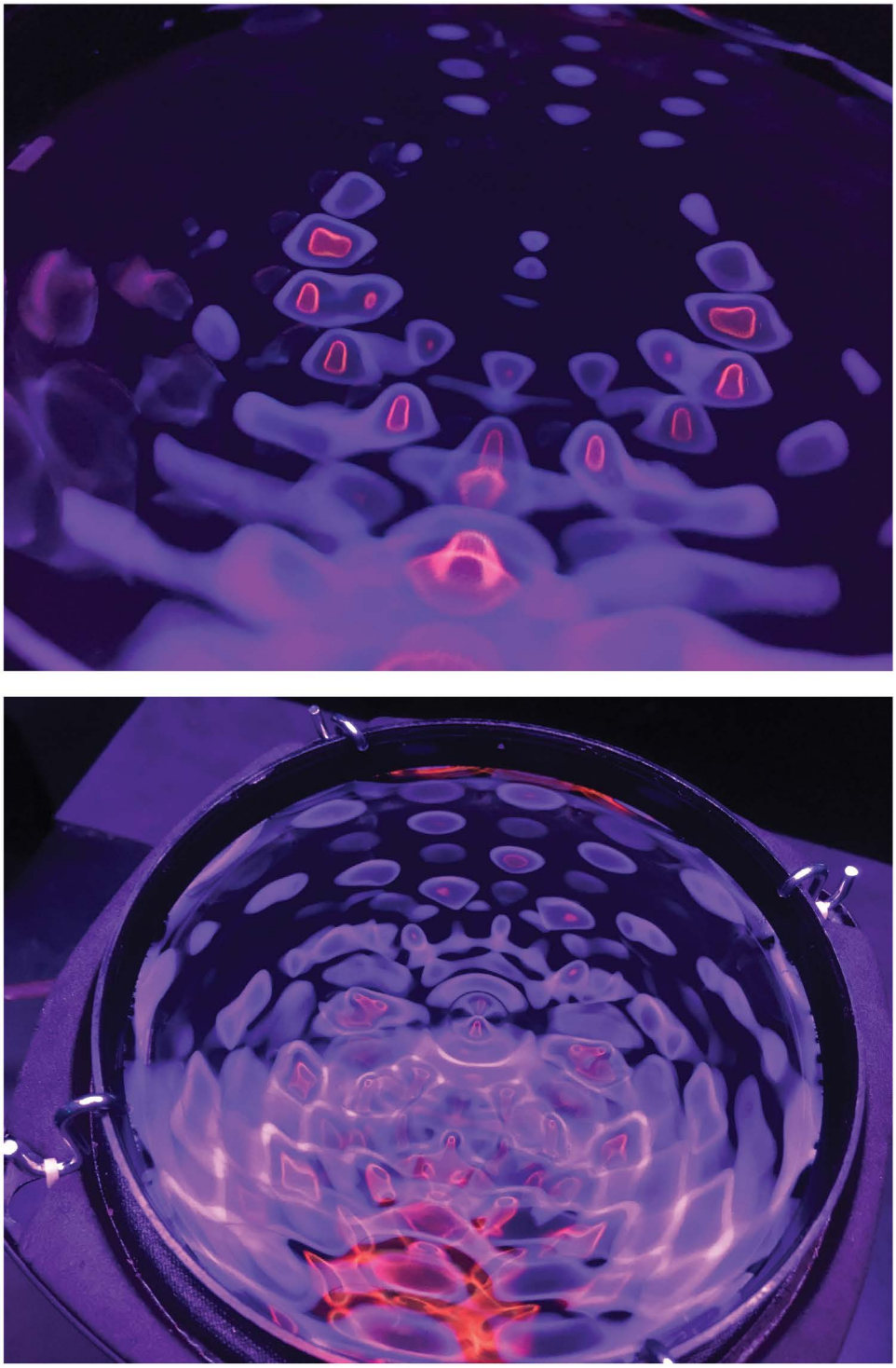

Fig. 7. Close-up of wave patterns in the water dish generated through sound in the *Resonant Waves* installation. (Photo © Richard Grillotti)

in Pasadena, California, for private viewings and continued development and refinement and will be showing at different spaces and events in the Los Angeles area throughout 2020.

In order to gather feedback from participants, we made a guest book available throughout both the *Receivership* exhibition and *UCSC Games Showcase*, in which visitors could leave comments about their experience. Richard Grillotti also hosted the piece for the majority of its time on display, speaking with many visitors as they explored the piece and having detailed conversations with them following their encounters with the installation. We were pleased that many participants indicated that they had feelings of relaxation, reduced stress and anxiety, alleviation of physical aches and pains, increased mental clarity, joy, recognition, awe and wonder. The realization that what they were seeing on the screen was simply sound passing through water in a dish resting on a speaker was a revelation to most of the visitors, and this new discovery made the experience much more meaningful for them. If a visitor did not at first see the physical water dish before sitting in the armchair, they often assumed the visuals were advanced computer-generated graphics; they were surprised once they realized that it was a physical system and became intrigued to find out more about the cymatic process once they realized the connections between the visuals, sounds and vibrations. Some visitors seemed to be "naturals," able to produce stable symmetrical geometric patterns on the water with ease, while others initially had greater difficulty creating stable patterns and instead generated more chaotic, asymmetrical waves. One visitor indicated that they felt overstimulated, and another told us that they did not enjoy the deeper vibrations and the rapidly flickering light reflections that some frequencies produce. Of course, we made sure that visitors were warned in advance of entering the installation so that those affected by rapidly flashing lights would not attempt to experience this piece.

Through feedback from and interaction with visitors during and after their time engaging with *Resonant Waves*, we explored many ideas for refining or adding to the project. Some possibilities we would like to explore in future iterations

include incorporating more vibration points in the armchair for a more full-body immersion, using a more intricate lighting setup that offers more visualization options, offering high-quality headphones for a more personalized audio experience, adding more options for adjusting the intensity of the vibrations and sound levels, including controls for zooming into the projected image and, finally, making a version that lets two or more visitors interact with the experience collaboratively.

We were especially pleased to have the mathematician and chaos theorist Ralph Abraham provide feedback. Abraham collaborated with Hans Jenny on cymatics in the 1960s, and he offered us useful suggestions about how to gain greater control of the cymatics. For example, he told us that by using a crystal dish (instead of a plastic petri dish), we could enable more precise control of the wave patterns in the fluid, since the crystal would reduce the vibrations in the material. He also shared that he and Jenny used a glycerine-water mixture for optimal results, harkening back to the early experiments by sound artist Margaret Watts Hughes.

Based on audience feedback, we believe that the multisensory experience created by *Resonant Waves* could have benefits in the area of health and wellness, offering individuals a positive and therapeutic experience. This could potentially include benefits for individuals with particular disabilities, such as visual or hearing impairments. One visually impaired visitor—Gordon Fuller, nephew of physicist Buckminster Fuller—told us that he found the installation to be "an extraordinary experience." He reported that the vibrations enabled him to "see" color in his mind's eye. This feedback has inspired us to develop future iterations with greater accessibility in mind. We plan to conduct further research to explore the range of physical and mental effects on participants.

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