Exploring an Extended Reality Floatation Tank Experience to Reduce the Fear of Being in Water

Maria F. Montoya
maria@exertiongameslab.org
Monash University
Melbourne, Australia

Hannah Qiao
hannah@ahlab.org
National University of Singapore
Singapore, Singapore

Prasanth Sasikumar
prasanth.sasikumar@nus.edu.sg
National University of Singapore
Singapore, Singapore

Don Samitha Elvitigala
don.elvitigala@monash.edu
Monash University
Melbourne, Australia

Sarah Jane Pell
research@sarahjanepell.com
Monash University
Melbourne, Australia

Suranga Nanayakkara
suranga@ahlab.org
National University of Singapore
Singapore, Singapore

Florian 'Floyd' Mueller
floyd@exertiongameslab.org
Monash University
Melbourne, Australia

Figure 1: Participant floating in a floatation tank using the extended reality system used in this study

ABSTRACT

People with a fear of being in water rarely engage in water activities and hence miss out on the associated health benefits. Prior research suggested virtual exposure to treat fears. However, when it comes to a fear of being in water, virtual water might not capture water's immersive qualities, while real water can pose safety risks. We propose extended reality to combine both advantages: We conducted a study (N=12) where participants with a fear of being in water interacted with playful water-inspired virtual reality worlds while floating inside a floatation tank. Our findings, supported quantitatively by heart rate variability and qualitatively by interviews, suggest that playful extended reality could mitigate fear responses in an entertaining way. We also present insights for the design of future systems that aim to help people with a fear of being in water and other phobias by using the best of the virtual and physical worlds.

KEYWORDS

water, fear of being in water, extended reality, floatation tank, flotation pod, exposure therapy, phobia, virtual reality

ACM Reference Format:

Maria F. Montoya, Hannah Qiao, Prasanth Sasikumar, Don Samitha Elvitigala, Sarah Jane Pell, Suranga Nanayakkara, and Florian 'Floyd' Mueller. 2024. Exploring an Extended Reality Floatation Tank Experience to Reduce the Fear of Being in Water. In *Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI '24), May 11–16, 2024, Honolulu, HI, USA.* ACM, New York, NY, USA, 17 pages. https://doi.org/10.1145/3613904.3642285

1 INTRODUCTION

Being in water has many mental, physical, and cultural benefits [24, 47, 88, 112]. However, people without access to bodies of water, such as public swimming pools and oceans, rarely experience water activities. This lack of access, and other cultural and skill-based reasons [80, 82, 105], offer possible explanations for a fear of being in water, or Aquaphobia [82]. Fear of being in water is an aversion to being in the water, and Aquaphobia is the clinically diagnosed irrational fear of water (i.e., a persistent fear with an inability to overcome it) [74, 80, 91]. People who fear being in water are often unable to enjoy recreational and playful activities in water, such as at swimming pools or beaches [80] and can even develop a fear of drowning [1, 13]. We believe there is an opportunity for interactive systems to bring people closer to water in fun and accessible ways. Although Human-Computer Interaction (HCI) researchers have developed tools for phobia treatment aiming to help people with specific fears [17], and the WaterHCI area (focused on the creation of interactive systems tailored for water-related activities [25, 73, 84]) keeps gaining attention, little knowledge exists on the use of interactive systems to reduce the fear of being in water [101, 106, 116]. With such knowledge, we believe we could begin reducing the barriers to accessing aquatic activities' physical and mental benefits.

In prior work, we presented an extended reality (XR) system that offers a playful water experience in a floatation tank, bringing people closer to water as well as allowing relaxation and entertainment [84, 85]. We are interested in the potential of this XR system to reduce people's fear of being in water. We hypothesized that this XR system could mitigate the fear of being in water for three main reasons. Firstly, floatation tanks are a controlled water environment (compared to dynamic natural water environments) and their salt-water buoyancy affords effortless floating, so people need little effort to stay afloat and can more easily enjoy their bodies being in water, similar to people who receive help to learn to float in pools [60, 110]. Secondly, the system's VR component (comprising different VR environments with hear rate biofeedback, thereby providing an extended immersive water environment) guides participants to relax and explore water worlds (real and virtual), similar to virtual reality exposure therapy (VRET), which progressively engages people to a fearful situation [17, 99, 108]. Thirdly, the system rewards participants with a playful experience through an entertaining interactive story, that could engage participants to be in water, similar to games used for VRET to engage people with the fearful element [8, 39, 79],

As an initial exploration of sensitizing people to water in general, we examined the XR system's feasibility to help a sub-clinical population of people with fear of being in water (Fig. 1). We conducted a mixed-method controlled study to investigate the research question: How does an XR system within a floatation tank influence people's perceived fear of being in water? Using heart rate variability (HRV) analysis, statistical analysis of anxiety and fear of water questionnaires, and thematic analysis of semi-structured interviews, we analyzed participants' perceived fear of being in water and their user experiences (UX). Our paper's contributions are:

- The articulation of participants' subjective UX with the XR system and their willingness to use interactive technology in water, which might be useful to WaterHCI researchers and designers interested in developing interactive technology not just for people with fears, but possibly for general health and wellbeing.
- The analysis of participants' HRV data, providing insights into the influence of combining water and interactive technology, which could be useful for WaterHCI designers interested in reducing the fear of being in water.
- Four design strategies to inspire stakeholders, such as psychologist, health practitioners, and wellbeing designers interested in wellbeing applications to use interactive technology as a tool in the treatment of fear of being in the water and possible for other phobias.

If XR systems like the one investigated in this study can help people reduce their fear of being in water, we believe that people would be more likely to engage in playful water activities and hence profit from the associated benefits. Moreover, we see our work not

CHI '24, May 11–16, 2024, Honolulu, HI, USA

ACM ISBN 979-8-4007-0330-0/24/05
https://doi.org/10.1145/3613904.3642285

as a conclusion on the topic, but rather as a stepping stone towards more work on the use of XR and water to help people.

2 RELATED WORK

2.1 Fear of being in water and Aquaphobia

Fear of water is characterized by a feeling of aversion towards water, and can be overcome [74]. Aquaphobia, an extreme fear of water, is clinically diagnosed as irrational and persistent, and cannot be overcome [74, 80, 91]. Psychology researchers [6, 78, 80] categorize the fear of being in water as a "specific phobia". Cognitive researchers have also investigated associated fears of being in water [70]. Although we are not investigating clinically diagnosed fear of being in water, we learned from this prior work that many factors influence fear of being in water, including past bad experiences and lack of skills to floating or moving in water, leading to a fear of drowning [13, 82, 97]. Consequently, we took these reasons into account when proposing different technologies as tools to reduce people's fear of being in water.

We have also learned from sports scientists that fear of being in water can be a barrier to performing water activities such as swimming, and sports researchers have investigated playful ways to reduce this fear, such as through water play activities [13, 62, 81, 90, 111]. While this research shows us that progressive, playful water contact can help people feel more comfortable in water, our work aims to contribute knowledge about how fear of being in water could be mitigated in the future through a combination of water and interactive technology.

2.2 Floatation tanks as psychological therapy

Psychologists originally designed floatation tanks, also known as sensory deprivation tanks, to conduct psychological studies or "restricted environmental stimulation therapy" (REST) [66, 67, 118, 120]. Floatation tanks enabled a specific type of REST, called "floatation therapy" [67, 120], that researchers demonstrated could be useful for patients with health disorders including hypertension [118], chronic pain [67], anxiety [35], burnout syndrome, and stress [59, 120]. While floatation therapy has been shown to reduce anxiety, which is the main symptom in fear response [80, 99], and many floatation centers advertise this benefit [57], there is little research on its use for specific phobias [58]. To the best of our knowledge, there are no investigations into the use of technology in floatation sessions to reduce fear of being in water. Nevertheless, floatation in pools is a common step towards overcoming fear of being in water when learning to swim [81, 82, 90, 110], which indicates its efficacy in reducing fear of being in water.

2.3 Virtual reality as therapy for phobias and fear of being in water

HCI researchers have proposed virtual water environments to treat anxiety, suggesting that water-related visualizations and soundscapes could induce relaxation [9, 56, 121]. Interestingly, Hafsteisson et al. [45] proposed a virtual visualization of water to potentially induce fear of water, without utilizing the physical water's tactile stimuli that could also induce fear of water. We believe that the combination of water-related virtual elements and water's physical touch could trigger a response in people who have a fear of being in water. On the one hand, as exposure therapy has suggested, exposing people to water may increase their anxiety [17]. On the other hand, as a controlled water environment in which people can float effortlessly, the floatation tank may reduce participants' anxiety. Hoffman et al.'s [50, 51] research results could be an indicator of this second possibility, given that they achieved pain reductions when combining wound treatment in a hydrotank with a water-related VR visualization.

Researchers have proposed VR environments to address fear in stressful situations [96] and treat phobias [17], such as arachnophobia (fear of spiders) [33, 41] and claustrophobia (fear of being in closed spaces) [20] under the term "virtual reality exposure therapy" (VRET) [17, 99]. VRET reduces anxiety, the basic phobia response [17, 99, 128]. Recent work investigated the use of VRET for water-related phobias, such as squalophobia (fear of sharks) [70] and thalassophobia (fear of large bodies of water) [95]. While these works showed us that virtual undersea environments tend to induce fear responses and that progressive exposure to VR water environments offers a first step toward overcoming water-related fear, there are few systematic VRET investigations into fear of being in water. We consider VRET to have great potential given that WaterHCI research has used VR headsets in pools [3, 100] and floatation tanks for physical rehabilitation and recreational purposes [4, 84, 85]. However, there exists little insight into people's UXs of being in the water while using this technology [84] or, more specifically, whether people with a fear of being in water are willing to use this technology, and the impact it may have on their fears or perceptions towards water.

Furthermore, very few investigations have proposed VR as part of a treatment for fear of being in water. In one example, Roche et al. [101] proposed 360° videos of aquatic environments to help children relax and climatize to water before a swimming lesson. We note that their research participants (2 swimming students, 11 and 12 years old) did not have contact with physical water during the 360° video projection; in contrast, our study participants did. Although Yang et al [106] developed a system for VR use in a pool for fear of water, they did not evaluate it with people with fear of water; hence, we extend this prior work with a systematic evaluation. While Adhatrao et al. [5] speculated on the use of a VR environment and physiological sensors for treating fear of being in water, they did not develop the systems or undertake a user study. While there has been some exploration of VRET use to treat fear of being in water, there is little evidence of its use and evaluation in a water environment.

2.4 Virtual reality exposure therapy (VRET) evaluation

Given our interest in the UXs, we also learned from prior studies evaluating VRET efficacy and UXs. For example, researchers studied healthy volunteers in a VR environment as a treatment tool for claustrophobia [20], evaluating it using claustrophobia and anxiety questionnaires. Since these questionnaires proved useful, and have been used in clinical trials of phobias [6, 35, 83, 108, 125], we also use them in our work and complement them with qualitative data from interviews to enrich our understanding of the UX and derive insights for future designs. Furthermore, VRET researchers have used biosignals to measure fear responses during VRET for fear of fire, reporting encouraging results [117, 128]. While these works used biosignals in on-land settings, we were inspired to use biosignals in our work because they provide a quantitative measurement of fear [23], the proposed XR system already incorporates heart rate biofeedback [84], and prior work has indicated the feasibility of biosignal measurements in floatation tanks [102].

Therefore, we looked at heart rate variability (HRV), a measurement that has previously been used to understand anxiety responses associated with fear [12, 16, 23, 27, 42, 117]. HRV refers to the variation between heartbeat intervals and reflects the autonomic nervous system's (ANS) influence on the heart. The ANS is known to regulate the fear responses and can be analyzed using HRV [12, 23]. We believe that interactions with this XR system could decrease the anxiety response of participants who have a fear of being in water. To begin understanding this effect, we investigated the differences in HRV measurements of participants floating with the XR system and without it. We hypothesized that a significant decrease in HRV indexes reflecting participants' anxiety levels could be found while participants use the XR system.

3 EXTENDED REALITY SYSTEM

We used an XR system as a research vehicle. This system offers a novel experience within a floatation tank [84], categorized as an XR experience according to Milgram's reality-virtuality continuum [71, 93]. The experience involves floating in the tank while a VR headset (Meta Quest 2) delivers a virtual auditory and visual environment. The participant's HR (sensed using the polar verity sensor [2]), breathing (sensed via the headset's microphone), and slight head movements (sensed via the headset's IMU sensors) control interactions within the virtual environment.

This XR experience provides an interactive journey where the participant is guided through three main virtual water worlds (Fig. 2C, Fig. 2D, Fig. 2E) by a virtual character called "water spirit" (which looks like a cinematic mystical water figure (Fig. 2A)). The water spirit is a guide that provides the participant with verbal assurances that they are doing fine and are safe and encourages them to enjoy the experience. We developed this experience in prior work [84], where through a somaesthetic approach, we provide the design decisions to create a playful floatation tank experience. In addition to the reasons pointed out in the introduction section arguing why we hypothesized that this XR system could mitigate the fear of being in water, we resonate with the following decisions we made when designing this system even though it was not originally designed for fear [84]:

- We believe that the "journey" in this VR experience could be seen as similar to the exposure therapy's "step-by-step" progressive exposure of participants to a fearful situation [17, 124]. For example, the VR journey starts with the water spirit guiding and accompanying the participant to be in contact with water entering a calm ocean (Fig. 2B). Then, they progress to sink into an underwater world (Fig. 2C), in which the participant is encouraged to control their breath and discover the environment. Second, the participant's avatar (guided by the water spirit) moves to a calmer space-like world without virtual contact with water (Fig. 2D), in which the participant is invited to collaborate with the water spirit to collect virtual water balls.
- We found the final stage of the VR journey is analogous to the challenging situations in water environments that sometimes can occur where it is vital to stay calm in order to respond accordingly, for example, when getting into a rip in the ocean. In this final stage, the participant moves skyward (Fig. 2E), and the water spirit guides them to navigate through cyclones and encourages them to control their heart rate to stop the rain and storms (Fig. 2F).
- We created this hands-free interaction by using the headset's IMU sensors and microphone, encouraging slow water movements and facilitating body relaxation in water [84]. We found these interactions suitable for people with a fear of being in the water since they would not have to be worried about doing strenuous movements in their fearful environment.

4 USER STUDY

4.1 Participants

Participants were recruited using advertisements sent to our mailing lists. Participants needed to have a self-described fear of being in water, aged 18 years or older, be healthy, and confirm that they suffered from none of a range of identified risk conditions or disabilities (consistent with previous work [67, 84]).

Twelve participants volunteered for the study (seven females and five males) with a mean age of 30 years (standard deviation of ±2.82 years). No participant reported previous experience using floatation tanks. Regarding their experience with VR technology, six participants described themselves as novices (VR use once in a lifetime or once per year), two as "average" (once a month), and four reported no previous experience. In terms of their experience with aquatic environments, eight participants described themselves as having "novice" experience in pools (mostly used once per year), and four described themselves with "average" experience (mostly used once per month). Only one participant self-described as having novice experience in the ocean, and one had novice experience visiting a water park. Five participants described themselves with a slight (f=1) fear of being in the water, five with a medium fear (f=2), and two with a high (f=3) fear (on a scale from 0 = none to 4 = very high). Ten participants completed the entire study procedure, while two completed all but the last floatation part of the study.

We ensured that all personnel involved followed the local safety guidelines for floatation practice as well as water and VR safety best practice. The ethics committee of our institution approved this study. No safety incidents occurred during the study, and the participants did not report any issues.

4.2 Measurements

The fear of water assessment questionnaire (FWAQ) [82] has helped swimming teachers identify students with a fear of being in water in order to change their coaching strategies. Misimi et al. [82] validated this questionnaire with 2,074 participants. We used this questionnaire as a screening tool to corroborate a participant's self-reported fear of being in water.

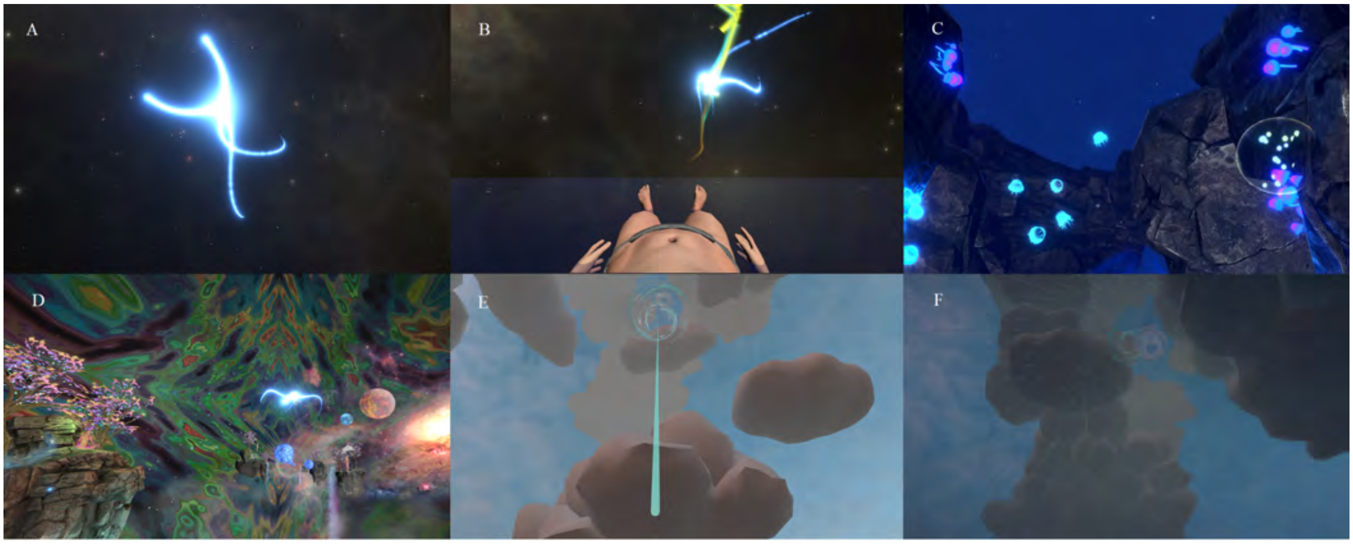

Figure 2: XR system's virtual elements and VR worlds: A) the water spirit; B) introductory calm ocean; C) underwater world; D) space psychedelic world; E) sky world; and F) sky world when raining.

We created a site-specific assessment tool, the Ad-hoc aquatic anxiety questionnaire (AAAQ), to gather participants' subjective anxiety levels. The assessment design needed to be short enough to be administrated during the procedure breaks (see below). This assessment consisted of five statements scored on a Likert scale (from one to five: 1= strongly disagree, 2 = disagree, 3 = not sure, 4 = agree, 5 = strongly agree) with specific statements about feelings that could be related to anxiety levels while in the water. The statements included: "I feel calm", "I feel secure", "I feel comfortable", "I am relaxed", "I feel nervous about water", and "I am worried about water". These statements were extracted from the FWAQ [82] and the anxiety STAI questionnaire [61, 109], which is a well-known anxiety questionnaire often used in studies related to fear [40, 64] and VRET [7, 8, 20, 70].

We conducted semi-structured interviews to assess the participant's UXs. We used a semi-structured approach to leave sufficient room to support deeper elucidation of participants' responses. Finally, we recorded the photoplethysmography (PPG) [103] signal using a second HR light sensor [2]. Participants' PPG signal data, measured during the procedure, was stored in a .CSV file for later analysis.

4.3 Procedure

The study was conducted in a commercial floatation center that owns floatation tanks of 225mm long, 145mm wide, and 30mm of water depth. The tanks are located in private rooms with showers. The lights remained on during the procedure, and the water temperature was 35°C. Our procedure had six stages (Fig. 3). In stage one, we introduced participants to the procedure. The participants completed the FWAQ. Then, we showed participants the floatation room. Participants privately showered and changed into bathing attire, then informed us of when they were ready by knocking at the door. In stage two, we helped participants to put two HR sensors on their arms, (one for the VR's feedback loop and one for the PPG recording) and asked them to lie still on a yoga mat for 5 minutes, while we recorded a baseline HR measurement. They then completed the AAAQ.

Stage three comprised a floating period without technology. We helped participants enter the floatation tank and provided guidance on how to float. Once participants acknowledged that they were floating and stable, we began the HR recording and asked them to float for 15 minutes. Next, they completed the AAAQ.

Stage four comprised a floating period using the XR system delivering the VR experience. We asked participants to stand up inside the floatation tank and dry their hands. We then helped them to put on the VR headset and the VR experience lasted 15 minutes. After this, we helped participants to remove their headset and they completed the AAAQ.

In stage five, participants were asked to float without technology again for 15 minutes with the HR still being recorded. They then completed the AAAQ again and exited the tank. We designed these stages to last 15 minutes each, with a total time of 45 minutes floating, aiming to offer a floating time similar to the commercial floatation sessions (usually 45 minutes to 1 hour) and avoid the "mammal reflex"[11, 37]. Finally, in stage six, we left participants alone in the room to take a shower and prepare for their interview. The lid of the tank remained open during the floating stages since we believed an enclosed space would enhance feelings of fear. For safety reasons, the researchers also remained in the room (at a distance) and monitored the participants at all times.

4.4 Data analysis

The questionnaires were mean scored in a way that was consistent with the scoring approach in prior work [82]. Additionally, the self-reported anxiety data was analyzed on a Likert scale. A repetitive measure ANOVA was performed, to identify differences in the anxiety level between the floating conditions. Additionally, we

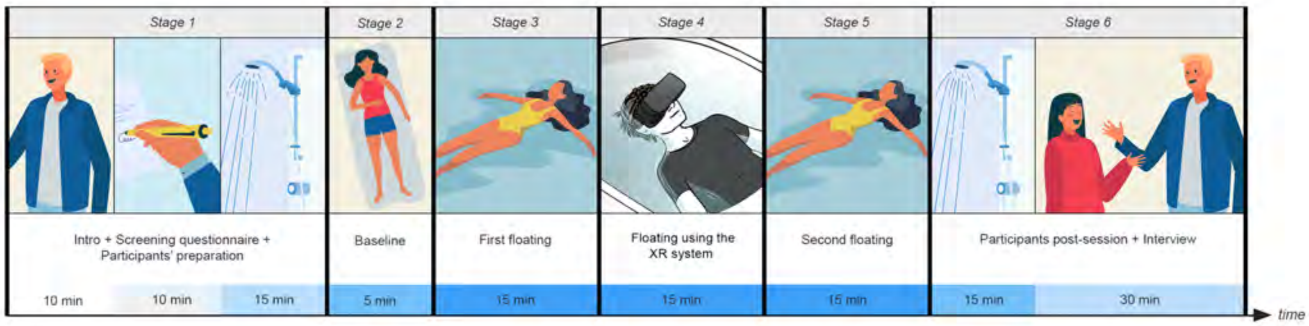

Figure 3: The six stages in our procedure. Stage 1: introduction, screening questionnaire and participant's preparation. Stage 2: baseline. Stage 3: first floating (without the system). Stage 4: floating with the XR system delivering the VR experience. Stage 5: second floating (without the system). Stage 6: participants showering and interview.

conducted a Holm post-hoc test when significant differences were found.

To identify key themes, the semi-structured interviews were analyzed in NVivo using an inductive thematic analysis approach [18] and an open coding process. Each data unit was a single coded quote, a practice we borrowed from others [10, 84, 104]. The coding process was "data driven" to minimize bias, whereby two coders worked separately and systematically through the entire data set (the interview notes transcripts), giving equal attention to each data item [18]. In total, the coders coded 420 units of data, which were subsequently grouped into high-level codes and discussed to generate themes.

Participants' PPG signal data were divided into the procedure stages and pre-processed in 5-minute windows using a 3rd order Butterford bandpass filter with cut-off frequencies between 0.2hz and 2.5hz to eliminate trends, motion artefacts, and ambient light noise. Peak-to-peak detection and the Heartpy python library were used to extract HRV from the pre-processed PPG signal. We extracted time and frequency indexes from the HRV signal. We focused our analysis on short-term indices such as the standard deviation of NN intervals (SDNN) and the high-frequency of the HR spectrum (HF-HRV). Low scores of these two indices are known to reflect the vagal activity and the ANS influence on the heart, which is associated with anxiety and stress responses [16, 23, 27, 117].

5 RESULTS

5.1 Subjective anxiety analysis

5.1.1 Screening fear of water assessment questionnaire (FWAQ). The analysis of the FWAQ confirmed that our participants (n=12) have a fear of being in the water. We compared the mean values of the FWAQ questions of our group (M=3.18, SD=0.68) to the mean values of the FWAQ fear group (M=3.47, SD=0.93) and non-fear group (M=2.15, SD=1.08) in the validation work of the FWAQ [82] (Fig. 4). We performed a T-test to understand if our group had a fear of being in the water when compared with the fear and non-fear groups of the FWAQ. We found no significant differences (p=0.176) between the FWAQ scores of our group and the fear group of Misimi et al. [82], and found significant differences (p=0.004) between the FWAQ scores of our group and the non-fear group of Misimi et al. [82].

5.1.2 Anxiety self-report. Since 2 participants did not complete the last stage of the procedure, we analyzed the AAAQ with n=10. Figure 5 shows the anxiety that participants reported during the procedure's floating stages. In general, we found lower scores of the negative statements "I'm nervous about water" and "I'm worried about water",which could suggest lower anxiety levels during the second floating stage. During the fourth stage (using the XR system delivering VR experience), we found that most participants reported lower scores in these same negative statements, which may suggest decreased worried and nervous feelings; however, they also reported decreased levels of calm, relaxed, secure and comfort feelings.

Every participant reported different levels of anxiety during the floating stages. For example, P4 reported high scores for all the statements in the baseline condition. After the first floating stage, P4's scores of calm, relaxed, secure and comfort feelings decreased by 3 points, while their scores of worried and nervous feelings stayed high. Moreover, during the fourth stage (using the XR system delivering the VR experience), the feeling of nervousness decreased by 1 point, while the worried feeling stayed the same, suggesting a low influence on P4's anxiety. Finally, during the second floating stage, P4 reported lower scores for worried and nervous feelings, and higher scores for calm, relaxed, secure and comfort feelings, which might suggest that the anxiety feeling decreased by the end. On the other hand, P11 experienced different levels of anxiety. P11 also began by reporting high scores for all the statements in the baseline condition. However, during the first floating stage, scores for calm, relaxed, secure and comfort feelings decreased by two points, and worried scores also reduced by two points, suggesting reduced relaxation but also anxiety. After having the VR experience, P11 reported lower scores of worried and nervous feelings, and higher scores for calm, relaxed, secure and comfort feelings than after the previous stage, Which suggest that the XR system delivering the VR experience could positively influence any

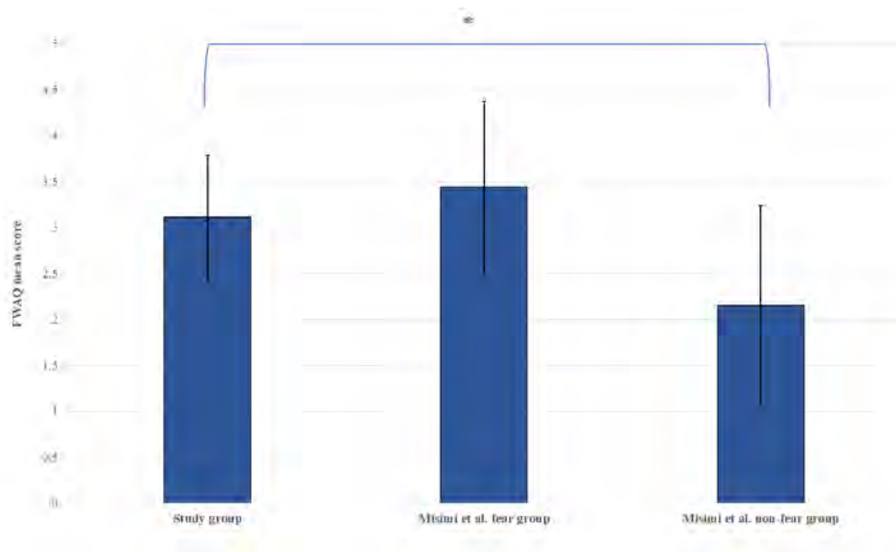

Figure 4: Results of the fear of water assessment questionnaire. Our participants showed a significant difference with the non-fear group participating in the validation study.

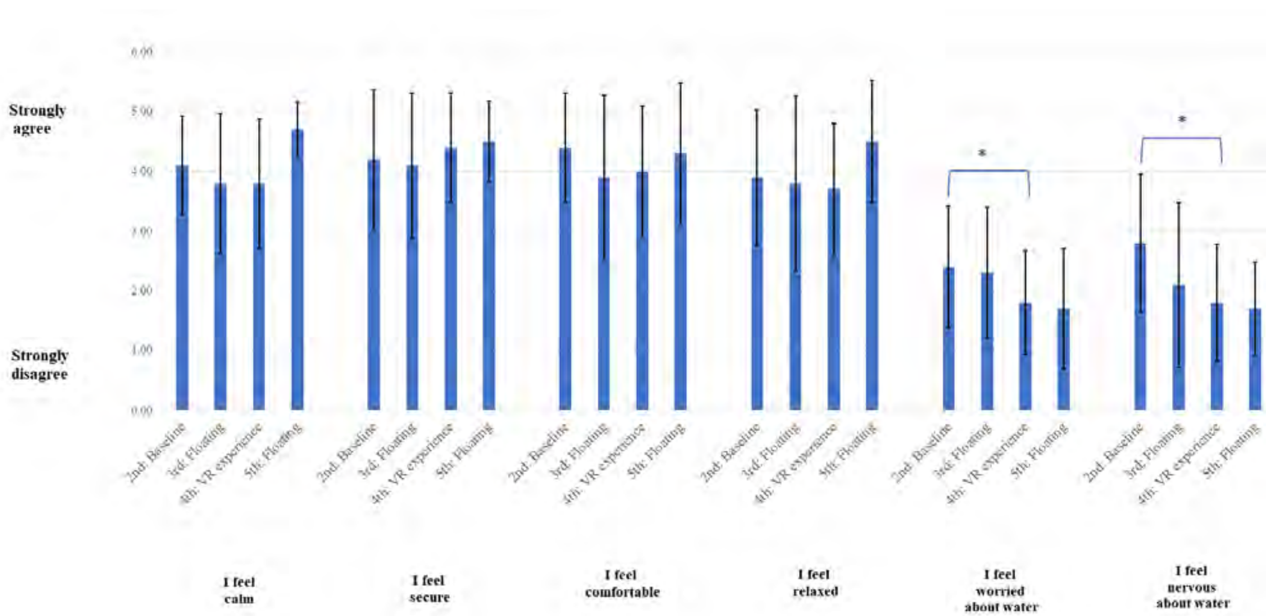

Figure 5: Average scores of the ad-hoc aquatic anxiety questionnaire comparing the protocol conditions. Significant differences (*) were found in the "I feel worried about water" and "I feel nervous about water" statements.

anxiety. Finally, after the second floating stage, P11 reported the same scores than the in previous stage for all the statements except for the relaxed feeling, which increased by one point.

The repeated measured ANOVA test revealed significant differences between the conditions for the worried ($p=0.010$) and nervous ($p<0.003$) statements (Fig. 5). For the worried statement, a Holm post-hoc test suggested that the significant difference ($P_{holm}=0.034$) was between the second (M=2.33, SD=1.03) and fourth stages (M=1.67, SD=0.85). Similarly, a significant difference ($P_{holm}=0.004$) was found between the second (M=2.67, SD=0.43) and fourth stages for the nervous feeling (M=1.67, SD=0.94). These findings might indicate that during the fourth stage (using the XR system delivering the VR experience), participants' worried and nervous feelings decreased when compared with the baseline.

Table 1: HRV indexes' values during the stages of the procedure

Stage	SDNN (ms)		HF (ms^2)	
	Mean	SD	Mean	SD
2nd: Baseline	63.51	19.39	1174.67	1177.40
3rd: First Floatation	63.40	15.47	802.77	323.06
4th: XR system	60.50	20.23	826.71	546.05
5th: Second Floatation	61.98	24.35	1125.20	964.45

5.2 Heart rate variability analysis

During the post-processing of the data, we realized some problems with the HR sensor's Bluetooth connection presented during the data capture. We initially disregarded this issue because Bluetooth tends to fail if the sensor is submerged 1 meter or more. Although in the floatation tank the sensor was only submerge approximately 10 centimetres, we had disconnection issues only detected when processing the data. Therefore, for this analysis, we did not use the data where Bluetooth issues led to incomplete data, nor the data from participants who did not complete the last stage. Consequently, for each floating stage, we have fewer participants (n=9) than the original sample (n=12). We compared the HRV indexes for each condition (Fig. 6). A repeated measurements ANOVA showed no significant difference between the stages ($p>0.05$). For both indexes, there were two outliers in the fourth and fifth stages. All the outliers correspond to P4, who was the participant who rated a high level of anxiety in the AAAQ, as we discussed in the previous section.

Both indexes had the highest values in the second stage (Figure 4 and Table 2), which may suggest a calmer state when compared with the other stages. Both indexes had lower values in the third stage, suggesting a high anxiety state when floating. Then, during the fourth stage, both indexes increased, which could be an indication of a calmer state using the XR system delivering the VR experience when compared with the previous stage. In the fifth stage, both indexes increased, indicating the participants were calmer in the second floating floating. While the SDNN index differences did not vary greatly, the HF did, probably because this index is more sensitive to anxiety than the SDNN [16, 23]. The indexes' values also indicated that contact with water evoked anxiety states in participants (which could suggest fear), with values lower than the baseline during all the floating stages. We expected this behaviour since the participants have been exposed to something they fear.

5.3 Thematic analysis

In this subsection, we present the qualitative results showing the UXs when interacting with the XR system. The study results suggest that most participants (n=12) found that the XR system delivering the VR experience was helpful to mitigate their fear of being in water. Our data analysis identified four themes.

5.3.1 Theme one: Dive into the past: The impact of previous water experiences. This theme comprises 48 units of data and describes participants' previous experiences that shaped their fear of being in water. We found that this information provided a context to understand participants' experiences while floating with and without using the XR system.

At the begining, participants were prompted about their previous experiences in water and their reasons for fear of being in water. All participants had previous bad or uncomfortable experiences in water, which they associated as the reason for their fear. We found that the scores on participants' self-reports of fear (from 0 to 4), and the reasons for their fear of being in water, were reflected in their experience while floating with and without the XR system. For example, P4 reported a score of 3 on the level of fear, and their main reason was the depth and lack of feeling of touching the bottom of the aquatic environment. Consequently, P4 did not enjoy floating since the high level of fear triggered worried feelings, and floating did not allow P4 to touch the ground. P4 explained: *"I felt like I would lose the perception of where I am, so it was difficult to let go [of the edge] while floating, also the same for the VR"*. However, other participants who rated 1 or 2 in the fear self-report, and the same reason for fear as P4, enjoyed floating with and without the XR system (P2, P3, P6 and P9). For example, P3 stated: *"I started focusing on my breathing, then I felt like I was floating in a slow shallow stream, I liked that"*. P1 and P8 provided another reason. They rated 1 or 2 in the fear self-report and reported fear of being in water because of a lack of swimming skills. We found that they enjoyed being able to float without effort, as mentioned by P1: *"I had fun floating on [the] water without [a] life jacket"*. Similarly, P11 and P12 enjoyed floating with and without the XR system, and they rated 1 or 2 in the fear self-report and reported fear of being in water because they had almost drowned in the past. This theme suggests overall that the floating experience with or without the XR system can be beneficial depending on the level of fear, and it appears to work better for participants who self-reported moderate fear (fear level <2).

5.3.2 Theme two: Floating Fears: Navigating the waters of anxiety and relaxation. This theme comprises 139 data units and describes how the floating experience, with and without using the XR system delivering the VR experience, influenced fear and anxiety feelings.

Eleven participants reported that floating helped them to relax and be calm. One reason for this effect was attributed to the feeling of weightlessness provided by the buoyant water. P2 explained: *"I felt weightless and very, very relaxed [...] I think it's the floating feeling. It's not a chance you'll always get to feel it"*. The buoyant water also appeared to generate a feeling of safety. P8 explained: *"I would say the reason I felt calmer was because I knew I wouldn't drown in the floatation tank"*. Another reason for feeling relaxed was the warm water temperature, which seemed to allow participants to forget about the body boundaries, as reported by P9: *"The time it takes for me to lose sense of the boundary of my skin and the environment takes [a] long time [...] but here [in the floatation tank] it was forced - like I could reach that state in 3 to 4 minutes"*. P2 explained that the lack of external sound calmed them: *"at one point I could hear my own heartbeat, that was really calming"*. P8 found that the salt disrupted their relaxation: *"The salt was getting everywhere, which was annoying"*. Interestingly, participants found that the VR worlds enhanced the calm feeling. P2 mentioned: *"Without the VR - It was just me trying to calm down, but I didn't have to make any effort*

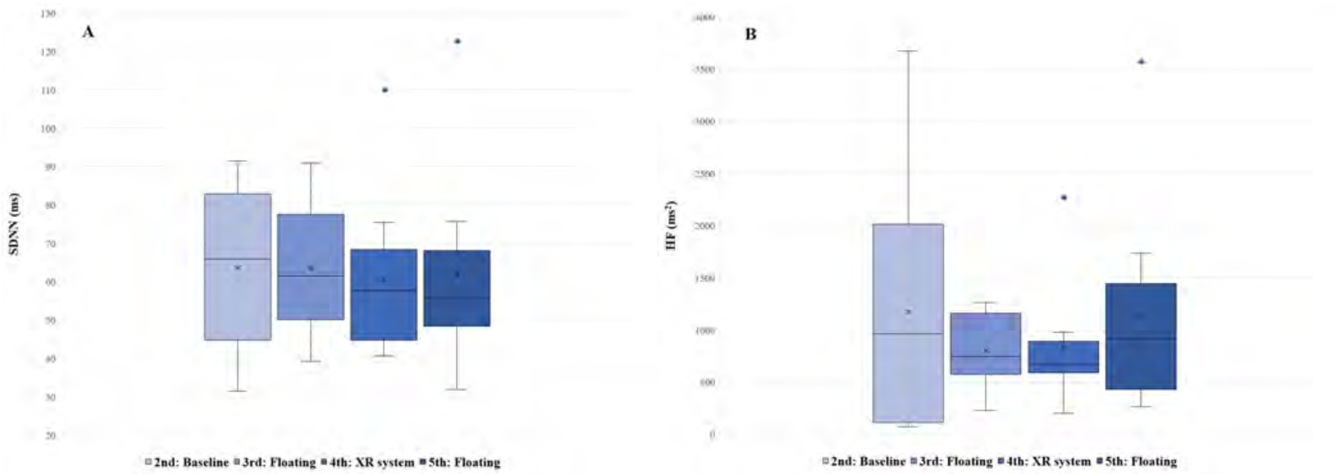

Figure 6: HRV indexes during the procedure stages. A) The standard deviation of NN intervals (SDNN, ms); B) The high frequency of the HR spectrum (HF, ms^2). The X marks represent the mean values in Table 1. The blue dots represent the outliers.

to do that when watching the scene". Moreover, some participants considered that floating in the tank would be a good step to getting used to water, as P10 mentioned: *"The density of the water was very high, so the pool and ocean would be different, but this was a safe mechanism for people to get floating and used to the water"*.

Eight participants reported that the VR experience helped reduce their anxiety and fear, articulating different reasons. Some participants mentioned that the VR environment helped them to forget about being worried about the water, as P1 explained: *"It [the VR environment] helped me, I forget I'm in the water, the water effect adds value to the VR experience you can feel like you are floating, I was not scared"*. Similarly, P11 mentioned the VR environment helped to distract them: *"VR definitely helped with the relaxation part, but also a distraction to not focus on the fear"*. Other participants stated that floating using the XR system delivering the VR experience helped them because they experienced fantasy worlds and different interactions. For example, P3 said: *"With VR, we can feel anything, do things we cannot do, e.g., going to space, or going underwater. With VR, we can feel it, so I think it's great in that way"*. Similarly, P8 mentioned that the interactions in VR helped: *"It makes you interact with the water to feel comfortable with it, especially floating in the first session; after VR, I felt more comfortable about being in the water"*. While the VR environment helped these participants, P2 and P9 pointed out that the underwater environment increased their anxiety feelings: *"I was so scared of being underwater, like the rocks and stuff, the fish was the only thing that made it okay"* (P2).

Two participants reported that the XR system delivering the VR experience did not help them and generated uncomfortable feelings. We discovered that the origin of this discomfort appeared to be a perceived reduction of their orientation affecting their proprioception sense. In the case of P4, who had a high level of fear of being in water, the lack of orientation in the tank space created anxiety, which increased when P4 donned the headset. They explained: *"I felt like I would lose the perception of where I am, so it was difficult to let go [of the edge] while floating, also the same for the VR [...] I was thinking about where I was, what if I drifted away?"*. P10 experienced nausea: *"The VR was a bit nauseating for me, I think it's because I'm not used to VR and have had some problems with VR before in the past with motion sickness"*. The participants mentioned that the VR experience could have worked better in two ways. First, they wondered if they could initially get used to simply floating, as mentioned by P4: *"Only after when I could let go and float properly then if I did the VR [it could've been ok], that [being able to float properly] would have helped after I relaxed"*. Second, they wondered if they could first experienced the system without floating, as P10 outlined: *"An intro to VR, before [being] in the floating tank, would be good for people like me. Sometimes you have to get over the nausea to focus on the actual message so maybe that would've been better for me"*.

Overall, floating without technology can provide a calm and relaxed feeling for people with a fear of being in water. Moreover, a XR system delivering a VR environment could positively influence the fear of participants who are not sensitive to an altered orientation affecting their proprioception sense.

5.3.3 Theme Three: Riding waves of fun: floating as an engaging experience. In this theme, we describe the different ways participants engaged. This theme comprises 133 units of data. In general, participants reported losing track of time, indicating engagement: *"I assumed there would be more, but it ended soon. I felt like I needed more, I wanted a little more"* (P1).

Participants reported being engaged by having fun. P10 explained: *"When you let go and start floating, it's actually fun"*. Other participants reported fun due to their interactions with the VR environment, as P1 mentioned: *"The game where I had to move my head to catch water bubbles, I didn't really have much feeling, but it was really fun, and I was engaged in it"*. Participants also described the entire experience as being "fun". When asked about the experience overall, P7 answered: *"It was very fun"*.

Moreover, participants reported being engaged by the interactions of the XR system delivering the VR experience, as P8 stated:

"I liked the interactions in the game, otherwise it becomes passive". Similarly, P1, who said: *"The water bubbles game was nice, I could do most of the actions, the interactivity was nice"*. Participants appeared to appreciate not having to do much: *"Interaction was ok, didn't really feel there was much"* (P2). Specifically, the participants were highly engaged in the space-psychedelic world. For example, P2 said: *"The second one was really interesting, felt like meditation, the sound was soothing, it was really good"*. Other participants enjoyed the movement in the other scenes, as P8 stated: *"The going up part [in the virtual world] was good"*. Nonetheless, for some participants, other interactions were confusing, especially in the sky world: *"The last one, the cyclone one, was extremely confusing, wasn't sure what to do to control the cyclone"* (P6).

Furthermore, participants appeared to be engaged because feelings of relaxation were facilitated, which invited such engagement. The experience overall was relaxing for them, as P5 mentioned: *"The experience as a whole: overall, it's fantastic, it's almost like a Bali experience (from a relaxation point of view)"*. Participants found that using the XR system delivering the VR experience increased their relaxing engagement: *"The main part, I would say, VR helped with, is the relaxation part"* (P11). In contrast, two participants reported that neck fatigue interrupted their engagement, although they were able to overcome this feeling, as P7 explained: *"In the beginning, I was a little uncomfortable, I think I was tensing my neck a lot. After that, I felt like I was lying down on my bed. At one point, I thought I might fall asleep, I was very relaxed"*.

Participants reported being engaged by the bodily illusions they experienced. The bodily illusions emerged in the form of feeling movement and forgetting they were floating in the water. As P10 explained, some of these illusions were triggered by the buoyant water: *"There was a dissonance between what I was feeling and being in the water, like when I wasn't paying attention to myself, I felt like I was on my bed"*. However, most of the illusions were triggered by the VR environments. In this regard, P9 said: *"When the background was moving, my engagement in the VR was so high that I must have lost that sense that I was in the water"*. Forgetting about water made P8 feel like being in outer space: *"For a very brief moment I forgot that I was in the water [while using VR], it was like being in outer space, but it was very brief, maybe 3 secs long"*. The virtual sky world made P2 feel like they were floating away: *"It felt like I could float away, especially the sky one, if I moved my legs, I could just go away"*. P6 appreciated how the VR experience could create these illusions: *"With VR, I can see how you'd overlay interesting visual experiences on top of that feeling of weightlessness"*. P9 reflected on the reasons why these bodily illusions happened: *"Your mind is trying to figure out what is there, if it's trying too hard to figure out the visuals, then your mind is too engaged in it and maybe not in your surroundings [water]"*.

Taken together, participants found the experience engaging through fun feelings, the VR interactions, relaxation, and bodily illusions. Albeit motion sickness hindered the emergence of fun for two participants. Also, six participants reported neck fatigue due to the headset, which *"kind of clashes with the experience"* (P5).

5.3.4 Theme four: Tech on the tide: navigating technology perceptions while floating. In this theme, we describe how participants perceived their interaction with the XR technology during the experience. This theme comprised 55 units of data.

Participants enjoyed different aspects of the technology. The virtual worlds took most of participant's attention, and they mainly enjoyed the visual aspects of the experience: *"The visual part of it was amazing, though I kind of just enjoyed the chill visuals"* (P6). P12 concurred: *"The way it [the visual] is made is very beautiful, gives a new experience to the users"*. While some participants enjoyed the sound, most of them could not hear it clearly because their ears were submerged: *"The sound wasn't really clear, probably because of the water"* (P11). Participants disliked the verbal and written instructions. For example, P6 said that *"The talking was a bit [disruptive], like, oh, I have to do this or that"*, and P8 added that *"the text was sometimes annoying, sometimes distracting"*.

The required headset adjustments emerged as an issue. While the researchers adjusted the headset straps and focused the lenses for every participant, some found the fit to be a problem. For example, P7 said that *"Sometimes the precision [fit of the headset] might've been annoying"*. While we informed the participants beforehand that their head interactions were made to prevent the headset's submersion, they still expressed concerns about it. For example, P7 said: *"I wasn't sure if my head would go into the water, so I was afraid to move my head too much. I think the alignment of [the] headset had some issues"*.

5.3.5 Theme five: Making waves: transforming willingness to perform future water interactions. In this theme, we describe how participants reported an increased willingness to perform water activities after the study. This theme comprises 45 units of data.

Ten participants reported that they would repeat the experience. One of the reasons was that they found it a good progression to start floating in a floatation tank, which is a controlled water environment: *"It was a good initial experience to start off within a small body of water without having too much fear of the water"* (P10). Participants also reported they knew they would not drown in a floatation tank: *"It was always in my mind that the water isn't too deep and I won't drown, I can always touch the sides"* (P2). Participants indicated that they enjoyed and would repeat the experience: *"I would do it again, it [floating using XR] is fun"* (P1). One participant mentioned that just floating without the system was more appealing, and one participant was negative about repeating the experience: *"I wouldn't like to go into a pod again. The one way that it helps [to reduce the fear, is because] in the pool there's company, you can start playing, but you can't play here. When you can play, it gets easy, maybe you were trying that with the VR, but I was too focused on the floating"* (P4).

Interestingly, eight participants stated that after the experience, they would like to try other water experiences: *"I would try again floating on seawater, but I would still use a life jacket"* (P1); *"I would like to do this again, I would like to do it without the salt, just general floating. Initially, in a swimming pool, I'm scared of the ocean"* (P11); and *"Maybe I'd be more open towards floating in the sea - because I personally can't tread water, I'm not sure whether I can float, but maybe with this experience I would be open to trying it more"* (P5).

6 DISCUSSION

In this section, we will discuss our results based on the assumptions we established in the introduction, and we will also compare them with the findings of previous HCI work and WaterHCI work. Firstly, we note that prior WaterHCI work have investigated the coming together of interactive technology and water, mostly from the perspective of using water to offer force-feedback [30, 53, 72]. Prior work also investigated water as an interface, such as display [76, 114]. In contrast, we extend WaterHCI by adding knowledge on the role of interactive technology when people are interacting with water while "in" water, i.e., immersed in water [21, 28, 34, 46, 92, 107, 126, 127]. As such, we believe that our findings will be particularly relevant to people working in this space, but might also be interesting to other WaterHCI researchers and even researchers in other sub-fields of HCI, such as healthHCI, people working on immersion and HCI, researchers working on HCI issues around mixed reality.

Secondly, in the next subsections, we will discuss our study results and their implications on the use of water playful activities to reduce fear of water and their possible applications in other phobias. Moreover, we highlight that as we are interested in the UXs, we wanted to begin the investigation of the coming together of XR, water and fear with a focus on the user experience as a holistic construct [29]. Hence, we will discuss the role of the system as a whole. Prior work highlighted the importance of such a holistic approach to UX in HCI, especially when it comes to novel and playful systems [14, 15, 48, 49, 87]. This was further cemented by research that argued that playful experiences such as our XR experience should be seen as "one" experience where the whole is bigger than its part [15, 87].

6.1 Dive in and thrive: Introducing people to water engagement

Our study results confirmed our hypothesis relating to the use of floatation tanks as a controlled setting to introduce people with a fear of being in water to a water environment. Our results suggest that the system was successful in progressively introducing participants to water and enhancing their engagement with it. Firstly, quantitative data from the AAAQ questionnaire revealed that participants felt less anxious while the floating experience progressed from the second (baseline), to the fourth (floating using the XR system delivering the VR experience) and fifth stages (last floating), as significant differences were found in the worried ($p=0.002$) and nervous ($p<0.001$) statements. This was aligned with the qualitative data suggesting that, while participants had a fear of being in water, most of them enjoyed floating effortlessly and reported being calm, knowing that the floatation tank was a safe water environment. Additionally, participants reported that the XR system helped them to be calm and relaxed. These findings appear to confirm previous sports science work, where researchers progressively introduced people to water before starting swimming lessons by helping them float in a pool [60, 90, 110] and used water visualisations prior to entering the water [101]. Furthermore, we extend this theory by suggesting that interactive technology, when used in water, can increase perceived calmness in participants while exposing them to an otherwise fearful environment. Our work also suggests that an interactive experience in a floatation tank could progressively introduce people to being in water. Floatation tanks could offer independence since there is no need for an instructor to hold the person's body to float in water.

The anxiety self-report scores support the subjective statements by participants reporting feelings of fun and enjoyment. These quantitative and qualitative findings suggest that the XR system enhanced participants' engagement with water through the VR interactions, relaxation, and bodily illusions (Theme three). We believe that this engagement led participants to report their willingness to engage in playful water activities in the future (Theme five). The findings appear to confirm prior work that showed that people who feel confident in water are more likely to engage in water activities [13, 62]. Our research also extends this prior work since we found that interactive technology could help to facilitate this engagement. However, our results also suggest that people with a fear of being in water and sensitive to an altered proprioception sense are unlikely to engage in such water activities, since they are negatively affected by the lack of orientation and their inability to touch the ground while floating.

6.2 Splash of courage: VR environments combined with water to conquer water fears

Our study results appear to confirmed our assumptions that an XR system could help participants mitigate their fear by being entertained. However, we acknowledge that this effect depends on several factors. First, our quantitative results suggest that the use of the XR system delivering the VR environment while floating helped to reduce most participants' perceived fear and anxiety levels. Although the HRV indexes did not show a significant difference, they revealed a tendency toward less anxiety in participants when floating using the VR environment, while anxiety levels were found to be high when participants were floating without the XR system. These results are aligned with the qualitative data showing that most participants (n=8) reported that the VR experience helped reduce their anxiety and fear (Theme 2). Additionally, results are consistent with exposure therapy theory, which predicts that if participants are exposed to what they fear, their anxiety increases [17, 41, 117]. Also, the lower anxiety levels in the fifth stage (last floating) can be explained by exposure therapy: if people are progressively exposed to what they fear, they become used to it [17, 70]. We extend this theory as our results suggest that exposing people to their fears in a real and virtual way at the same time can have different results. On the one hand, XR exposure could introduce people to their real fear, while avoiding uncomfortable feelings by providing a virtual version of what they fear (water visuals). On the other hand, XR exposure could trigger more fear in comparison to traditional exposure because the virtual exposure might make participants uncomfortable due to the realism of the environments. For two participants, the combination of floating in water with the XR system delivering the VR experience triggered motion sickness and disorientation, which increased their anxiety and became a barrier to their engagement.

Furthermore, contrary to most VRET systems that present visual simulations of what is being feared to induce the fear, only one VR world used in our study was a simulation of being in water (the underwater world). One VR world did not simulate water at all (the space psychedelic world), while another involved exposure to water through virtual rain (the sky world) but no immersion in water. According to the thematic analysis, these two worlds appeared to help our participants reduce their fear most. In this regard, when exposing participants to what they fear in the real world, VR could distract them, which might allow them to overcome the fearful situation.

6.3 Design strategies

We now articulate strategies to assist designers of interactive technologies for water activities to facilitate user experiences of reduced fear of being in water. These strategies might also be valuable for researchers interested in interactive applications for other phobias.

6.3.1 Exploit distraction through XR play. Our results suggest that the XR system's playful interactions could distract participants, reducing their fearful responses. These results confirm prior theory where swimming teachers facilitate playfulness in pools to distract students from their fear of being in water [60, 129]. These results also confirm prior VRET work suggesting that playful design could help people with fear [8, 39]. Moreover, we extend both theories, having found that interactive technology use, while exposing participants to the actual fearful element (water in our case), can also distract people from their fear.

Design strategy: We recommend that designers consider exploiting distraction through XR play. Apart from using VR environments, designers could create interactive experiences in bodies of water that combine visual and auditory stimuli with the performing of a task. This could include using speakers to trigger entertaining sounds when people go from shallow water depths to deeper parts (inspired by prior work on sonification tasks to encourage physical activity [65]), or using projections of relaxing visuals while people try to let go of floatation aids. Nonetheless, if designers are going to include entertaining visuals by means of VR headsets, they must consider their usability, as pointed out in our findings (Theme four), confirming prior work that suggest VR headset's usability can influence the user experience [43, 77]. Moreover, playful experiences could also be created through storytelling, as other HCI work has proposed [89]. As with the water spirit used in our system, providing a playful story could encourage people to confront their fear of being in water. Designers could consider co-designing systems where participants tell their personal reasons behind their fear, inspired by the personal stories our participants told us (see Theme one). These stories could be delivered as distractions using waterproof headphones, as prior participatory design works suggested co-design for VRET [36]. Additionally, designers could consider providing a companion through XR, such as a conversational agent that guides people through their floating, talks to them, and makes them feel safe (inspired by the water spirit). These conversational agents have exhibited the potential to support accompaniment in other contexts, such as daily life [123], and we believe they also have the potential for accompaniment in fearful situations.

6.3.2 Utilize XR's ability to draw from the tactile experience of the world. Creating a tactile experience of water is challenging in virtual worlds due to current haptic interface limitations [38, 94]. XR systems have the advantage that they can draw from the physical world, as our system demonstrated by using real water to create a tactile experience. Our results (Theme two) suggested that despite the participants having a tactile experience with the fearful element (water in our case), warm water made some participants realx. This contradicts prior VRET theory arguing that fearful elements in other phobias can create a fear response through contact (such as a spider mount). In contrast, we found that the tactile experience of water through direct contact appears to be able to reduce any fearful response.

Design strategy: We therefore recommend that designers consider utilizing XR's ability to draw from the tactile experience of the world. In particular, we encourage designers to leverage the tactile experience of water while using XR, which could be achieved with public swimming pools, inflatable pools, and hot springs (to further encourage relaxation and calmness). Additionally, even if designers employ "virtual" water and its tactile experience, they still might need to consider the heat that comes from it to mitigate the fear (and can facilitate well-being according to prior work [88]). As such, designers might still benefit from employing XR that allows engagement with real water once they have considered participants' degrees of fear and understood their potential positive or negative responses to tactile water experiences. In similar ways, designers interested in addressing other phobias may consider mixing VRET with the tactile experience of a related fearful situation. For example, most acrophobia (fear of heights) researchers just simulate the wind sound when creating a VR environment [44, 69, 113], however, they could consider adding the tactile feedback of the wind sensation [54].

6.3.3 Utilize XR's ability to draw from the physics of the world. Simulating real-world situations in VR is challenging due to the difficulty of recreating the physics of the world. Prior HCI work has proposed technology efforts to address this [19, 52, 68]; however, these are only solutions for specific cases and are still at the prototype stage. Hence, we find that recreating the physics of the world is still difficult to achieve in situations such as when aiming to help people with fears. Nevertheless, due to the reality-virtuality combination of XR systems, they can take advantage of real-world physics, like the XR system used in this study leveraged the water's buoyancy, which allowed feelings of weightlessness [84]. Without XR, facilitating this feeling can require extensive engineering efforts, for example, see prior work that created complex structures including harness [55]. In contrast, using buoyant water appears to be a relatively easy way for interaction designers to achieve weightlessness. Although our results (sections 5.1, 5.2) suggested that the fact of being submerged in water can create anxiety feelings, we also found (Theme 2) that the buoyant water can create a safe environment for people with a fear of being in water and a lack of swimming skills. Furthermore, we found that the XR system's visualizations of outer space and the sky could amplify the weightlessness feeling in participants, increasing calm. These results extend prior work that suggested that technically amplifying buoyancy could have benefits, such as facilitating engagement [84].

Design strategy: Taken together, we therefore recommend to designers to consider utilizing XR's ability to draw from the physics of the world. For example, to take advantage of buoyancy, designers might want to explore the use of physical props such as swimming teachers do, such as analog aids (e.g., pullboys) or digital aids (e.g., digital inflatables). Designers might also want to consider augmenting the water's density as is the case with floatation tanks that get filled with Epsom salt; however, the density is fixed in natural bodies of water. Nevertheless, rather than taking on the difficult task of changing water's fixed buoyancy, designers could amplify water's natural buoyancy by using VR visualizations that could simulate users floating or flying, for example, and make them think they are more buoyant than they actually are. However, if interaction designers want to use VR and buoyancy, they should be cautious and remember that most VR engines assume a standing body. In contrast, when a designer employs water buoyancy, their user will most likely be in a supine position. This body-position difference will interfere with the headset sensors and tracking will need to be reprogrammed (as with our system).

6.3.4 Consider XR's capacity to disrupt proprioception via sensory mismatches in the physical and virtual world. A fear of being in water often has to do with the loss of our sense of orientation in space, affecting proprioception [119]. Our results are aligned with this theory since we found that our participants with fear of being in water became anxious when they lost the sense of orientation when floating. Our results are also consistent with prior theory arguing that neck proprioception shapes human body orientation [98] (participants' necks were floating, like the rest of their body) and that, in general, low gravity environments (like water with high buoyancy) can affect proprioception [63]. Hence, it makes sense that floating can affect proprioception and, as some of our participants mentioned, floating may lead them to lose their sense of where they are in space (theme two). Moreover, some of our participants reported motion sickness, which suggests that the XR system amplified their loss of orientation, affecting proprioception. These results confirm prior VR theory that argues that, as visual stimuli are dominant in influencing proprioception, the high visual stimuli in VR interactions influence orientation [22, 119]. However, the proprioception of the majority of participants was not affected. Furthermore, while some lost their orientation in space, this loss did not increase their anxiety (theme 2). In these cases, we found that the XR system could leverage the participant's loss of their sense of orientation in space to encourage more immersive experiences because it appeared to become easier for them to believe that they were in the virtual world.

Design strategy: Taken together, we recommend designers to consider XR's capacity to disrupt proprioception via sensory mismatches in the physical and virtual world. In particular, when combining XR and altered proprioception in water, designers should consider two things. Firstly, designers could create (playful) interactions to introduce participants to floating and VR, especially if they are prone to experience a loss of the sense of orientation in space. Secondly, designers could also provide static, non-moving VR environments to avoid motion sickness, as was suggested in prior VR work [22]. Thirdly, designers could also create grounding mechanisms while people are floating, providing them with a (physical) anchor to help them avoid drifting or losing orientation. Moreover, we note that XR's capacity to disrupt proprioception might need to be considered when designing for other fears since a lack of awareness of one's location in space will add to the anxiety already associated with exposure to the fearful element. For example, people with sensitive proprioception, alongside fear of heights or claustrophobia, may experience heightened fear if they lose their sense of their location in space.

7 EXPLORING LIMITATIONS AND CHARTING FUTURE WATERS

We acknowledge that the length of the stages constituted a limitation of this research since the stages could have been prolonged to provide an extended HRV recording. However, long floatation sessions (often >1h) can trigger the "aquatic mammal reflex", which automatically decreases the heart rhythm and allows for relaxation [11, 37]. These changes could have interfered with our findings on the XR system's impact. Furthermore, an extended period in a floatation tank results in the discomfort of "pruned" skin. Water-HCI studies need to consider this effect, and the designers of future studies need to carefully balance data collection and user comfort outcomes.

Moreover, we acknowledge that we investigated the impact of the XR system as a whole, which did not provide the specific impact of each component of the system over the participant's experiences. As such, we follow similar work that investigated the impact of an entire system design on people's experiences through both qualitative and quantitative data [31, 32, 86]. Future work could investigate particular sub-aspects of our work and provide additional understanding of how XR can support our participants. For example, we can envision a study that involved only one VR environment at a time, or a study where participants were only immersed in VR, but not engaged in gameplay, or a study where the water temperature was significantly different to their body temperature. However, we believe that our holistic approach could serve as a useful scaffolding to such future studies to complement our work.

We also acknowledge that we have so far only investigated one XR system. Future work might consider more systems, including different headsets or even haptic technologies, as well as bespoke XR experiences, to both validate and interrogate our findings. Future work could enhance our understanding of how to design XR systems that offer the welcoming "side-effect" of entertaining people with fears as well as those without. Such "side-effect" developments could extend our understanding of serious games. Also, such an enhanced understanding of how to design XR systems could be useful in future work concerned with designing for specific user groups, including people with diagnosed phobias.

Finally, we note that our participant number is in line with similar studies in prior work [26, 75, 84, 115, 122], although we did not find significant differences in the HRV data. Nonetheless, the analysis of the data with a lower number of participants was made to ensure accurate results instead of adding data that could be compromised. Then, we encourage future studies with a larger number of participants to expand our results. We believe that our work might be scaffolding to inform such future studies. Furthermore, we believe that our work has value as it is the first investigation into the use of an XR system within a floatation tank to reduce fear, hence could form a basis for future studies considering interactive technology and the wellness industry.

8 CONCLUSION

We presented a study evaluating the potential of an XR system to mitigate the fear of being in water. Our qualitative and quantitative results suggested that the XR system, which combined a real water environment (in the form of a floatation tank) and VR interactive technology, could help people with a fear of being in water to feel calmer and, thereby, mitigate their fearful responses. We provided an articulation of the user experiences of people with a fear of being in water when interacting with such an XR system and we presented strategies for the future design of XR systems for people with particular fears. More broadly, we hope that our work helps HCI practitioners using interactive technology for wellbeing and WaterHCI researchers to engage people in playful water activities and hence profit from the associated benefits.

ACKNOWLEDGMENTS

The authors would like to thank the director and staff of the floatation center Palm Ave Float Club in Singapore for allowing us to conduct our study in their facilities and for collaborating with us. Moreover, we would like to thank the director of the floatation center Water Temple in Melbourne for allowing us to record research activities at their facilities. Additionally, we would like to thank all the participants who volunteered to take part in the study presented in this work. Florian 'Floyd' Mueller thanks the Australian Research Council, especially DP190102068, DP200102612 and, with Sara Jane Pell, they thank LP210200656.

REFERENCES

[1] August 10, 2023. Global report on drowning: preventing a leading killer. https://www.who.int/publications-detail-redirect/global-report-on-drowning-preventing-a-leading-killer

[2] January 2021. Polar Verity Sense | Polar Australia. https://www.polar.com/au-en/products/accessories/polar-verity-sense

[3] March 2022. Ballast VR – Virtual Reality for Waterparks. https://www.ballastvr.com

[4] March 2022. Virtual Reality and Sensory Deprivation. https://www.matrise.no/2018/10/sensory-deprivation-floating-in-virtual-reality-floatation-tank/

[5] Ashlesha S Adhatrao and Zakir M Shaikh. 2019. Detecting Water Phobia Using Virtual Reality. *International Research Journal of Engineering and Technology* 6, 1 (2019).

[6] Shaunak A Ajinkya. 2015. Cognitive hypnotherapy for panic disorder with aquaphobia. *Sleep and Hypnosis (Online)* 17, 1/2 (2015), 11.

[7] Ghaida Albakri, Rahma Bouaziz, Wallaa Alharthi, Slim Kammoun, Mohammed Al-Sarem, Faisal Saeed, and Mohammed Hadwan. 2022. Phobia exposure therapy using virtual and augmented reality: a systematic review. *Applied Sciences* 12, 3 (2022), 1672.

[8] Dmitry Alexandrovsky, Georg Volkmar, Maximilian Spliethöver, Stefan Finke, Marc Herrlich, Tanja Döring, Jan David Smeddinck, and Rainer Malaka. 2020. Playful user-generated treatment: A novel game design approach for VR exposure therapy. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play*. 32–45.

[9] Judith Amores, Anna Fusté, Robert Richer, and Pattie Maes. 2019. Deep Reality: An Underwater VR experience to promote relaxation by unconscious HR, EDA and brain activity biofeedback. (2019).

[10] Josh Andres, MC Schraefel, Nathan Semertzidis, Brahmi Dwivedi, Yutika C Kulwe, Juerg Von Kaenel, and Florian Floyd Mueller. 2020. Introducing peripheral awareness as a neurological state for human-computer integration. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–13.

[11] Andrea Andrews. 2019. How to help people float. *International journal of aquatic research and education* 11, 4 (2019), 1.

[12] Bradley M Appelhans and Linda J Luecken. 2006. Heart rate variability as an index of regulated emotional responding. *Review of general psychology* 10, 3 (2006), 229–240.

[13] Rofiza Aboo Bakar and Jazredal Aboo Bakar. 2017. Aquaphobia: Causes, symptoms and ways of overcoming it for future well-being. *International Academic Research Journal of Social Science* 3, 1 (2017), 82–88.

[14] Regina Bernhaupt. 2010. User experience evaluation in entertainment. *Evaluating user experience in games: Concepts and methods* (2010), 3–7.

[15] Regina Bernhaupt and Florian" Floyd" Mueller. 2016. Game user experience evaluation. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. 940–943.

[16] Xavier Bornas, Antonio Riera del Amo, Miquel Tortella-Feliu, and Jordi Llabrés. 2012. Heart rate variability profiles and exposure therapy treatment outcome in flight phobia. *Applied psychophysiology and biofeedback* 37 (2012), 53–62.

[17] Cristina Botella, Javier Fernández-Álvarez, Verónica Guillén, Azucena García-Palacios, and Rosa Baños. 2017. Recent progress in virtual reality exposure therapy for phobias: a systematic review. *Current psychiatry reports* 19 (2017), 1–13.

[18] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 22 (2006), 77–101.

[19] Jas Brooks, Steven Nagels, and Pedro Lopes. 2020. Trigeminal-based temperature illusions. In *Proceedings of the 2020 CHI conference on human factors in computing systems*. 1–12.

[20] Morgan Bruce and Holger Regenbrecht. 2009. A virtual reality claustrophobia therapy system-implementation and test. In *2009 IEEE Virtual Reality Conference*. IEEE, 179–182.

[21] Jan Čejka, Attila Zsíros, and Fotis Liarokapis. 2020. A hybrid augmented reality guide for underwater cultural heritage sites. *Personal and Ubiquitous Computing* 24 (2020), 815–828.

[22] Eunhee Chang, Hyun Taek Kim, and Byounghyun Yoo. 2020. Virtual reality sickness: a review of causes and measurements. *International Journal of Human–Computer Interaction* 36, 17 (2020), 1658–1682.

[23] Ying-Chih Cheng, Min-I Su, Cheng-Wei Liu, Yu-Chen Huang, and Wei-Lieh Huang. 2022. Heart rate variability in patients with anxiety disorders: A systematic review and meta-analysis. *Psychiatry and Clinical Neurosciences* 76, 7 (2022), 292–302.

[24] Laurie Clancy. 2004. *Culture and customs of Australia*. Laurie Clandy.

[25] Christal Clashing, Ian Smith, Maria F Montoya, Rakesh Patibanda, Swamy Ananthanarayan, Sarah Jane Pell, and Florian Floyd Mueller. 2022. Going into Depth: Learning from a Survey of Interactive Designs for Aquatic Recreation. In *Designing Interactive Systems Conference*. 1119–1132.

[26] Miriam Clemente, Beatriz Rey, Mariano Alcañiz, Juani Bretón-López, Cristina Botella, Aina Rodríguez-Pujadas, Alfonso Barros-Loscertales, César Ávila, and Rosa M Baños. 2013. fMRI assessment of small animals' phobia using virtual reality as stimulus. In *2013 7th International Conference on Pervasive Computing Technologies for Healthcare and Workshops*. IEEE, 344–347.

[27] Hagit Cohen, Jonathan Benjamin, Amir B Geva, Mike A Matar, Zeev Kaplan, and Moshe Kotler. 2000. Autonomic dysregulation in panic disorder and in post-traumatic stress disorder: application of power spectrum analysis of heart rate variability at rest and in response to recollection of trauma or panic attacks. *Psychiatry research* 96, 1 (2000), 1–13.

[28] Raphael Costa, Sarah Richmond, Paula Geigle, and John Quarles. 2020. Aquatic Therapy With Virtual Reality for Children With Neuromotor Needs: A Preliminary Feasibility Case Series. *The Journal of Aquatic Physical Therapy* 28, 22 (2020), 10–17.

[29] Andrew Crabtree, Mark Rouncefield, and Peter Tolmie. 2012. *Doing design ethnography*. Springer Science & Business Media.

[30] Paul H Dietz, Gabriel Reyes, and David Kim. 2014. The PumpSpark fountain development kit. In *Proceedings of the 2014 conference on Designing interactive systems*. 259–266.

[31] Vipula Dissanayake, Vanessa Tang, Don Samitha Elvitigala, Elliott Wen, Michelle Wu, and Suranga Nanayakkara. 2022. Troi: Towards understanding users perspectives to mobile automatic emotion recognition system in their natural setting. *Proceedings of the ACM on Human-Computer Interaction* 6, MHCI (2022), 1–22.

[32] Don Samitha Elvitigala, Philipp M Scholl, Hussel Suriyaarachchi, Vipula Dissanayake, and Suranga Nanayakkara. 2021. StressShoe: a DIY toolkit for just-in-time personalised stress interventions for office workers performing sedentary tasks. In *Proceedings of the 23rd International Conference on Mobile Human-Computer Interaction*. 1–14.

[33] Natalie Eustace, James Head-Mears, and Andreas Dünser. 2013. Exploratory development and evaluation of user interfaces for exposure therapy treatment. In *Proceedings of the 25th Australian Computer-Human Interaction Conference: Augmentation, Application, Innovation, Collaboration*. 527–530.

[34] Géraldine Fauville, Anna Queiroz, Erika S Woolsey, Jonathan W Kelly, and Jeremy N Bailenson. 2021. The effect of water immersion on vection in virtual reality. *Scientific Reports* 11, 1 (2021), 1–13.

[35] Justin S Feinstein, Sahib S Khalsa, Hung Yeh, Obada Al Zoubi, Armen C Arevian, Colleen Wohlrab, Marie K Pantino, Laci J Cartmell, W Kyle Simmons, Murray B Stein, et al. 2018. The elicitation of relaxation and interoceptive awareness using floatation therapy in individuals with high anxiety sensitivity. *Biological psychiatry: cognitive neuroscience and neuroimaging* 3, 6 (2018), 555–562.

[36] Eivind Flobak, Jo D Wake, Joakim Vindenes, Smiti Kahlon, Tine Nordgreen, and Frode Guribye. 2019. Participatory design of VR scenarios for exposure therapy. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–12.

[37] MC Flux, Thomas H Fine, Tate Poplin, Obada Al Zoubi, William A Schoenhals, Jesse Schettler, Hazem H Refai, Jessyca Naegele, Colleen Wohlrab, Hung-Wen Yeh, et al. 2022. Exploring the acute cardiovascular effects of Floatation-REST. *Frontiers in Neuroscience* 16 (2022), 995594.

[38] Euan Freeman, Graham Wilson, Dong-Bach Vo, Alex Ng, Ioannis Politis, and Stephen Brewster. 2017. Multimodal feedback in HCI: haptics, non-speech audio, and their applications. In *The Handbook of Multimodal-Multisensor Interfaces: Foundations, User Modeling, and Common Modality Combinations-Volume 1*. 277–317.

[39] Julian Frommel, Martin J Dechant, and Regan L Mandryk. 2021. The Potential of Video Game Streaming as Exposure Therapy for Social Anxiety. *Proceedings of the ACM on Human-Computer Interaction* 5, CHI PLAY (2021), 1–25.

[40] J Ganesh Kumar, R Athilakshmi, R Maharishi, and R Maya. 2015. Relationship between fear of negative evaluation and anxiety. *The International Journal of Indian Psychology* 3, 1 (2015), 74–80.

[41] Azucena Garcia-Palacios, Hunter Hoffman, Albert Carlin, Thomas A Furness III, and Cristina Botella. 2002. Virtual reality in the treatment of spider phobia: a controlled study. *Behaviour research and therapy* 40, 9 (2002), 983–993.

[42] Jack M Gorman and Richard P Sloan. 2000. Heart rate variability in depressive and anxiety disorders. *American heart journal* 140, 4 (2000), S77–S83.

[43] Stefan Greuter, Florian 'Floyd' Mueller, and Thuong Hoang. 2022. Designing public VR installations. In *Designing Interactive Systems Conference*. 792–806.

[44] Daniel Gromer, Octávia Madeira, Philipp Gast, Markus Nehfischer, Michael Jost, Mathias Müller, Andreas Mühlberger, and Paul Pauli. 2018. Height simulation in a virtual reality CAVE system: validity of fear responses and effects of an immersion manipulation. *Frontiers in Human Neuroscience* 12 (2018), 372.

[45] Hörður M Hafsteinsson, Ari Þórðarson, and Gunnar H Björnsson. [n. d.]. Inducing Phobia Response Using Virtual Reality. ([n. d.]).

[46] Ping-Hsuan Han, Tzu-Hua Wang, and Chien-Hsing Chou. 2023. GroundFlow: Liquid-based Haptics for Simulating Fluid on the Ground in Virtual Reality. *IEEE Transactions on Visualization and Computer Graphics* 29, 5 (2023), 2670–2679.

[47] Jane Hart. 2019. Blue space: How being near water benefits health. *Alternative and Complementary Therapies* 25, 4 (2019), 208–210.

[48] Marc Hassenzahl. 2013. User experience and experience design. *The encyclopedia of human-computer interaction* 2 (2013), 1–14.

[49] Marc Hassenzahl and Noam Tractinsky. 2006. User experience-a research agenda. *Behaviour & information technology* 25, 2 (2006), 91–97.

[50] Hunter G Hoffman, David R Patterson, Jeff Magula, Gretchen J Carrougher, Karen Zeltzer, Stephen Dagadakis, and Sam R Sharar. 2004. Water-friendly virtual reality pain control during wound care. *Journal of clinical psychology* 60, 2 (2004), 189–195.

[51] Hunter G Hoffman, David R Patterson, Eric Seibel, Maryam Soltani, Laura Jewett-Leahy, and Sam R Sharar. 2008. Virtual reality pain control during burn wound debridement in the hydrotank. *The Clinical journal of pain* 24, 4 (2008), 299–304.

[52] Veera Hokkanen, Thomas Holmes, Hannu Koivuranta, Antti Sandberg, Helena Sorva, Juuso Toikka, Perttu Hämäläinen, and Maximus Kaos. 2018. Plusminus: Augmenting physics to promote emergent gameplay. In *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts*. 321–327.

[53] Lode Hoste and Beat Signer. 2014. Water Ball Z: an augmented fighting game using water as tactile feedback. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction*. 173–176.

[54] Nazrita Ibrahim, Mustafa Agil Muhamad Balbed, Azmi Mohd Yusof, FH Salleh, Jaspaljeet Singh, and Mohamad Shahrul Shahidan. 2008. Virtual reality approach in acrophobia treatment. In *WSEAS International Conference. Proceedings. Mathematics and Computers in Science and Engineering*. World Scientific and Engineering Academy and Society.

[55] Dhruv Jain, Misha Sra, Jingru Guo, Rodrigo Marques, Raymond Wu, Justin Chiu, and Chris Schmandt. 2016. Immersive scuba diving simulator using virtual reality. In *Proceedings of the 29th Annual Symposium on User Interface Software and Technology*. 729–739.

[56] Lee Jones, Paula Gardner, and Nick Puckett. 2018. Your body of water: A display that visualizes aesthetic heart rate data from a 3D camera. In *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction*. 286–291.

[57] Kristoffer Jonsson and Anette Kjellgren. 2014. Curing the sick and creating supermen–How relaxation in flotation tanks is advertised on the Internet. *European Journal of Integrative Medicine* 6, 5 (2014), 601–609.

[58] Anette Kjellgren, Hanna Edebol, Tommy Nordén, and Torsten Norlander. 2013. Quality of life with flotation therapy for a person diagnosed with attention deficit disorder, atypical autism, PTSD, anxiety and depression. *Open Journal of Medical Psychology* 2, 3 (2013), 134–138.

[59] Anette Kjellgren, Francisca Lyden, and Torsten Norlander. 2008. Sensory isolation in flotation tanks: Altered states of consciousness and effects on well-being. *The Qualitative Report* 13, 4 (2008), 636–656.

[60] Per-Ludvik Kjendlie and Marcel Mendritzki. 2012. Movement patterns in free water play after swimming lessons with flotation aids. (2012).

[61] Kelly A Knowles and Bunmi O Olatunji. 2020. Specificity of trait anxiety in anxiety and depression: Meta-analysis of the State-Trait Anxiety Inventory. *Clinical psychology review* 82 (2020), 101928.

[62] Benjamin Kuntz, Laura Frank, Kristin Manz, Alexander Rommel, and Thomas Lampert. 2016. Social determinants of swimming ability among children and adolescents in Germany. Results of KiGGS Wave 1. (2016).

[63] James R Lackner and Paul DiZio. 2005. Vestibular, proprioceptive, and haptic contributions to spatial orientation. *Annu. Rev. Psychol.* 56 (2005), 115–147.

[64] Pollyana Caldeira Leal, Tiago Costa Goes, Luiz Carlos Ferreira da Silva, and Flavia Teixeira-Silva. 2017. Trait vs. state anxiety in different threatening situations. *Trends in psychiatry and psychotherapy* 39 (2017), 147–157.

[65] Judith Ley-Flores, Laia Turmo Vidal, Nadia Berthouze, Aneesha Singh, Frédéric Bevilacqua, and Ana Tajadura-Jiménez. 2021. Soniband: Understanding the effects of metaphorical movement sonifications on body perception and physical activity. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. 1–16.

[66] John Cunningham Lilly. 1977. *The deep self: Profound relaxation and the tank isolation technique*. Simon & Schuster.

[67] Leonie F Loose, Jorge Manuel, Matthias Karst, Laura K Schmidt, and Florian Beissner. 2021. Flotation restricted environmental stimulation therapy for chronic pain: a randomized clinical trial. *JAMA network open* 4, 5 (2021), e219627–e219627.

[68] Pedro Lopes, Sijing You, Lung-Pan Cheng, Sebastian Marwecki, and Patrick Baudisch. 2017. Providing haptics to walls & heavy objects in virtual reality by means of electrical muscle stimulation. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. 1471–1482.

[69] Jean-Luc Lugrin, Ivan Polyschev, Daniel Roth, and Marc Erich Latoschik. 2016. Avatar anthropomorphism and acrophobia. In *Proceedings of the 22nd ACM Conference on Virtual Reality Software and Technology*. 315–316.

[70] Eric Malbos, George H Burgess, and Christophe Lançon. 2020. Virtual reality and fear of shark attack: A case study for the treatment of squalophobia. *Clinical Case Studies* 19, 5 (2020), 339–354.

[71] Steve Mann, Tom Furness, Yu Yuan, Jay Iorio, and Zixin Wang. 2018. All reality: Virtual, augmented, mixed (x), mediated (x, y), and multimediated reality. *arXiv preprint arXiv:1804.08386* (2018).

[72] Steve Mann, Michael Georgas, and Ryan Janzen. 2006. Water jets as pixels: Water fountains as both sensors and displays. In *Eighth IEEE International Symposium on Multimedia (ISM'06)*. IEEE, 766–772.

[73] Steve Mann, Mark Mattson, Steve Hulford, Mark Fox, Kevin Mako, Ryan Janzen, Maya Burhanpurkar, Simone Browne, Craig Travers, Robert Thurmond, et al. 2021. Water-Human-Computer-Interface (WaterHCI): Crossing the borders of computation clothes skin and surface. *Proceedings of the 23rd annual Water-Human-Computer Interface Deconference (Ontario Place TeachBeach, Toronto, Ontario, Canada). Ontario Place TeachBeach, Toronto, Ontario, Canada* (2021), 6–35.

[74] Isaac M Marks. 2013. *Fears and phobias*. Academic Press.

[75] Diogo Martins, Martim Neves, Bernardo Marques, Susana BráS, and José Maria Fernandes. 2023. Immerse Yourself in a Fight Against Your Fears: A Vision for Using Virtual Reality Serious Games and Physiology Assessment in Phobia Treatment. In *Proceedings of the 22nd International Conference on Mobile and Ubiquitous Multimedia* (, Vienna, Austria,) *(MUM '23)*. Association for Computing Machinery, New York, NY, USA, 471–473. https://doi.org/10.1145/3626705.3631781

[76] Yu Matsuura and Naoya Koizumi. 2018. Scoopirit: A method of scooping mid-air images on water surface. In *Proceedings of the 2018 ACM International Conference on Interactive Surfaces and Spaces*. 227–235.

[77] Mark McGill, Daniel Boland, Roderick Murray-Smith, and Stephen Brewster. 2015. A dose of reality: Overcoming usability challenges in vr head-mounted displays. In *Proceedings of the 33rd annual ACM conference on human factors in computing systems*. 2143–2152.

[78] Neil Mehta and Zelde Espinel. 2021. Aquaphobia: A Case Report on the Unique Presentation of a Specific Phobia. *The American journal of geriatric psychiatry* 29, 4 (2021), S139–S140.

[79] Deniz Mevlevioğlu, David Murphy, and Sabin Tabirca. 2021. Visual respiratory feedback in virtual reality exposure therapy: a pilot study. In *ACM International Conference on Interactive Media Experiences*. 1–6.

[80] Irena Milosevic and Randi E McCabe. 2015. *Phobias: The psychology of irrational fear: The psychology of irrational fear*. Abc-Clio.

[81] Fatmir Misimi, Tanja Kajtna, and Jernej Kapus. 2022. The effect of using goggles and snorkel for aquatic skills acquisition in youth learn-to-swim programs. *Perceptual and motor skills* 129, 5 (2022), 1525–1545.

[82] Fatmir Misimi, Tanja Kajtna, Samir Misimi, and Jernej Kapus. 2020. Development and validity of the fear of water assessment questionnaire. *Frontiers in psychology* 11 (2020), 969.

[83] Ramona Moldovan and Daniel David. 2014. One session treatment of cognitive and behavioral therapy and virtual reality for social and specific phobias. Preliminary results from a randomized clinical trial. *Journal of Evidence-Based Psychotherapies* 14, 1 (2014), 67.

[84] 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. *Proceedings of the ACM on Human-Computer Interaction* 7, CHI PLAY (2023), 948–975.

[85] Maria F Montoya, Rakesh Patibanda, Christal Clashing, Sarah Jane Pell, and Florian'Floyd' Mueller. 2022. Towards an Initial Understanding of the Design of Playful Water Experiences Through Flotation. In *Extended Abstracts of the 2022 Annual Symposium on Computer-Human Interaction in Play*. 120–126.

[86] Florian'Floyd' Mueller, Richard Byrne, Josh Andres, and Rakesh Patibanda. 2018. Experiencing the body as play. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*. 1–13.

[87] Florian'Floyd' Mueller, Louise Matjeka, Yan Wang, Josh Andres, Zhuying Li, Jonathan Marquez, Bob Jarvis, Sebastiaan Pijnappel, Rakesh Patibanda, and Rohit Ashok Khot. 2020. " Erfahrung & Erlebnis" Understanding the Bodily Play Experience through German Lexicon. In *Proceedings of the Fourteenth International Conference on Tangible, Embedded, and Embodied Interaction*. 337–347.

[88] Wallace J Nichols. 2014. *Blue mind: The surprising science that shows how being near, in, on, or under water can make you happier, healthier, more connected, and better at what you do.* Little, Brown.

[89] Kristina Niedderer, Vjera Holthoff-Detto, Thomas Jl Van Rompay, Armağan Karahanoğlu, Geke DS Ludden, Rosa Almeida, Raquel Losada Durán, Yolanda Bueno Aguado, Jennifer NW Lim, Tina Smith, et al. 2022. This is Me: Evaluation of a boardgame to promote social engagement, wellbeing and agency in people with dementia through mindful life-storytelling. *Journal of aging studies* 60 (2022), 100995.

[90] Olga Obrazhey. 2017. Overcoming the Fear of Water at the Initial Stage of Learning to Swim. *Physical education, sport and health culture in modern society* 1 (37) (2017), 66–71.

[91] Thomas H Ollendick, Neville J King, and Peter Muris. 2002. Fears and phobias in children: Phenomenology, epidemiology, and aetiology. *Child and Adolescent Mental Health* 7, 3 (2002), 98–106.

[92] Leif Oppermann, Lisa Blum, and Marius Shekow. 2016. Playing on AREEF: evaluation of an underwater augmented reality game for kids. In *Proceedings of the 18th international conference on human-computer interaction with mobile devices and services*. 330–340.

[93] Fabrizio Palmas and Gudrun Klinker. 2020. Defining extended reality training: A long-term definition for all industries. In *2020 IEEE 20th International Conference on Advanced Learning Technologies (ICALT)*. IEEE, 322–324.

[94] Daniel Sutopo Pamungkas and Koren Ward. 2016. Electro-tactile feedback system to enhance virtual reality experience. (2016).

[95] Dandan Pan, Qing Xu, Shiqiang Ma, and Kunlong Zhang. 2018. The impact of fear of the sea on working memory performance: a research based on virtual reality. In *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology*. 1–9.

[96] Subin Park, Hansu Lee, Minji Kwon, Heejae Jung, and Hyunggu Jung. 2023. Understanding experiences of older adults in virtual reality environments with a subway fire disaster scenario. *Universal Access in the Information Society* 22, 3 (2023), 771–783.

[97] Amy E Peden and Richard C Franklin. 2020. Learning to swim: an exploration of negative prior aquatic experiences among children. *International journal of environmental research and public health* 17, 10 (2020), 3557.

[98] Vito Enrico Pettorossi and Marco Schieppati. 2014. Neck proprioception shapes body orientation and perception of motion. *Frontiers in human neuroscience* 8 (2014), 895.

[99] Mark B Powers and Paul MG Emmelkamp. 2008. Virtual reality exposure therapy for anxiety disorders: A meta-analysis. *Journal of anxiety disorders* 22, 3 (2008), 561–569.

[100] John Quarles. 2015. Shark punch: A virtual reality game for aquatic rehabilitation. In *2015 IEEE Virtual Reality (VR)*. IEEE, 265–266.

[101] Lionel Roche, Ian Cunningham, Cathy Rolland, Régis Fayaubost, and Sébastien Maire. 2022. Reducing fear of water and aquaphobia through 360 degree video use?. In *Frontiers in Education*, Vol. 7. Frontiers Media SA, 898071.

[102] Jesse Schettler, Steven R Green, Hazem H Refai, and Justin Feinstein. 2016. The Selection and Validation of Biosensors for Studying a Novel Healthcare Environment. In *2016 IEEE First International Conference on Connected Health: Applications, Systems and Engineering Technologies (CHASE)*. IEEE, 312–321.

[103] Nandakumar Selvaraj, Ashok Jaryal, Jayashree Santhosh, Kishore K Deepak, and Sneh Anand. 2008. Assessment of heart rate variability derived from finger-tip photoplethysmography as compared to electrocardiography. *Journal of medical engineering & technology* 32, 6 (2008), 479–484.

[104] Nathan Arthur Semertzidis, Annaelle Li Pin Hiung, Michaela Jayne Vranic-Peters, and Florian 'Floyd' Mueller. 2023. Dozer: Towards understanding the design of closed-loop wearables for sleep. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. 1–14.

[105] Carolyn B Shank. 1987. A child's fear of the water environment. *Children's Environments Quarterly* (1987), 33–37.

[106] Bo Chen Shuo Yang, Mingsi Zhou. August 2, 2023. Underwater VR System for Overcoming Fear of Water. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://courses.ece.ubc.ca/518/previous/hit2016W/papers/YangZhouChen-2017.pdf

[107] Christian Sinnott, James Liu, Courtney Matera, Savannah Halow, Ann Jones, Matthew Moroz, Jeffrey Mulligan, Michael Crognale, Eelke Folmer, and Paul MacNeilage. 2019. Underwater virtual reality system for neutral buoyancy training: Development and evaluation. In *25th ACM Symposium on Virtual Reality Software and Technology*. 1–9.

[108] Leila M Soravia, Markus Heinrichs, Livia Winzeler, Melanie Fisler, Wolfgang Schmitt, Helge Horn, Thomas Dierks, Werner Strik, Stefan G Hofmann, and Dominique J-F de Quervain. 2014. Glucocorticoids enhance in vivo exposure-based therapy of spider phobia. *Depression and anxiety* 31, 5 (2014), 429–435.

[109] Charles D Spielberger, Sumner J Sydeman, Ashley E Owen, and Brian J Marsh. 1999. *Measuring anxiety and anger with the State-Trait Anxiety Inventory (STAI) and the State-Trait Anger Expression Inventory (STAXI).* Lawrence Erlbaum Associates Publishers.

[110] Robert Keig Stallman, Malfrid Junge, and Turid Blixt. 2008. The teaching of swimming based on a model derived from the causes of drowning. *International journal of aquatic research and education* 2, 4 (2008), 11.

[111] Robert Keig Stallman, Kevin Moran Dr, Linda Quan, and Stephen Langendorfer. 2017. From swimming skill to water competence: Towards a more inclusive drowning prevention future. *International Journal of Aquatic Research and Education* 10, 2 (2017), 3.

[112] Veronica Strang. 2020. *The meaning of water.* Routledge.

[113] Erick Marchelino Suyanto, Denny Angkasa, Harfondy Turaga, and Rhio Sutoyo. 2017. Overcome acrophobia with the help of virtual reality and kinect technology. *Procedia computer science* 116 (2017), 476–483.

[114] Yoichi Takahashi, Yasushi Matoba, and Hideki Koike. 2012. Fluid surface: interactive water surface display for viewing information in a bathroom. In *Proceedings of the 2012 ACM international conference on Interactive tabletops and surfaces*. 311–314.

[115] Markus Tatzgern, Michael Domhardt, Martin Wolf, Michael Cenger, Gerlinde Emsenhuber, Radomir Dinic, Nathalie Gerner, and Arnulf Hartl. 2022. Airres mask: A precise and robust virtual reality breathing interface utilizing breathing resistance as output modality. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems*. 1–14.

[116] Sanket Tembekar, Rohit Modak, and SP Patil. 2019. Tackling aquaphobia using Virtual Reality. *Int. J. Adv. Res. Ideas innov. Technol* 5 (2019), 693–695.

[117] Chai-Fen Tsai, Shih-Ching Yeh, Yanyan Huang, Zhengyu Wu, Jianjun Cui, Lirong Zheng, et al. 2018. The effect of augmented reality and virtual reality on inducing anxiety for exposure therapy: a comparison using heart rate variability. *Journal of Healthcare Engineering* 2018 (2018).

[118] John W Turner and Thomas H Fine. 1983. Effects of relaxation associated with brief restricted environmental stimulation therapy (REST) on plasma cortisol, ACTH, and LH. *Biofeedback and Self-regulation* 8 (1983), 115–126.

[119] Irene Valori, Phoebe E McKenna-Plumley, Rena Bayramova, Claudio Zandonella Callegher, Gianmarco Altoè, and Teresa Farroni. 2020. Proprioceptive accuracy in Immersive Virtual Reality: A developmental perspective. *PloS one* 15, 1 (2020), e0222253.

[120] Dirk van Dierendonck and Jan Te Nijenhuis. 2005. Flotation restricted environmental stimulation therapy (REST) as a stress-management tool: A meta-analysis. *Psychology & Health* 20, 3 (2005), 405–412.

[121] Marieke Van Rooij, Adam Lobel, Owen Harris, Niki Smit, and Isabela Granic. 2016. DEEP: A biofeedback virtual reality game for children at-risk for anxiety. In *Proceedings of the 2016 CHI conference extended abstracts on human factors in computing systems*. 1989–1997.

[122] Francesco Vona, Francesca Pentimalli, Fabio Catania, Alberto Patti, and Franca Garzotto. 2023. Speak in Public: an Innovative Tool for the Treatment of Stuttering through Virtual Reality, Biosensors, and Speech Emotion Recognition. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*. 1–7.

[123] Alexandra Vtyurina and Adam Fourney. 2018. Exploring the role of conversational cues in guided task support with virtual assistants. In *Proceedings of the 2018 CHI conference on human factors in computing systems*. 1–7.

[124] Jaye Wald and Steven Taylor. 2000. Efficacy of virtual reality exposure therapy to treat driving phobia: a case report. *Journal of behavior therapy and experimental psychiatry* 31, 3-4 (2000), 249–257.

[125] André Wannemueller, Svenja Schaumburg, Sally Tavenrath, Alina Bellmann, Katharina Ebel, Tobias Teismann, Sören Friedrich, and Jürgen Margraf. 2020. Large-group one-session treatment: Feasibility and efficacy in 138 individuals with phobic fear of flying. *Behaviour Research and Therapy* 135 (2020), 103735.

[126] Shogo Yamashita, Shunichi Suwa, Takashi Miyaki, and Jun Rekimoto. 2018. Investigation of tracer particles realizing 3-dimensional water flow measurement

for augmented swimming training. In *Proceedings of the 9th Augmented Human International Conference*. 1–9.

[127] Shogo Yamashita, Xinlei Zhang, and Jun Rekimoto. 2016. Aquacave: Augmented swimming environment with immersive surround-screen virtual reality. In *Adjunct Proceedings of the 29th Annual ACM Symposium on User Interface Software and Technology*. 183–184.

[128] Shih-Ching Yeh, Yuan-Yuan Li, Chu Zhou, Pin-Hua Chiu, and Jun-Wei Chen. 2018. Effects of virtual reality and augmented reality on induced anxiety. *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 26, 7 (2018), 1345–1352.

[129] Ye Zhao et al. 2021. Discussion on the Application of Swimming Assisted Training in College Swimming Teaching. *Journal of Human Movement Science* 2, 4 (2021), 44–47.