Fluito: Towards Understanding the Design of Playful Water Experiences Through an Extended Reality Floatation Tank System

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Water's pleasant nature and associated health benefits have captivated the interest of HCI researchers. Prior WaterHCI work mainly focused on advancing instrumental applications, such as improving swimming performance, and less on designing systems that support interacting with technology in water in more playful contexts. In this regard, we propose floatation tanks as research vehicles to investigate the design of playful interactive water experiences. Employing somaesthetic design, we developed a playful extended reality floatation tank experience: "Fluito". We conducted a 13-participant study to understand how specific design features amplified participants' water experiences. We used a postphenomenological lens to articulate eight strategies useful for designers aiming to develop digital playful experiences in water, such as designing to call attention to the water and designing to encourage breathing and body awareness in water experiences. Ultimately, we hope that our work supports people to be playful and benefit from the many advantages of being in water.

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2573-0142/2023/11-ART410 $15.00
https://doi.org/10.1145/3611056

CCS Concepts: • **Human-centered computing → Interaction paradigms**.

Additional Key Words and Phrases: water, floatation tank, flotation pod, extended reality, WaterHCI, water activities, playful experience, somaesthetic, postphenomenology

ACM Reference Format:
Maria F. Montoya, YuYang Ji, Ryan Wee, Nathalie Overdevest, Rakesh Patibanda, Aryan Saini, Sarah Jane Pell, and Florian 'Floyd' Mueller. 2023. Fluito: Towards Understanding the Design of Playful Water Experiences Through an Extended Reality Floatation Tank System. *Proc. ACM Hum.-Comput. Interact.* 7, CHI PLAY, Article 410 (November 2023), 28 pages. https://doi.org/10.1145/3611056

1 INTRODUCTION

Interactions in aquatic environments are increasingly gaining traction in human-computer interaction (HCI). This "WaterHCI" [34, 79] sub-field is concerned with designing interactive systems for water activities. The resulting systems have, so far, mainly focused on supporting instrumental aspects such as improving athletic performance in water. This has sparked efforts to advance the field by also considering experiential aspects like playful water activities. Although water is a treasurable resource, it has not yet fully profited from the benefits of digital technologies in aquatic play [99]. We find that despite maritime and terrestrial technological advancements, only a limited amount of research has explored the synergistic potential of technology, water, and humans for enhanced playful user experiences. We believe it is the right time to begin exploring this potential since prior work demonstrates that encouraging the practice of water activities can positively influence people's mental and physical health [40, 90], create sustainability awareness [48, 96], and help people to re-connect with their water-based cultural heritage [29, 104]. The time is ripe to do such aquatic investigations now, as more and more interactive technology is getting smaller (useful for travel to water environments), more affordable (useful for users outside technical domains, such as water sports enthusiasts) and water-proof (useful for technology engagement use around, and in water). Therefore, to begin exploring the design of playful water experiences, we use a floatation tank as a research vehicle to further our understanding of the design of playful water experiences. A floatation tank (Fig. 1), or sensory deprivation tank, is a bathtub filled with water warmed to skin temperature (35 degrees Celsius) and saturated with Epsom salts (approx. 20%) to increase water density (1.23 g/cm3) and support floatation [72]. It affords a heightened sense of weightlessness, calmness, and relaxation. Furthermore, the controlled body of water more easily accommodates technological implementation and facilitates repeatable design explorations (when compared, for example, to an open water environment).

Our floatation tank work builds on somaesthetic design methodologies, aiming to bring our body close to the water and enrich the associated experiences [53, 55, 121], all while adding game design elements to facilitate a playful experience by encouraging exploration, relaxation, and captivation [73]. Our resulting "Fluito" design is a novel extended reality (XR) prototype within a floatation tank. The experience involves air pumps and a virtual reality (VR) headset delivering a virtual environment controlled by heart rate (HR), breathing, and slight head movements (Fig. **??**). We conducted a study to understand participants' experiences. Thematic analysis [28] revealed four themes on the question: How do we design playful water experiences in floatation tanks?. These themes supported the conceptualization of postphenomenological "Soma(body and mind)-Technology-Water" relations [100], describing how technology mediates participants' interactions with the environment, in our case, the water. Postphenomenological relations describe how humans use technology to shape their relationship with the world, originally proposed by philosophers Ihde [56, 57] and Verbeek [51, 100, 126]. Through our analysis via this lens, we propose that when

Fig. 1. Participants inside Fluito's floatation tank wearing the heart rate sensor, the virtual reality headset and experiencing Fluito's bubbles delivered through the air pumps' hoses attached to the tank's walls

we design water interactions, we need to consider technology as an amplifier, supporter, facilitator, and encourager of perceptions and experiences in water.

Our contribution is four-fold: an original design of the "Fluito" system; an articulation of the user experiences with a playful XR floatation tank system to inspire practitioners to create novel floatation sessions; an understanding of the design of interactive components that facilitate certain user experiences through a postphenomenological lens, valuable for WaterHCI researchers aiming to understand the interaction between the soma (body and mind), technology, and water; and six considerations suitable for interactions designers aiming to create future playful water experiences. The aim is that this work supports people to be playful in water and profit from water's many benefits.

2 RELATED WORK

2.1 Water interactions in HCI

WaterHCI addresses how HCI engages with water [34] and commonly explores the human-technology-water intersection in water sports [33, 71, 101] and water as an interface between humans and computational systems (fluidic interfaces) [39, 46, 61]. However, while there are taxonomies addressing the possibilities for designing such systems [79, 99], WaterHCI user experience research is still only emerging. Moreover, where water interaction design is specifically for playful purposes [95], prior work focuses mostly on experiences with water but not in water.

2.2 Playful water interactions

Play, the emerging joy and pleasure from engaging in activities in an unfamiliar way [73, 118], has occurred in water settings for a long time. Nichols [90] suggests that water facilitates play, since how we interact with water differs from interacting with air in most of our land-based activities. Moreover, the enjoyment of the aesthetics of water can encourage affective engagement [90] (which is important to foster water care), while this affective engagement has been highlighted as a key component of digital play [18, 73]. In addition, playful water activities have proven to improve people's mental and physical health [40, 90]. However, playful water interactions have not benefited from digitalization to the same extent as land play [99]. Nevertheless, efforts by Pell et al. [95] and Raffe et al. [99] showed research interest in digital water play. Clashing et al. [35] reviewed different recreational systems to examine the interaction between water and humans. In particular, we note that playful digital water systems have been proposed using extended realities. We found inspiration in this prior work.

2.3 Use of extended realities in water

Extended realities (XR) - technologies that augment human senses by mixing the extremes of reality and virtuality - are popular in HCI [76, 110]. However, few WaterHCI systems have explored XR for water [35, 80], with one exception being underwater augmented reality (AR) [23, 31, 92]. Although the authors faced challenges around waterproofing, we were inspired by the proposal that play in water could be enhanced by XR. Hence, we considered using XR for our system.

Mann et al. [80] noted that XR for water activities has been adopted by industry but is rarely researched by academia. We hypothesize that this is because the associated systems are not easily accessible. For example, the commercial "DIVR" headset costs approximately $US 50K [9, 43]. Nevertheless, this work showed to us how VR in water could facilitate playful activities by taking advantage of the sensory pleasure of being in contact with real water. Furthermore, VR in neutral buoyancy environments (NBE), or pools used for space exploration research [2, 24, 111], demonstrated that VR could familiarize users with unfamiliar environments. These studies also showed the feasibility of biosignals combined with VR, further inspiring our design. While related small tank studies revealed the challenges of signal quality [103], custom sensors and headsets are available [32, 91], and researchers have also used biosensors on the parts of the body that are not submerged [75], which guided our design.

Games and rehabilitation therapies have also combined VR and water [36, 37, 97]. However, while these systems suggest that VR can support playful activities, little is known about how people engage in water while using VR. Furthermore, although these prior works show the potential of using XR for being playful in water, they lack empirical evaluation, which is partly due to a lack of evaluation platforms. In this paper, we introduce a floatation tank as one of the possible evaluation platforms for playful XR experiences in water.

2.4 Use of extended realities in floatation tanks

Although the use of VR in floatation tanks is underexplored, technological feedback in a floatation tank is increasingly attractive to the floatation tank industry [27]. A survey of floatation users and floatation centers indicated that both are open to experiencing technological stimuli in a floatation tank. Moreover, Mann et al. [78] designed a VR experience in which tank users can interact with each other by watching visual representations of them singing together (captured via a microphone in the tank). While this work leverages the tanks' deprivation features and water's buoyancy, future designs could leverage other interactions that water can facilitate, such as tactile feedback [39, 46]. Also, industry efforts have used VR in floatation tanks [11], suggesting that off-the-shelf VR headsets (Oculus Quest 2) and floatation tanks can work well together. We have also engaged with this combination. However, although these efforts have led to individual reports [13, 26], as well as art provocations [15, 20], we know little about the respective design challenges from an HCI perspective.

Prior work articulated the advantages that VR can bring to interactions, such as control over visual and auditory feedback, and the possibilities it offers via simulated virtual worlds [112]. We examined whether these advantages apply to experiencing simulated virtual worlds in VR while in contact with water. We anticipated that using VR while floating could encourage play through visual elements, and be immersive, thanks to the isolation provided by the tank. Additionally, prior on-land work proposed that haptic systems can complement VR systems to augment the experience's sense of realism and user engagement [47, 66]. By leveraging the advantages of combining VR and haptic systems, such as exploration, discovery, relaxation sensation, and captivation [18, 73], we aim to develop playful experiences unique to a floatation session.

3 DESIGN APPROACH

3.1 Soma design for water experiences

Somaesthetics [108] has been suggested as an approach to designing introspective bodily experiences [53]. Somaesthetics is made up of the terms soma, referring to "the self that is a united whole of mind and body" [53], and aesthetics, referring to how we perceive and interact through our bodily senses and movement [53]. Soma design encourages practices for cultivating our somatic sensibility by leveraging experiential first-person exercises [53, 121]. We followed three design stages to cultivate this sensibility [53, 55, 69, 83, 121]: engaging with body practices, material exploration, and prototyping.

3.1.1 Engaging with body practices. In this stage, the designer engages with their bodily experiences and documents their perceptions [53]. The main designer (the first author) interacted with water in different settings over one month, ranging from simple water interactions, such as haptic experiments with water from a tap or walking on the beach, to more complex interactions, such as swimming in the ocean, submersion in hot springs, and a floatation tank session (Fig. 2). She documented her perceptions before, after, and (where possible) during these experiences using body maps, written descriptions and video recordings [119, 121]. Her reflections on these bodily practices supported discoveries about how water's properties, such as temperature and flow, created different perceptions, which informed our design decisions, as we explain next.

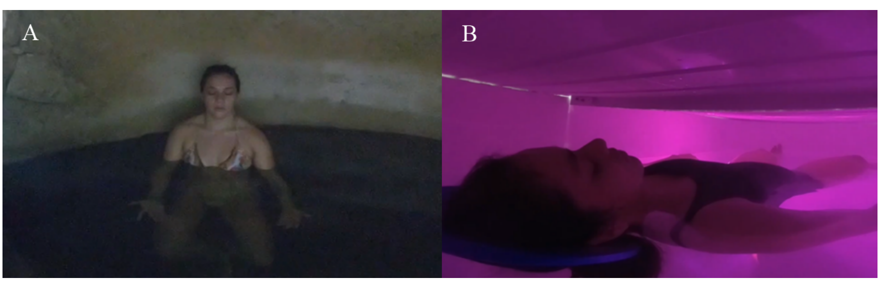

Fig. 2. Engaging with body practices to sensitize the soma to water perception. A) Submersion in a hot spring. B) A floatation tank session.

3.1.2 Material exploration. The designer is encouraged to touch, feel, and interact with different digital and physical materials and imagine possible interactions related to the body practice they developed [53, 121]. Our main designer explored different technologies in water settings, including water pumps and speakers in buckets filled with water, and different buoyant materials. The designer simulated most of the bodily perceptions experienced during the body practices and, confirming prior work, found digital and physical materials that could amplify those perceptions. For example, water pumps can be used to amplify the ocean's pleasant tactile aesthetics. Similarly, peristaltic water pumps can drive cold water into warm water in a way that produces tactile sensations because of changes in temperature [94].

3.1.3 Prototyping. In this stage, the designer explores ideas by "doing," using self-experience and project goals to develop the floatation tank prototype design [53, 121] and add the aforementioned technology and materials (Fig. 3). As prior soma design work suggested [119, 121], we conducted, recorded, and documented three 30-minute sessions in our laboratory-installed floatation tank.

In the first floatation tank session, the designer used a waterproof speaker at the bottom of the tank to listen to whale sounds and feel sound vibrations while playing a relaxation VR game called "TRIPP" [6] using the Oculus Quest 2 headset. In the second session, the designer explored a pneumatic system [5] feeling the bubbles from the air pump. Finally, in the third session, the designer explored the feeling of water jets on her hands and feet while wearing a heart rate (HR) sensor [3] and playing the same VR game.

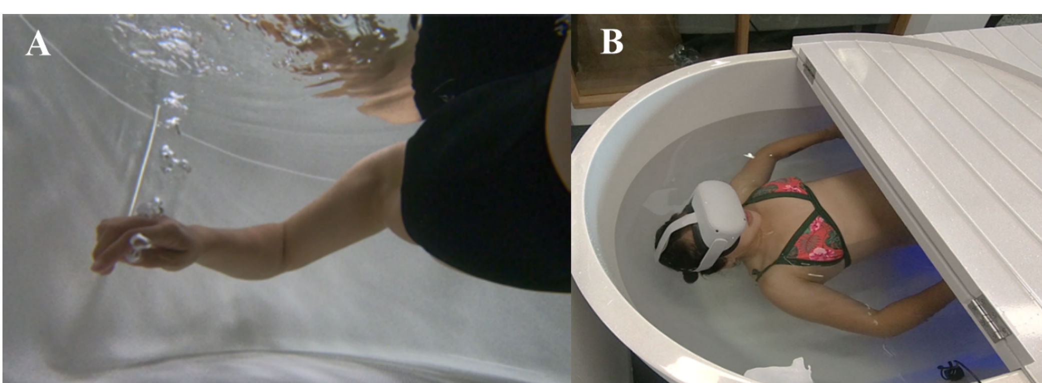

Fig. 3. Engaging with prototyping: A) Exploring a pneumatic system while floating in the tank B) Exploring a VR relaxation game while floating in the tank.

We found that safety can be a concern while prototyping. While we could have used waterproof technology for rapid prototyping, we found it easier to use tethered technology, taking care of the electrical risk by placing the device's connections outside the tank. The technology needed to be salt-resistant because salt water can easily damage technology such as waterproof pumps. Furthermore, we found that any floatation tank VR experience should consider the point of view from lying down (most software renders the user's virtual body as standing up by default, skewing the point of view). Finally, in these sessions, we realised that using VR and tactile feedback creates a stimulating experience while being in contact with water, providing options to encourage play, such as bodily illusions and relaxation [73]. The next subsection explains our design choices based on this prototyping.

3.1.4 Slowstorming: Combining interactive technology with a floatation tank. Slowstorming is a soma design method to translate insights into design work via slow reflection on the designer's somatic experiences [53, 67]. These reflections were based on the findings of our soma prototyping, informed by prior work, and led to the following design decisions:

- We used the Oculus Quest 2 VR headset because we found it suitable during our soma design prototyping. Despite the headset not being waterproof, it is suitable for a floatation tank session where a participant's head naturally floats above water due to the high salt content and the use of a floatation pillow. We opted for an existing stand-alone headset rather than a waterproof VR case with a waterproof mobile phone [9, 97] or a custom-made waterproof headset [78] because the Oculus Quest 2 is more freely available, accessible, and performs better than the alternatives. High-resolution VR can facilitate an immersive world and realistic experiences [70] and simulate elements that encourage play, including discovery, relaxation, and captivation [18, 73].
- We decided not to use the Oculus controllers because the floatation tank's size (2m*1.5m*06m) was inadequate to perform the gross-motor movements for which the controllers' sensors are optimized. Although larger floatation tanks exist [8], and prior works have presented ways to waterproof controllers [36], avoiding the use of controllers leaves participants' hands free to support floating without worrying about hitting tank walls. We also found that leaving the hands free seems to support relaxation. Slowly moving the hands allows the user to feel the water in a very intimate way. Furthermore, we decided not to encourage body movements, given that our soma practice indicated that one of the appeals of being in water is the sense that there are no bodily boundaries.
- In response to the lack of interaction afforded by the controllers, we decided to use the headset's IMU sensors. Our soma design prototyping indicated that moving the head when in water, especially in a floatation tank, is a much more deliberate action than it is for land-based activities. We aimed to avoid strenuous head movements (sometimes required in traditional VR experiences) by limiting the range of head movements that the software invited participants to perform.
- As common in floatation tank research [72], we decided to monitor participants' HR to support safety and use it as an input for the experience (prior work [15, 42, 59] used HR data to control relaxing visual elements). Furthermore, our soma design experience indicated that the floatation tank allows users to hear their breathing and HR, encouraging relaxation and self-awareness. Similar to prior work [93], our design aimed to amplify this experience through respiratory tracking using the headset's microphone. We also used the HR as an input to create background changes in the VR environment as a slow play interaction [81]. These changes are triggered when the participant's HR exceeds 80 beats per minute (which is the normal resting heart rate in healthy adults [88, 89] and it is a threshold that has been used in prior work [42]).
- Our soma design prototyping indicated that the sensation of bubbles touching the skin while submerged in water was delightful, pleasurable, and encouraged relaxation. Consequently, we decided to use pneumatic pumps to provide tactile feedback. Also, we believe bubbles can be used as a playful reward since prior work suggests that tactile feedback complements visual rewards and synchronizing both types of feedback can increase immersion [47, 66].

3.2 Playful design of an XR water experience

This section presents our design process to create a playful XR floatation tank experience. Aiming to facilitate a playful experience, we used game design elements because play is defined as an informal type of game [118], games are a systematic complement to playfulness, and games facilitate a playful attitude [74]. Prior work informed our use of four basic game elements when designing playful experiences: story, aesthetics, technology, and game mechanics [84, 102].

- Story: Inspired by our soma design prototyping, we focused on visual water associations and the concept of the water as an external force supporting the participant. To represent such an external force, we took inspiration from indigenous beliefs [115, 116] and included a game companion called the "water spirit". The design of our companion was inspired by cultural representations of water beings in movies as metamorphic entities [44, 47, 49]. Finally, in our experience, the water spirit guides the participant through different virtual scenes where, together, they must overcome challenges, such as guiding the water spirit in collecting water droplets to boost their energy.
- Technology: We used Unity3D game engine to develop a VR environment for the Oculus Quest 2. We used the lightweight, wireless Polar Verity sensor to capture HR [4] and provide real-time data transfer using the plugin "Excite-O-Meter" [98]. We decided to place the HR sensor over the participant's forehead since their forehead will not be in contact with water, ensuring data quality and a stable Bluetooth connection. We placed four air pumps [7] outside the tank, delivering air inside the tank through hoses attached to the tank's walls. The air pumps are powered by two TB6612FNG dual motor drivers connected to an ESP8266 microcontroller (Fig. 4). The microcontroller communicates with Unity3D over WIFI. We used the Uduino plugin [12] and Arduino Servo libraries.
- Aesthetics: We drew from our soma practice and were inspired by prior work associating water elements with relaxation [15, 42, 125]. We chose water-related virtual environments with minimal visual distractions, such as an ocean, a waterfall, various water splash effects, and rain effects. Associated water sounds and slow background music complemented the immersive experience.
- Game Mechanics: Schell's [102] game mechanics offer a coherent approach to creating a game-like experience [52, 84]. The game mechanics established the space, time, objects, and rules of our experience [102] as follows: The journey unfolds across six distinct 3D virtual scenarios: onboarding, underwater, psychedelic water, rainy sky, transitions, and offboarding. Various objects within each scenario can be manipulated by participants, including the virtual avatar and light particles representing breath. Participants engage in three primary actions: collecting objects, guiding the water spirit, and changing the environment. While competition is discouraged, exploration and discovery are encouraged, with participants' actions having consequences. For instance, participants can manipulate light particles through head movements and breathing, make the water spirit collide with water droplets, and their heart rate controls the background color, which remains undisclosed to foster discovery. Details of game mechanics will be explained in section 4.

Finally, soma design suggests testing the designed system, often called "encountering others" [53, 55]. Consequently, an iterative development process was carried out, including prototyping and playtesting with all authors and two designers. One designer had water sport expertise, and another had game design expertise. Playable prototypes were developed approximately every two weeks for six weeks, with participants providing feedback to implement improvements.

4 RESULTS FROM THE DESIGN PROCESS

Our system is called "Fluito," Latin for "float". Fluito comprises a floatation tank, VR headset, HR sensor, and pneumatic system (Fig. 5). Experiencing Fluito means being guided by a virtual water spirit (Fig. 6E) on a journey through different VR worlds where they must overcome challenges.

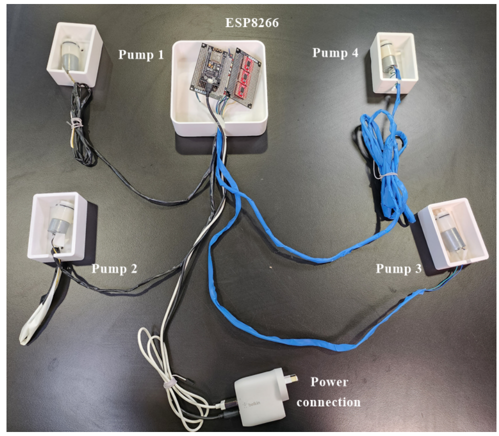

Fig. 4. Pneumatic system: Four 5V air pumps are connected through electrical cables covered in waterproof tape. An ESP86222 microcontroller is connected to three motor drivers powered by two USB power cables.

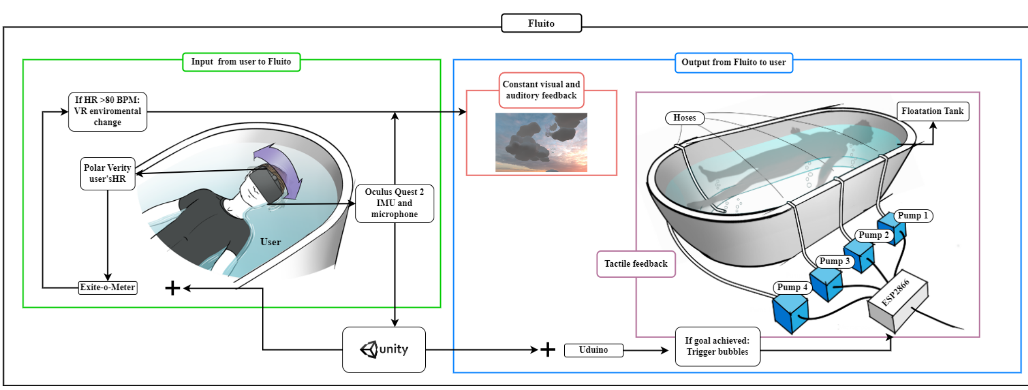

Fig. 5. Components of Fluito. Left: input from participant to Fluito. Right: output from Fluito to participant.

First, the participant onboards via a virtual water world. This scene begins with the participant's avatar floating in an infinite ocean at night with a sky full of stars, hearing the ocean's small waves (Fig. 6A). The journey continues to the first interactive scene: an underwater world, where the participant dives to the ocean bed (Fig. 6B). Here, the participant is encouraged to explore the environment and search for emerging lights by performing small head movements and breathing the lights "in", promoting rhythmic breathing to facilitate relaxation and breath awareness. The air pumps are activated when the participant points their head to the lights and breaths aloud.

Next, the participant enters a "psychedelic" water scene, where they see a multicolored horizon with floating islands and planets while hearing relaxing music (Fig. 6C). The participant guides the water spirit via head movements to collect the water droplets approaching the participant's avatar position. The participant is then transported to the last interactive scene: a "rainy sky" scene on top of a cloud, where they can hear and see the wind, cyclones, dark clouds, and rain (Fig. 6D). Here, the participant's avatar rises through the clouds as they collect the moving cyclones with their head movements. All interactive scenes change their background color if participants' HR is above the resting threshold. Additionally, in the rainy sky, the rain and the storm will be created in response to the high HR. All transitions between scenes are made using a simulated water tunnel (Fig. 6F). Finally, the participant offboards into a calm water world on the ocean's surface, where the participant floats until the experience is over (Fig. 6E).

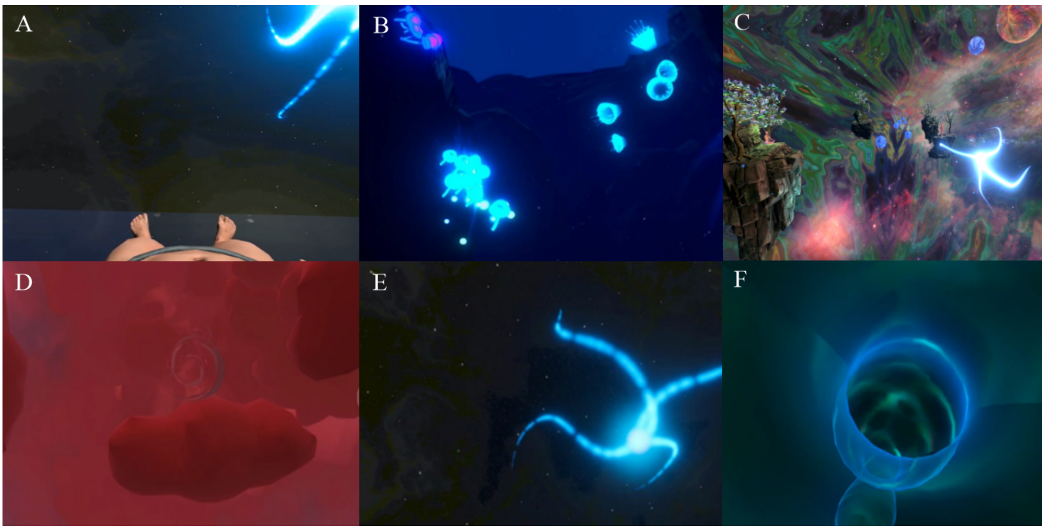

Fig. 6. Fluito's VR scenes. A) Onboarding floating in the ocean. B) The underwater world. C) The psychedelic water world. D) The rainy sky world (here, it started to rain, and the color turned red because the HR was above the threshold). E) Offboarding. F) Transitions.

5 STUDY METHODOLOGY

We conducted a 13-participant study (six female, seven male, no non-binary or self-described) to gather insights into the experience. Recruitment was conducted through social media and mailing lists. The participants' ages ranged from 22-65 years with an average age of 31.8 years and a standard deviation of 11.1 years. Two participants had experience in a floatation tank, and 10 had experience using VR. The participants had different skill levels and experience in aquatic environments: six described themself as experts, two as standard, two as novices, and three as having no swimming or floatation skills. Participants were recruited if they meet the inclusion criteria (older than 18 years and do not have any of the following conditions: epilepsy, kidney disease, low blood pressure, any contagious disease including diarrhea or gastroenteritis (and for 14 days following), claustrophobia, asthma, sensitivity to chlorine, bromine, sulfate or magnesium, severe skin conditions such as psoriasis and eczema, psychosis, flu, influenza, Covid-19 and for 14 days following, physical disabilities, learning difficulties, blind (people using glasses were not excluded), deaf and hard of hearing (people using waterproof hearing aids were not excluded [10]). As established in the ethics protocol approved by our organization, participants were free to end the session whenever they wanted by asking the researcher to stop the session. Also, the floatation tank was equipped with an emergency alarm and a camera pointing at the participant's head, from approximately 0.5m, for safety monitoring.

5.1 Protocol

Participants were asked to take a shower before starting the experience. Then, we helped them to put on the HR sensor over their forehead and, if needed, get into the tank. We also provided a floatation pillow. Participants were asked to float for 10 minutes to get used to the floatation inside the tank. Then, participants were asked to put on the VR headset, and the experience began. After the experience, we helped the participants get out of the tank, provided a towel, and asked them to shower. Finally, we provided a hot beverage and held a 30–45-minute interview.

5.2 Data sources and analysis

We used a semi-structured interview approach to leave sufficient room to support deeper elucidation of participants' responses and thinking processes. The main topics discussed in the interviews were: their previous experiences in water and virtual environments, their bodily perceptions during and after using Fluito, their user experience and comparisons between their experience using and not using Fluito (the first 10 minutes) while floating, among others. We took notes, and the interviews were recorded and later transcribed. The videos were used as support material. The interviews were analyzed using an inductive thematic analysis approach [28] in NVIVO. We used open coding to identify key themes. Each data unit was a single coded quote, a practice we borrowed from others [17, 105]. In total, the coders coded 1099 units of data. The coding process was "data driven" to minimize bias [28] where two coders worked separately and systematically through the entire data set (the interviews' transcripts), giving equal attention to each data item (question and answer), and identifying interesting aspects in the data items resulting into each data unit, forming the basis of repeated patterns. These repeated patterns were the high-level codes iteratively clustered into agreed-upon groupings between the researchers until they were converged into themes. The disagreements between the two coders were solved using Patton's dual criteria for judging categories, which consider the internal homogeneity and external heterogeneity of the themes [28]. Then, the two coders included the high-level code under discussion if it cohered together meaningfully (homogeneous) and if it has clear and identifiable distinctions with other high-level codes (heterogeneous).

6 STUDY RESULTS

The study results suggest that participants greatly enjoyed Fluito. Our data analysis identified four themes (T1-T4), which we describe using 15 findings (F1-F15).

6.1 T1: Fluito as an amplifier of the water experience

This theme presents our findings concerning the different UXs that participants reported. Although several of the UXs are often achieved while being in bodies of water (weightless floatation, breathing awareness, and altered state of consciousness) [62, 64, 72], Fluito appeared to amplify them.

6.1.1 F1. A new floatation experience thanks to Fluito. We found that the interactive technology appeared to amplify the floatation. Firstly, we noticed that following the standard of 1.22 specific gravity for floatation tanks [8] allowed an effortless floatation, according to all participant reports. However, P3 and P13, who had previous experience with floatation tank sessions, noted that Fluito made floating easier. For example, P3 said: *"I guess it had a lot of salt because it made it so easy to float compared to the other times I've tried before"*. Secondly, and more importantly, we noticed that the VR environments amplified the participants' floatation:*"I think, in the latter part [while experiencing Fluito], I wasn't even moving my hands at all. I was just floating nicely [. . .] with the VR you could do that forever kind of thing"* (P11).

6.1.2 F2. Breathing awareness through interactions using the headset's microphone. In the underwater scene, the main interaction was the sensing of the participant's breathing sound by the headset's microphone to control the virtual light particles. In the other two scenarios, the HR indirectly sensed the breathing and the background virtual environment changed accordingly. Six participants reported that mapping breathing to the virtual scene elements made them more aware of their breathing. P3 confirmed a heightened breathing awareness: *"100 percent, in the first part [the underwater world scene] of the game, like, when you actually breathe in the lights"*. Similarly, P8 said that he felt aware of his breathing in *"the first exercise [underwater world scene] and the third exercise [cloudy scene] when your breathing was a big part of it.* P6 used their meditation experience to describe how the influence his breathing had over the virtual world could not be captured via the conventional concept of "awareness": *"But I was so much [more] aware of my breathing, as I was trying to control it. But it wasn't like an awareness. Like, if you, like, meditate for something, you know, you sit, and you just watch it. It wasn't an objective experience. It was like actively engaging that kind of parasympathetic nervous system"*. Seven participants reported that the VR environment made them less focused on their breathing. For example, P5 said the VR environment provided enough stimulation to take participant's focus away from their breathing: *"There was enough stimulation for me to, like, not focus on the breathing and, like, there are other things"*.

6.1.3 F3. An altered state of consciousness as a result of losing track of time while using Fluito. Ten participants reported losing track of time, which is a common part of floatation tank experiences [64] and considered a type of altered state of consciousness [63]. Our interactive technology appeared to amplify this loss of track of time for some participants while dampening it for others. Five participants felt that the initial floatation duration (10 minutes) without experiencing Fluito was shorter, and five participants felt it was longer. For example, P1 said: *"At the start [without experiencing Fluito], you feel it [the time], like, so long"*, while P7 stated: *"The first 10 minutes was very fast"*. Moreover, all participants estimated that the duration using Fluito was shorter than the 25 minutes it took. For example, P10 compared his perception of time with and without the interactive technology: *"10 minutes felt longer than the VR part"*. The participants reported that they felt that the time passed quicker because they were focused on the virtual environment: *"I think it is because something is happening, so you're actually focused on it"* (P3). In addition, P11 mentioned that he felt the time was shorter because he felt in a flow state: *"I was in the flow, I felt I'm in control. I lost track of time; the task was challenging but not overly challenging"*.

6.2 T2. Fluito as a facilitator for relaxation

Floatation tanks are often used to facilitate relaxation [64, 72, 124]. Our results align with these works since all participants reported mental and bodily relaxation. While some participants reported relaxation due to floatation, all participants reported additional reasons relating to the interactive technology, which we elaborate on next.

6.2.1 F4. Water's affordance for relaxation is amplified by Fluito's aesthetically pleasing VR water environments. All participants reported that the aesthetically pleasing VR water environments amplified water's affordance for relaxation. P8 commented: *"I felt being relaxed, and being in a really calm scene [...] I think it almost encouraged the experience of relaxing"*. It seemed that the VR water environments' aesthetically pleasing nature elements (such as the jellyfish, waterfalls, and clouds) helped participants to relax, as mentioned by P11: *"The first part [underwater scene] where you had these little mushrooms and light, I think they were nice because I can take my time and slowly move around and see them, and they had a nice visual appeal to it"*.

6.2.2 F5. Water's affordance for relaxation is amplified by Fluito's HR biofeedback encouraging participants to pay attention to their body. Three participants reported that HR biofeedback through the virtual elements appeared to encourage them to pay attention to their bodies, which amplified water's affordance for relaxation. For example, P8 commented on the cloudy scene: *"I said relax because it [the voice in the virtual world] said 'control your breath and relax, and then it will stop* *the storms,' and every time it started raining, I paid attention to everything [his body], and I tried to set everything down because maybe I was getting a faster heart rate from missing cyclones"*. P10 associated the jellyfish movement with their HR:*"For some reason, I really fixated on the jellyfish. I think that kind of rhythmic movement was, gave me something to focus on. And especially since it said, like, the game, kind of, reacts to your breathing"*. We note that the jellyfish was not designed to be HR controlled. With our design, we hoped that participants would explore what they could control with their HR, although we found that ten of them did not notice the background environmental changes produced by the HR. P13 reported that knowing someone was monitoring her HR helped her relax. She remembered a previous experience in a professional floatation tank center: *"I told them [the floatation center] that it's, technically, it's not really relaxing because there's no reassurance of that, okay, we will [be] monitoring, we're watching you"*. In contrast, with Fluito, she said that *"at least you know, you know that someone is watching you, rather than not being disturbed"*.

6.2.3 F6. Bubbles' touch facilitating relaxation encouraged bodily awareness. The bubbles resulted in feelings of touch, as mentioned by P12 when she said the bubbles felt like *"a little touch"*. We noticed that this touch amplified water's affordance for relaxation. Two participants said that the haptic feedback facilitated relaxation. For example, P2 said: *"I respond very well to touch [. . .] and definitely touch makes me relax"*. In addition, four participants said that the bubbles helped them to become aware of their bodies. For example, P5 stated that the bubbles helped them become aware of the special position of his body: *"I mean, [to feel] parts of my body, I mean, [to feel] spatial, spatial existence of my body within the pool [. . .] I noticed that: 'Oh, I'm somewhere above my right side' that [it's] because of the bubbles"*. Moreover, participants felt the bubbles in different parts: *"Especially because the way at least my back is shaped, they [the bubbles] kind of like got trapped in the, in the small [hole] of my back. And then it [the bubble] would, like, build up and build up, and then we'd like run up. I bet. They [the bubbles] run up to my leg, you know, and it would kind of, sticks to your body with the air. But yeah, so that was kind of cool"* (P6). Furthermore, ten participants reported the bubbles as a complementary feedback modality. For example, P2 mentioned: *"In most of the things, they [the bubbles] felt like a reward like: 'Oh yeah, I hit the bubble, I hit the droplet, and now I get bubbles.' So, I quite like the feeling of bubbles"*.

6.3 T3. Fluito as a facilitator to experience water as a playground

Bodies of water are known as a space to produce feelings of well-being [50]. They are also spaces to perform playful and recreational activities [35, 90]. In this manner, bodies of water can be considered a space for play, demarking the "magic circle of play" [118], where water is experienced as a playground [109]. This theme describes our participants' engagement with Fluito as a facilitator to experience water as a playground.

6.3.1 F7. Perceptions of water as a playground changed thanks to Fluito. The three participants with no swimming skills reported very few instances where they had entered water bodies. They initially expressed discomfort and fear, but these feelings diminished when they engaged with Fluito. P17 said: *"I was a bit more scared because I feel like I was, at some point, I felt like I was not floating completely at the start. I was a bit scared of that. And then, at some point, I felt like I could feel my body weight. But with this [the VR], I feel like it's fine"*. They noted that the VR environment helped them overcome their initial fear. For example, P11 said: *"The initial bit [without experiencing Fluito], I was struggling to let go, and even after that, I was holding on to the [tank's] lid [. . .]. So, I think by the time I got [to understand] the VR, I was very used to floating without having any fear"*. Our videos showed that, before experiencing Fluito, this participant held the tank lid with his hands while floating. However, while experiencing Fluito, the participant's hands floated free. We also noticed that after experiencing Fluito, the three participants had changed their perception of water as a playground. For example, P12 said: *"I think is a new experience for most of us. And I think maybe we can find some new games to play in water, and for some people like me, fear of water"*, and she added, *"I think it [VR scenarios] helped me to reduce the fear of water"*.

6.3.2 F8. Experiencing Fluito as "soft" play. Nine participants with swimming skills reported perceiving water bodies as a playground and described engaging with Fluito as a playful experience, like playing a game. For example, P8 said he was *"playing a game"* since he *"was trying to figure out what to do"*. As exemplified by P13, other participants felt they were playing a game because they were receiving rewards: *"You know, all the games that you played, they always get the reward"*. However, not everyone considered the experience a game. For example, P9 expected more action in a game: *"To be fair, a game, it's more interactive, right, game, but maybe more fast-paced, whereas this is more like going to a soft experience"*. The use of the term "soft experience" suggests that the participant's experience was different from their traditional game experiences and had characteristics of a "slow game" [81], which is described as a game that encourages slow movements intended to focus attention, while providing periods and opportunities for reflection and contemplation [81], as opposed to action games in which players often need to respond to many fast moving objects [14].

6.3.3 F9. Altered water perceptions thanks to Fluito. The participants reported that Fluito altered their water perceptions. Eleven participants reported two main reasons for forgetting they were in water while experiencing Fluito: water temperature (7 participants) and Fluito's VR environment (4 participants). Regarding temperature, P3 explained: *"I know [that is] what you feel that you don't necessarily notice a boundary between your skin. I think that was mostly because the water was a very nice temperature"*. Regarding the VR scenes, P7 explained: *"I was more focused on the game than the environment [water]"*. In contrast, all participants reported that the bubbles reminded them that they were in physical water. For example, P7 said: *"I could feel it [the water], I knew it was there, especially when the jets were there, I felt it more"*. In summary, Fluito's features moved the experience back and forth between awareness and unawareness of being in water, with the VR scenes making participants forget and the bubbles reminding participants that they were in water.

6.3.4 F10. Experiencing bodily illusions thanks to Fluito. Five participants reported experiencing bodily illusions thanks to Fluito. For example, referring to the animation when the virtual avatar dives underwater, P7 stated: *"I liked the feeling of when – at the start –, like, going down. I felt like I was going down as well"*. Concerning the "psychedelic water" scene, P1 stated: *"I felt like I was moving around in a bigger place, not in this tank"*, suggesting that the virtual scene made the (small) movements in the tank appear to be larger. Speaking about the same scene, P1 added: *"I felt my body lying, like lying in the air"*. Also, the bubbles enhanced these illusions. For example, P7 explained: *"You see it [the tunnel], and you also feel like you're going through it [the tunnel] with the jets [bubbles]"*.

6.3.5 F11. Fluito providing entertainment for participants who find floatation boring. Four participants experienced boredom during the first ten minutes of floating (without experiencing Fluito). Two participants expected floatation tank sessions to be boring. For example, P13 mentioned a floatation tank experience she had before the study: *"It was way too long, and then, anyway, there's nothing interesting, it was all dark"*. P9, who did not have previous floatation experience, felt that the first 10 minutes floating without Fluito were boring because *"it is sitting there doing nothing"*. Nevertheless, these four participants reported that Fluito helped them experience entertainment and fun. For example, P13 said: *"The difference is because there's entertainment in your floatation"*, and P9 said: *"I find it was a different experience. That was more fun"*.

6.3.6 F12. A sense of presence facilitated by Fluito. We noticed that VR elements that related to water appeared to amplify participants' sense of presence in the water (a perception of "being there" [91]). For example, P7 said: *"It's just fascinating that you just put on that [the VR headset] and then see stuff that is not real [floating in the sky], but also in the water you're floating, it feels like more real"*. As presence is a consequence of immersion [29], we expected reports of immersive feelings, as P2 mentioned: *"The VR environment makes you feel immersive"*. Three participants mentioned that the bubbles made them feel more immersed. For example, P12 said: *"I said it [the bubbles] was giving me more immersion [than only the VR scenes]"*, and P2 added: *"I see the ocean waves and feeling bubbles, and [am] thinking: 'Oh yeah, that kind of feels like that'"*.

6.4 T4 Fluito as technology mediator to facilitate playful water experiences

This theme presents participants' descriptions of how they engaged with Fluito, including design issues they pointed out.

6.4.1 F13. Engaging with Fluito through water buoyancy amplified by the VR scenes. As proposed by prior work, fun is the most common way to engage in play [118]. Participants reported fun, excitement, and entertainment while experiencing Fluito, specifically due to the elements in the VR scene amplifying the floating sensation. For example, as exemplified by P8, participants found the space scene fun: *"I found it really interesting. I didn't expect it. It was fun, though. It was exciting, it was more captivating [than floating without experiencing Fluito]"*. We noticed that the space theme amplified the sensation of floating in water, which was fun for participants. P13 explained: *"It's fun to be in outer space as well. It's like, you know, your opportunity to be in outer space"*. Participants described their feelings about this scenario using phrases such as *"swimming in the universe"* (P12), *"wonderful"* (P6), *"unique" (P5)*, and *"cosmic"* (P10). We noticed that this kind of play aligns with prior work proposing fantasy to facilitate play [73] and commercial work proposing visualizing space during floatation sessions [11]. Furthermore, ten participants reported that Fluito's VR scenes helped them understand the playful experience. We noted that participants did not find audio instructions very suitable while floating; instead, they relied on visual cues. According to this finding, we propose that visual cues can play an important role in water interactions.

6.4.2 F14. New bodily sensations thanks to bubbles. Six participants said that the tactile sensations produced by the bubbles were new to them, and they compared those sensations to experiences with spa tubs with more powerful water jets. For example, P5 described the sensations as *"unique"*, while P13 described them as *"similar to having a soft massage"*. Interestingly, P12 mentioned a *"water vibration"* rather than air bubbles. Three participants noticed that the bubbles elicited skin sensations akin to tickling. P6 appreciated this feeling: *"It was quite pleasant; it was kind of nice and fun [...]. It was definitely ticklish for me, but then it went from being, like, really ticklish, to just, like, a bit ticklish"*. Our videos showed this participant laughing aloud while experiencing the bubbles. In addition, P2 also mentioned that it was a nice feeling: *"It felt slightly ticklish. Like, it's not to the point that you start to giggle and squirm, but it's like the nice little tingly feeling"*.

6.4.3 F15. Neck fatigue from VR headset use. Although we designed our prototype to avoid strenuous head movements, ten participants reported experiencing neck fatigue associated with the head movement they had to perform. For example, P10 stated: *"I think the weight of the headset was a big factor, like, my neck definitely got sore. I think, because, you know, with controlling it, I had to move my head around quite a bit"*. For three participants, the technology was disruptive. For example, P7 mentioned: *"The neck thing was a bit annoying. Even with the pillow, it was a bit annoying"*. However, P8 explained: *"It was just the fact that you were aware of it [the neck fatigue], but I think I was engaged enough that I wouldn't stop the experience for it"*.

7 DISCUSSION

Based on our soma design process and analysis of participants' experiences with Fluito, we now discuss our findings in relation to prior work. We use a postphenomenological lens [51, 56, 57, 100, 126] that sees technologies as the shapers of our connections to the world. We used this lens because prior work suggested its usefulness for accessing subjective experiences of soma-designed systems [41, 60] including VR systems [127]. Verbeek's [51, 100, 126] postphenomenological lens, building on Idhe [56, 57], proposes bodily-perceptual relationships with technologies to mediate human-world relations, which echoes the intentions of our somatic design process [60]. These relations influence the human experience of the world both subjectively and objectively, as drawn by Hauser et al. [51] in the left diagram in figure 7. By discussing our findings regarding to postphenomenology's notion of *"Human-Technology-World"* relations [51], we propose *"Soma-Technology-Water"* relations (Fig. 7), where we replace the original "human" with "soma", (indicating both body and mind), in response to the heightened role of the soma in water as experienced in our soma design approach. Moreover, we replace Verbeek's "world" with "water", allowing us to focus on the "world" that is "being in water" and, in our case, within a physical and virtual world of Fluito.

Verbeek's postphenomenological lens [100, 126] proposed seven human-world relations, which we examined in regard to our *Soma-Technology-Water* relations (embodiment, hermeneutic, background, alterity, cyborg, immersion, and augmentation). Three of these relations appeared most strongly in our findings: embodiment, background and immersion relations. Based on these relations, we propose a *"Soma-Technology-Water"* notion where the technology is merged with the water (/) and amplifies it (+), and at the same time, has a bi-directional relation (⟵⟶) with the soma (Fig. 7). Moreover, when we use technology in water, it not only acts as an amplifier of the water to the soma, but it also facilitates, encourages and supports perceptions and experiences for the soma. In addition, we confirm Verbeek's postphenomenological suggestion that technology invites and inhibits actions and practices from the soma to the water (Fig. 7).

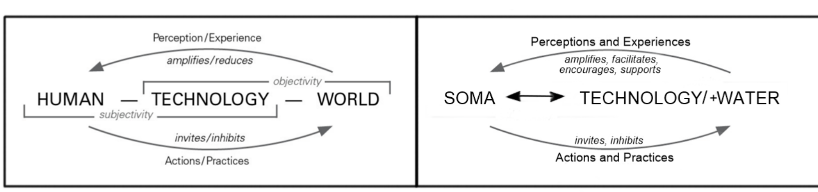

Fig. 7. Diagrams of the postphenomenological mediation theory. Right: Human-Technology-World relations. Left: Our Soma-Technology-Water relations proposed through a postphenomenological lens.

Finally, we explore the three mentioned relations in the following subsections (Sections 7.1-7.3) and identify design implications (summarised in Table 1 at the end of this section) for each one that designers can consider when aiming to create future playful water experiences. We leave the remaining four postphenomenological relations to future work.

7.1 Embodiment relations: (Soma-Technology) → Water

The purpose of a technology design in embodiment relations is to call attention to aspects of the world given through it [56, 100, 126]. This relation is represented using the following notation: *(Human-Technology)* → *World* [56, 100, 126] wherein the human and technology are together since the technology becomes invisible to the human and, together, they create a new concept of the perceived world. Ihde used eyeglasses as an examples to describe this relation as "a user looks through the glasses upon a transformed world, and the glasses can be conceived as a part of the user's perceptions" [100]. The main feature of embodiment relations is that they simultaneously reduce and amplify what is experienced through them [100]. Verbeek referenced binoculars to describe this effect: "A pair of binoculars enables one to see over a distance, but at the sacrifice of visual awareness of one's immediate surroundings" [100]. We propose an alternative version of this relation with the notation *(Soma-Technology) → Water*. The following subsections discuss how such embodiment relations emerged with Fluito.

7.1.1 (Soma-Technology) → Water: Designing to call attention to the water. We find that embodiment relations emerged as participants reported that Fluito's bubbles called their attention to the real water (F9), as mentioned by P5: *"[I] was reminded that I was in the water when the bubbles were flowing"*. As such, we use *(Soma-Technology) → Water* to highlight that design features can call participants' attention to the water. Calling attention to the water can be useful to ensure safety, allowing designers to make participants aware that they have been in the water for an extended period, and it can highlight the pleasure of being in touch with water [35].

However, this calling attention to the water has advantages and disadvantages. In our case, calling attention to the water appeared to break the user's immersion (F9). Taken together, we highlight through *(Soma-Technology) → Water* that design features can call participants' attention to the water.

Design implication: We found the bubbles, delivered through the water via air pumps, an effective means to facilitate this embodiment relation. Participants appreciated the bubble's *"gentle massage"*, which produced novel bodily sensations. While prior work used pumps to squirt water at users [54, 77], its main purpose was to deliver haptic feedback. Moreover, prior WaterHCI work focused on what technology can add to the experience of being in water [71, 101] but did not utilize that technology to call attention to the water. While prior HCI work also examined how technology could be used to call attention to environmental features [25], such systems do not call attention to the environment that the user is in more broadly (i.e., the fact that the user is in the world, or here, water). We extend this prior work by suggesting that pumps can be used to call users' attention to the water they are in. In particular, we believe that pumps could be used to create this relation in other water environments, such as pools and wave parks.

7.1.2 (Soma-Technology) → Water: Designing to ***amplify*** *the relaxation facilitated by water.* An embodiment relation arose when participants used Fluito and experienced relaxation. Participants reported that the technology amplified water's relaxation potential. Technology mediates an embodiment relation when it amplifies what is experienced through it [100]. In this case, Fluito amplified the relaxation produced by water. Building on prior work demonstrating that proximity to water is relaxing [90, 116], clinical research showed that floatation tanks could facilitate relaxation [65, 72, 124]. Our results confirm this theory (F4, F5, F6), and we extend it by highlighting (Soma-Technology) → Water as a way to amplify the relaxation facilitated by water. Considering relaxation's many benefits (such as improved quality of life and longer life expectancy [107, 130]), designers are advised to design to consider utilizing this relation to amplify water's relaxation potential. While prior HCI work suggested technology to support relaxation, it aimed primarily at guiding the user towards relaxation, for instance, via meditation systems [16]. Limited research exists that aims to amplify the relaxation potential of the user's environment. While Mueller et al. proposed technology to amplify the relaxation potential of a user being outdoors [85], this work did not implement a system.

Together, these experiences appeared to amplify water's relaxation potential as part of a *(Soma-Technology) → Water* relation. This relation resulted in creating relief from bodily or mental work, a definition that prior work uses to describe a playful experience in the form of relaxation [18, 73]. Since relaxation as a playful experience has been proposed in serious games [125], for example, to reduce aggressive behaviors [128], game designers may want to consider designing for embodiment relations to facilitate play through relaxation.

Design implication: We, therefore, present evidence that technology can amplify the relaxation facilitated by the water, and we offer guidance on how to achieve that amplification. Firstly, we found adding complementary digital sounds of water an effective strategy to amplify water's relaxation potential. Secondly, we found introducing digital animations that are congruent to the water environment (water-themed and slow-moving) to be an effective strategy. Thirdly, soft tactile sensations complementing the touch sensation of water on the user's skin appeared to be another effective strategy. These strategies to amplify the relaxation facilitated by water could be implemented in other water environments, for instance, we can envision delivering relaxing sounds when people are diving or introducing relaxing animations projected onto pool's walls [1, 129] (as prior work demonstrated from an engineering perspective).

*7.1.3 (Soma-Technology) → Water: Designing to **amplify** water's potential for bodily illusions.* We found an embodiment relation when Fluito amplified the bodily illusions our participants perceived while they floated. Participants reported that the technology amplified their sensations of blurred body boundaries and movement in the space (F9 and F10). Prior clinical research suggested that floatation tanks can facilitate bodily illusions by blurring the body's boundary thanks to the warm water [64]. However, we extended this theory since Fluito facilitated different bodily illusions than those typically reported in prior work, such as the feeling of being inside a womb [63]. For example, thanks to Fluito's VR scenes, participants perceived themselves to be moving through the virtual space while floating (F10), confirming the prior theory that VR can make people perceive movement independently from whether they are moving less (redirected walking [68]) or moving more (walking in a circle [91]). In addition, when the VR scenes presented movement reinforced with bubbles, participants perceived realism in the movement through the virtual world (F10). Another bodily illusion facilitated by Fluito was the amplification of the sense of weightlessness, when participants reported sensations of "floating in the air" (F1, F13) thanks to the VR worlds. In this regard, previous work has used VR in combination with neutral buoyancy environments to simulate the experience of floating in air and space [111]. However, this setup is difficult to achieve in water because designers must use harnesses and build their own waterproof VR headsets [87, 111]. We extend this prior work by suggesting that the research on weightlessness can benefit from our findings that VR is feasible in floatation tanks without waterproof VR headsets. Consequently, we highlight *(Soma-Technology) → Water* as a way to amplify water's potential for bodily illusions.

Moreover, the right design elements do not just amplify bodily illusions; they can also be perceived as playful. Experiencing bodily illusions can be considered a playful experience in the sense that playfulness arises from the enjoyment of stimulating the senses in new ways [18, 73].

Design implication: Prior work suggests that bodily illusions can change people's body image. While it has been suggested that VR modulates body image disturbances using bodily illusions [122], this prior research has not considered how tactile feedback or the environment can be used to amplify bodily illusions. We extend this prior work by presenting our findings that such amplification is possible while floating in water: first, warm water (35°C) facilitates the blurring of the body's boundaries, second VR scenes associated with floating (in our case, psychedelic space and rainy sky scene) can amplify these bodily illusions; and third, that VR synchronized with tactile feedback can generate a sense of realism in those body illusions. We believe that by following these design strategies, designers could facilitate bodily illusions and an amplified sense of weightlessness also in other water settings, such as while people floating in a pool or sitting in a hot tub, and, thereby, provide those users with greater access to the advantages of water buoyancy.

7.2 Background relations: Soma → (Technology/Water)

A background relation emerges when the technology shapes the experiential context, acting as a backstage unconscious experience [56, 100, 126].

This relation uses the notation *Human→(Technology/World)* [56, 100, 126], whereby technology and world merge since the technology aims to shape the users' surrounding world, with or without their conscious interaction. The cold air from air conditioners provides a good example of background technologies being a context for human existence [100, 126]. We propose a specific version of this relation with the notation *Soma→(Technology/Water)*, which describes the background mediation of Fluito as a soma-technology relation design used in water.

7.2.1 Soma → (Technology/Water): Designing for indirect biosignal control to ***facilitate*** *slow water play.* A background relation emerged when participants realized that their HR, usually an unconscious function, could control visual elements in Fluito. The HR sensor shaped the experiential context of being in water by changing the virtual water (if the HR was above the threshold, the background virtual environment's color changed or activated the rain). This helped participants pay attention to their bodies (F5), which can be useful, for example, when designers want to enhance bodily awareness to improve body posture in water. HCI has explored biofeedback as an added game mechanic (directly controlling avatars) in serious games [86], for example, to support motor rehabilitation [82]. Our approach to controlling the virtual water context was inspired by prior work that used HR for direct control of water animations [15, 42], and biofeedback research showing that biosignals are helpful to directly reflect the user's action in a virtual world [86], what prior work called "slow play" [81]. This slow play could be facilitated by using biosensors to indirectly control [86] the user's water world. We believe that biofeedback can support slow water interactions and exploration [81] and open opportunities for people to reflect on their water perceptions and playfully explore [18, 73].

Design implication: Therefore, to encourage *Soma→(Technology/Water)* relations, we suggest designers consider facilitating slow water play, for example, by using biosignals to indirectly control the user's water (physical or virtual) world, as a way to facilitate reflection on the experience. We believe this strategy could be used in other water environments that demand attention, such as the ocean (for safety, for example, but also to raise sustainability awareness, etc.), allowing users to focus on the water while their biosignals control background interactions.

7.3 Immersion relations: Soma ←→ Technology/Water

Immersion relations emerge when technologies are an interactive context for our existence, not just a background [100, 126]. These relations are represented as *Human ←→ Technology/World*, where technology is merged with the world. The bi-directionality of the arrow represents how technology intentionally directs humans' attention to the world while re-directing their attention to themselves [21, 126]; thus, humans can create new perceptions toward themselves through technology [100]. In these relations, technology is not necessarily literally merged with the world, it could be that technology becomes the world in which users are immersed. Immersion relations can emerge from technologies that perceive users and act upon them [21], such as "smart environments," described by researchers as interactive environments that become our world themselves [21].

We propose a specific version of immersion relations with the notation *Soma ←→ Technology/Water*, whereby Fluito acted as an immersive technology, becoming the world for the participant's thanks to its interactive technology working simultaneously with the surrounding water. Fluito responded intentionally to participants' actions, such as altering visuals based on rules in response to participants' head movements and breathing, creating new perceptions toward themselves that became "their world".

7.3.1 Soma ⟵⟶ Technology/Water: Designing to ***encourage*** *breathing and body awareness in water experiences.* Breathing and body awareness in water can be considered valuable skills. For example, a diver can control their body's submersion and buoyancy through breath control [117, 120]. We highlight that an immersion relation emerged when Fluito participants experienced breathing awareness while immersed. As an immersion relation, the bi-directionality of Fluito mediation was established when Fluito was sensing participants' breathing, then, Fluito guided them intentionally to regulate their breathing using VR visuals and tactile feedback through the water, changing the participants' virtual and real water worlds. Our results (F5 and F6) suggest that these two features directed participants' attention to themselves, especially the bubbles, because they were perceived as complementary to the virtual environment's visual cues (finding 6), pleasurable, and enjoyable (F14). However, participants were often so focused on the VR scenes' appeal (F13) that they ended up deviating their attention, negatively affecting their breathing and bodily self-awareness (F5 and F9).

Design implication: We conclude that designers should consider balancing the appeal and number of visual cues with timely tactile feedback to facilitate breathing and bodily awareness in water experiences. Their bodily awareness might diminish if the visual cues require too much attention. To address this risk, and echoing the theory that our bodily awareness is a multisensory construct enhanced by tactile sensations [38], timely tactile feedback through the water could help participants become more bodily aware. Prior somaesthetic design work has proposed systems using tactile feedback to facilitate breathing and bodily awareness [114]. We extend this prior work by suggesting also leveraging the environment to create bodily awareness, as we did by leveraging the natural pleasure of being surrounded by water to create tactile feedback with bubbles. Hence, we highlight the opportunity for designers to encourage breathing and bodily awareness technologies that support the *Soma ⟵⟶ Technology/Water* relation. This bodily awareness may also be valuable for designers that aim to encourage people to control the buoyancy of their bodies while submerged in water, for example, while diving, or in water sports, such as underwater rugby.

7.3.2 Soma ⟵⟶ Technology/Water: Designing to ***encourage*** *a sense of presence through new bodily sensations facilitated by water.* We found that an immersion relation arose when participants felt an increased sense of presence (the perception of "being there" [106]). The bi-directionality of the mediation was characterized by Fluito's bubbles being directed to the participants to redirect their attention to the VR scenes. We highlight that Fluito is a dynamic experience, with different stages and different interactions through time, and as shown in our results section, participants' experiences were diverse. Thus, we acknowledge an opposite finding when we realize that in some stages of Fluito's interaction, bubbles helped participants become more aware of their bodies and break the sense of presence by directing their attention to them. On the contrary, in other stages, the bubbles reinforced the sense of presence created by the VR scenes (F12) by triggering new body sensations, providing realism to the VR scenes. While Fluito's VR scenes and bubbles' tactile feedback can facilitate the sense of presence, we also contend that the bubbles can be perceived as playful. By stimulating their senses, people can experience playfulness in terms of excitement [18, 73]. HCI researchers have explored sensitive, playful experiences through haptic and tactile feedback in the creation of games, showing that haptics increases the interaction with players and the game experience by leveraging the sense of touch [22, 47]. Our work with Fluito confirms this theory since participants reported having fun due to the bubbles' sensation (F6, F11, and F12).

Design implication: We note that the bubbles facilitated a range of engaging bodily sensations (F14), such as gentle touch, tickles, and tingling. Hence, our results align with prior VR work, which showed that combining visual and haptic or tactile feedback was associated with a greater reported sense of presence [47, 66, 106]. We also extend prior work because Fluito's tactile feedback was

Table 1. Discussion summary: design implications derived from a postphenomenological lens

Postphenomenological framework	Design implication	Fluito specifications
Embodiment relations: (Soma-Technology) ⟶ Water	Designing to call attention to the water	Using bubbles, delivered through the water via air pumps, to direct the participant's attention to the water.
	Designing to amplify the relaxation facilitated by water	Using complementary digital sounds of water, digital animations congruent to the water environment (water-themed and slow-moving), and soft tactile sensations complementing the touch sensation of water on the user's skin, to amplify the relaxation facilitated by water.
	Designing to amplify water's potential for bodily illusions	Using warm water (35°C) facilitates the blurring of the body's boundaries. Using VR scenes associated with floating, and VR synchronized with tactile feedback can generate a sense of realism in the body illusions.
Background relations: Soma ⟶ (Technology/Water)	Designing for indirect biosignal control to facilitate slow water play	Using biosignals to indirectly control the participant's water (physical or virtual) world, as a way to facilitate reflection while playing.
Immersion relations: Soma ⟵⟶ Technology/Water	Designing to encourage breathing and body awareness in water	Using timely tactile feedback through the water (air bubbles, in our case) to help participants become more breathing and bodily aware.
	Designing to encourage a sense of presence through new bodily sensations facilitated by water	Using tactile feedback synchronized with VR to create engaging bodily sensations and encourage a sense of presence.

provided using the water surrounding the participants, which is novel in the VR and haptics and tactile fields. We believe that designers could also encourage a sense of presence through new bodily sensations when considering *Soma ⟵⟶ Technology/Water* relations in other water environments, such as a pool or the ocean, by using similar tactile technology attached to the walls environment or embedded in a wetsuit (as commonly used in surfing and diving).

8 LIMITATIONS AND FUTURE WORK

8.1 Data Collection

We acknowledge that our work has limitations, in particular the fact that our implications were derived from the specific water environment (the floatation tank). We chose floatation tanks as research vehicles to begin investigating the experiential aspects for the design of the Human-Technology-Water intersection. Although this setting has very specific water conditions, our methodology and analysis allowed us to provide design implications that could be used in other water environments, we believe. However, of course, validating this is an avenue for future work. In addition, the sample size (n=13) is another limitation, although it is in line with related qualitative studies in WaterHCI [78, 97, 111]. Moreover, we believe that our work could be used to structure future larger studies in collaboration with floatation tank centers, since we proved that technology could be used in a safe way in this type of setting. Moreover, physiological data could also be collected; for example, a future study could record Fluito's HR readings to analyze the HR variability as additional data. Furthermore, other technologies, such as eye tracking or gesture recognition, could be used to collect data and to create interactions, once the waterproofing challenge is overcome. Therefore, we encourage designers to explore these avenues for future work.

8.2 Data analysis

Although the coding process during our analysis was "data driven" [28] following the recommendations of prior work [17, 105], where the two coders worked separately and systematically through the transcripts, we acknowledge that bias can exist. Moreover, we acknowledge that the data is the result of the subjective descriptions of our participants; hence, future work could aim to understand the effects of our prototype also in the emotional and physical state of participants by analyzing quantitative data, such as physiological measurements.

8.3 Discussion approach and framework applicability

Another limitation is the discussion of our results through three postphenomenological relations. We acknowledge that we have not (yet) discussed all the postphenomenological relations proposed by Verbeek [100, 126]. As such, future work could investigate additional postphenomenological relations by introducing other technological prototypes in different aquatic environments. For example, future work could design soft robots for a playful underwater activity, where researchers could find other relations when analyzing the participants' experience through a postphenomenological lens.

9 CONCLUSION

This paper presents the design of a novel WaterHCI system called Fluito, which aims to facilitate a playful water experience in a floatation tank. When designing the system using a somaesthetics approach, we wanted to understand the integration of the soma, technology, and water to synergistically facilitate the benefits of being playful in water. Based on our study, we have articulated four themes connecting Fluito's features and participants' experiences. Employing a postphenomenological lens, we have proposed a novel *Soma-Technology-Water* relation that highlights how designing for water experiences should simultaneously consider embodied, background, and immersive relations. This approach stands in contrast to traditional, land-based HCI, which is usually concerned with one relation at a time [51]. However, according to our analysis, designing for water should consider designing for all three relations because water can be considered embodied, provides the background for many human activities (such as walking along the beach), and can be immersive (such as when diving underwater).

Using this *Soma-Technology-Water* relation, we have articulated design implications to guide designers of playful water experiences in the future and to support WaterHCI researchers studying the interaction between the soma, technology, and water, by highlighting through technology the lived and felt body in water. Moreover, our work fits within larger discourse in HCI, such as designing technologies for mental health [30, 58, 131], games beyond entertainment [82, 123] and slow design [19, 45, 67, 113]. In addition, our work can inspire more HCI researchers to contribute to the WaterHCI area, and demonstrate how soma design practices can be applied to other HCI subfields. Ultimately, we hope our work begins to expand the HCI understanding of designing playful water experiences to foster the benefits of being playful in water.

ACKNOWLEDGMENTS

We would like to thank all the participants who volunteered to take part in the study presented in this work. This research was supported by an Australian Research Council(ARC) grant (DP200102612). Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the ARC.

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