Exploring the Design of Playful Devices for Surfing

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

Aryan Saini
aryan@exertiongameslab.org
Monash University
Melbourne, Australia

Nathalie Overdevest
nathalie.overdevest@monash.edu
Monash University
Clayton, Australia

Benjamin Randall
bran0010@student.monash.edu
Monash University
Melbourne, Australia

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

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

ABSTRACT

Surfing is a popular recreational activity that benefits from technological innovation, such as the precision manufacturing of surfboards and apps for coaching. These advances have mostly focused on improving athletic performance, while the experiential aspects of surfing remain underexplored in terms of the design of mediating interactive technology. Hence, We aim to explore how playful interactive technology design can enrich the surfing experience. We adopted a soma design approach, considering the simultaneous influence of technology, body, and environment on surfing practice. Our process resulted in two design concepts: a smart wearable top and a soft robot, both aiming to connect the surfer to ocean information through haptic stimuli. By analysing and reflecting on our soma-technology-water design process, we provide design insights advancing the knowledge for future design of interactive technology to enrich the surfing experience in a playful way. Our research contributes to aquatic interactive design knowledge, inspiring WaterHCI researchers and industry stakeholders to leverage interactive technology to enrich the water activity experiences of the world's most iconic coastal water sport.

CCS CONCEPTS

• **Human-centered computing → Interaction paradigms**.

KEYWORDS

surf, surfing, playful experience, interactive technology, soma design

ACM Reference Format:
Maria F. Montoya, Aryan Saini, Nathalie Overdevest, Benjamin Randall, Sarah Jane Pell, and Florian 'Floyd' Mueller. 2024. Exploring the Design of Playful Devices for Surfing. In *Companion Proceedings of the Annual Symposium on Computer-Human Interaction in Play (CHI PLAY Companion '24), October 14–17, 2024, Tampere, Finland*. ACM, New York, NY, USA, 8 pages. https://doi.org/10.1145/3665463.3678786

CHI PLAY Companion '24, October 14–17, 2024, Tampere, Finland

ACM ISBN 979-8-4007-0692-9/24/10
https://doi.org/10.1145/3665463.3678786

1 INTRODUCTION

Surfing, the "art of riding waves with a board" [93], is a globally popular activity driving innovation in surf equipment [80]. Stakeholders, including industry, researchers, and local surfers, focus on enhancing equipment (i.e., surfboards, wetsuits) [2, 11, 63, 73, 92], and promoting environmental awareness [19, 20], all prioritizing surfers' athletic performance [38, 40]. However, the design of interactive technology for the experiential aspects of surfing, such as enjoyment through play, remains underexplored. Ethnographic studies show athletic performance is not the only reason people surf, and showcase several experiential barriers that surfers encounter [35, 75]. We see this as the next design wave domain to catch opportunities for innovation in WaterHCI. While HCI practitioners have advanced interactive systems for aquatic activities [32, 62, 68], outdoor water activities like surfing are less explored. Recognizing the potential for unexplored interactions in all sports [72, 86], and the opportunity to enrich surfing's experiential aspect through play, we pose the research question: How can playful interactive technology support the experiential aspects of surfing?

We adopted a soma design process [46, 50, 55, 87], previously successful in other sports [54, 61, 88] and beneficial in WaterHCI work [64, 65], to address this challenge. Soma design considers technological and bodily affordances in the environmental context [69, 90], crucial for surfing due to its oceanic setting, where complex interactions occur. Inspired by prior work [13, 19, 21, 40, 72] and the playful framework of Lucero et al. [17, 57, 58], we hypothesise that by supporting surfers' playfulness we could enhance engagement and intrinsic motivation [60]. Prior work shows that focusing on play rather than performance increases meaningful experiences and motivation [18, 70, 91]. Our soma design process resulted in two design concepts that we started prototyping: A wearable top and a soft robot, aiming to communicate ocean information (i.e, depth, wave rate, wind speed) to surfers in embodied ways (i.e., haptic stimuli).

This work in progress starts exploring playful technology for surfing's experiential aspects to elicit design insights into the future design of interactive technology to enrich the surfing experience. This research contributes to knowledge for designing interactive aquatic experiences for a dynamic environment like the ocean, offering a starting point to WaterHCI researchers, designers, and industry stakeholders interested in enhancing water activity enjoyment. Our project's ultimate goal is to enhance the surfing experience using interactive technology, unlocking the numerous benefits of being in the water.

2 RELATED WORK

2.1 HCI methods and playful design for surfing

Researchers across fields often employ a playful approach to design for everyday situations, facilitating a playful attitude: viewing activities with a lighthearted attitude and without serious consequences [17, 57, 58]. This approach extends to sports like surfing, which inherently contains elements of both play and game [85]. While some surfers find enjoyment in the challenges of performance also leading to frustration [12], others find more satisfaction in sensation and experience seeking [35, 66]. Moreover, ethnographic studies show surfers encounter experiential barriers, such as long waiting times on crowded or multi-use surf beaches, and discrimination to their bodily expressions, reducing their enjoyment of the surfing experience. Recognizing these diverse user experiences, our goal is to design a playful surfing experience that enhances enjoyment. Drawing inspiration from similar work on-land [86], we aim to leverage play to make water activities more enjoyable and foster meaningful experiences [57, 59], while also helping to alleviate performance anxiety [49, 70].

HCI researchers have explored the design of playful sports experiences, where designers use interactive technology to make monotonous parts of the training "more" fun by adding engaging playful elements [86]. Examples of this include skateboarding [79], swimming [28, 29], bouldering [52] and trampoline [51]. From these works, we learn that although the practice of sports sometimes leads to fun for practitioners, it is "play" that facilitates fun and makes sports more engaging [53, 86]. Then, we aim to facilitate a playful experience for surfers through a combination of methods considering the affordances of the environment: a thoughtful bodily design process (soma design), and playful design, such as the PLEX framework [57, 58, 60], which identifies discovery, exploration, and sensation as key elements of play. This framework proposed how stimulating the senses and discovery of new interactions can facilitate play, which we aim to enhance, for example, by providing vibrations in water and discovering hinder information about water. We consider that this approach will allow us to better understand the human-technology-water interaction dynamic in surfing, giving equal importance to the three agents of this synergetic interaction. Moreover, other HCI work for sports has used the soma design methods (Tai Chi [54], dance[39], yoga [88] and martial arts [61]). Specifically, Montoya et al. [64] proposed design strategies for interaction in an indoor water environment from a soma design approach. We take inspiration and aim to extend this work to discover the specific design strategies applicable to an outdoor water activity such as surfing.

Furthermore, WaterHCI researchers have recognized water's unique properties and sensory appeal that facilitate play, often evoking pleasurable experiences [45, 71]. Hence, they have introduced games in water sports using interactive technology, for example, immersive exploration games for kid's swimming classes [76], and collaborative games for group swimming training [28]. Even within technological limits due to the environment (i.e., Bluetooth does not work well underwater), these related works show us that a playful experience can be designed within a water sports activity by adapting the interactive technology to its dynamics. For example, the players can be digitally connected depending on the pauses for breathing and rest periods of the activity. However, This research does not yet indicate sufficient translation of design solutions for an open, powerful and dynamic body of water like the ocean. Hence, we can identify research value in facing the different design challenges in adapting interactive technology for outdoor water environments like the ocean.

2.2 Interactive technologies for surfing

The adoption of interactive technologies in surfing practice remains limited in both industry [30, 82] and research [43], and is mostly performance-oriented [26, 40, 63]. Romanin et al. highlight the surfing industry's focus on designing equipment like surfboards [41, 80], wetsuits [92] and fins [19, 80]. Still, we can highlight a few efforts from which we learn. Microsoft's collaboration with USA Surfing involved MoCap recordings to enhance surfers' performance during training [33]. Similarly, Redbull partnered with researchers to study surfers' brain waves using brain-computer interfaces and GPS trackers [13]. These collaborations showed us the adaptability of technology from land-based activities to surfing equipment, such as attaching small, low-weight devices to surfboards without affecting their dynamics. However, this work does not specify how they came to these design ideas nor provide design implications for the use of these technologies in a surfing session. Our work aims to start building this design knowledge.

Surfers have independently innovated their surf equipment, such as hacking commercial surfboards with electronic devices [11, 23, 67] and 3D printing their own boards [4, 84]. Their motivation often stems from enhancing safety and expanding surfing capabilities, like surfing at night [67] and understanding their environment to avoid collisions [11]. Industry stakeholders have started recognizing these needs and exploring similar designs, leading to new business opportunities [2, 15]. Our work aligns with these efforts, aiming to enrich surfers' understanding of their environment through interactive ocean information.

3 DESIGN APPROACH AND PRELIMINARY FINDINGS

Soma design places our somas centrally as the site of meaning-making when interacting with technologies and the world at large [46, 54, 61], providing the potential to understand the synergistic human-technology-water interactions. Hence, soma design has the potential to highlight the interconnected, dynamic, and non-linear interactions among the surfing performer, task, and water environment. Therefore, we adopted the stages in the soma design process proposed in prior work [46, 50, 55, 87]: engaging with bodily practice, material exploration, and prototyping, which we describe next.

3.1 Exploring bodily practices

In this stage, the designer must engage in bodily practices related to the activity to inform the design and gain appreciation of the body as part of the experience [46, 50, 87]. The first author, as the main designer and novice at surfing, engaged in different bodily

Figure 1: The main designer engaged with bodily practices. A) Taking an online class of Yoga-Surfing. B) Taking a surf lesson in a wave pool. C) Taking a surf lesson in the ocean.

experiences related to surfing. Therefore, she started with two online sessions of yoga-surfing (Fig 1A) and then took surfing classes, two sessions in a local wave pool (Fig. 1B) and two sessions on the local beach (Fig. 1C). She also aimed to gain a deeper understanding of the activity from surfing books [31, 93], podcasts [7], documentaries [1, 5, 6], and informal conversations with surfers. Additionally, the main designer had the chance to travel to Hawai'i, have a surfing session and get involved in informal conversations with surfers of this culture. Through this process, she believes that she developed somatic awareness and more conscious control of the muscles and movements involved in the postural movements needed while being on top of a surfboard, as well as the physicality of the surfing experience. She documented perceptions before, after, and (where possible) during these experiences through videos and notes.

3.1.1 Findings. The main designer employed the Slowstorming technique from soma design, reflecting on her bodily experiences and discussing them with the design team. Firstly, the main designer noted environmental features like strong currents, turbulence, and wave patterns, leading her to reflect that interactive technology must be waterproof, saltproof, and able to resist these conditions. For instance, technology attached to the leg or ankle must withstand strong currents when surfers walk or fall. It should be properly placed, secure, and lightweight to avoid disturbing balance. This aligns with prior work on biofeedback in water sports, which highlighted challenges in placing wearable devices without interfering with the athlete's movement [13, 25, 47, 56].

Secondly, the main designer became aware of the strength and balance needed for surfing, including paddling, positioning, waiting, and riding waves. She reflected that interactive technology should not obstruct these movements. For example, technology on the arms could hinder paddling, which accounts for 50% of surfing time [63]. She realized technology could be used during natural breaks in surfing, like the 40% of time spent waiting for waves [63]. Utilizing these breaks for technology use was also proposed by Clashing et al. [32] for water activities.

Thirdly, during ocean surfing sessions, the main designer frequently thought about sea life, which caused some anxiety that turned into curiosity. Conversations with surfers and insights from documentaries [9, 14], and blogs [10, 48] revealed that surfers are aware of sea life for safety, enjoyment, and sustainability reasons. These reflections led to envisioning a surfer companion in the shape of a sea animal, like an octopus, mounted on the surfboard. Inspired by real-life encounters with sea life, this interaction could facilitate a playful experience through "simulation", as described in the PLEX framework [17, 57, 58].

3.2 Exploring Materials

The first author undertook material explorations using different analog and digital technologies. The main designer explored digital materials such as actuators that could be useful to transmit information to the surfer in an embodied way. Then, she started to try vibrotactile actuators while submerged in water (Fig. 2B) and also a VR headset while on a standing platform in a pool (Fig. 2A) visualizing a virtual environment simulating standing on a board in the middle of a calm ocean. In addition, she explored sensors that could be used while surfing and adjusted them to fit a surfboard, such as depth sensors. In parallel, the main designer explored analog materials such as thermochromic fabric and hydrochromic ink (Fig. 2C). The thermochromic fabric changed with hot and cold water, as well as with the infrared light of the environment. However, the hydrochromic ink was easily removed from the surfaces (Fig 2D).

3.2.1 Findings. The main designer used the slowstorming technique to reflect on the material explorations. Particularly, the VR headset occluded her vision and avoid, which is crucial for balance and environment prediction, making it unsuitable for feedback. This aligns with prior work emphasizing the avoidance of cognitive overload and environmental disruption when using visual feedback [77, 78]. More importantly, a virtual water environment avoids interaction with the real water environment, which we aim to highlight instead of neglect. Nonetheless, future tests could include LEDs, which have been effective in other water sports for performance improvement [24, 44], and we aim to test them as interactive visuals to facilitate playfulness through "sensation" [57, 58]. We note that our focus here is on immediate, embodied feedback about environmental factors, like ocean depth and wave dynamics, since we believe this can facilitate playfulness through the enrichment of human-water connections.

Reflections on haptic actuators in water revealed that vibrations create an embodied sensation. Inspired by Montoya et al.'s design

Figure 2: A) testing a VR headset while getting into a standing platform in a swimming pool. B) Testing the vibration of a haptic actuator while in the water and over the standing platform. C) Thermochromic fabric changes depending on cold and hot water. D) Hydrochromic ink on different materials.

strategies [64], which suggest haptic feedback can direct attention to water and facilitate playful attitudes [57, 58], the designer decided to explore haptic feedback for communicating ocean information to surfers in a embodied. By informing ocean states with vibrotactile sensations, the designer believes they can facilitate a connection with water, which can lead to a playful experience. Haptic feedback has been used in other water sports like swimming [47, 56] and rowing [81, 89] to communicate performance technique, and we believe it holds potential value for experiential aspects of surfing.

Analog material exploration with thermochromic fabric led to envisioning it as a reflective material for environmental contact. For example, it turns orange when in contact with water and yellow with sunlight. This color-changing dynamic could facilitate a playful attitude through "exploration" as proposed by the PLEX framework [57, 58], allowing surfers to explore how the material changes with water and sunlight exposure. This is in line with prior work exploring the playful affordances of thermochromic materials [27].

3.3 Prototyping

Based on the results of the slowstormig reflections of the previous soma design stages, we decided to start exploring the prototyping of two design concepts. These design concepts were inspired by our reflections on the above-mentioned prior work.

A size-adjustable top: made with thermochromic fabric, embedded with waterproof vibrators positioned in the front part, connected to a microcontroller positioned in the back (Fig. 3A). It is intended that the top will not obstruct surfer's movement to perform any of the activities involving surfing, from the paddling to the wave riding. The top is designed to resist the strong currents and turbulence when the surfers fall into the water. The thermochromic fabric of the top aims to reflect the surfing dynamics, for example, when surfers are on top of the surfboard receiving infrared light from then sun, the top will become yellow, but it will change its color to orange when it receives a splash of cold water or when the surfer falls into the water. We believe this feature could encourage discovery and reflections on surfing, facilitating a playful experience, as explained before. The vibrators could transmit information about the ocean, for example, the wave frequency, through different vibration patterns that will be felt on the surfer's collarbone area. This will be triggered only when surfers are paddling or waiting for a wave, sensed through IMU sensors, to allow surfers to fully focus on riding a wave. We believe that the presentation of the ocean information in the form of vibration could facilitate different sensations (i.e. haptic vibrations in wave patterns), and encourage them to reflect on their body, and its meaning in relation to the ocean, which can lead to a playful experience.

A soft robot [22, 42] in the shape of an octopus, to be attached to the nose of the surfboard, embedded with waterproof vibrators, LEDs, and a microcontroller (Fig. 3B). The soft robot aims to represent the sealife and act as a companion. We got inspired by surfers' real-life encounters with sealife that created a fun and out-of-normal experience for them[3, 8]. We believe that the soft robot could recreate these encounters and facilitate a playful experience for surfers. The soft robot will be positioned on the nose of the surfboard, aiming to avoid obstruction and change of the surfboard dynamics while surfing. The soft robot will be flat and attached to the surfboard with self-adhesive tape and wrapped with sticky plastic, to be able to resist the water currents and turbulence. The soft robot will deliver vibrations through the surfboard aiming to provide ocean information with different patterns, similar to the first prototype. We believe that the vibrations felt through the surfboard will create different sensations in the surfer's body and encourage them to reflect on the ocean's state. In addition, the soft robot will be connected to pressure sensors positioned in the middle of the board, which will trigger different light patterns depending on the pressure change by the surfers while paddling and waiting. We believe this could help keep surfers engaged in the activity when they get frustrated or bored waiting for the next wave [74, 75].

3.3.1 Prototype developing and findings. The wearable top was initially made with thermochromic fabric and has inside pockets where the vibrators and the microcontroller will be positioned (Fig. 4A). We used an ESP8266 as the microcontroller networked through a wifi hot spot to a waterproof mobile phone (CAT s62 pro) using an app created in Unity 3D platform. The app allowed us to develop the tests using a "Wizard of Oz" method [36], triggering the actuators through buttons, which in future will be automatically triggered depending on the ocean conditions. We initially tested a three-vibration motor configuration on the top in an on-land setting, finding that a linear array offered distinguishable vibration sensations. We expanded this to a five-motor waveform but noticed

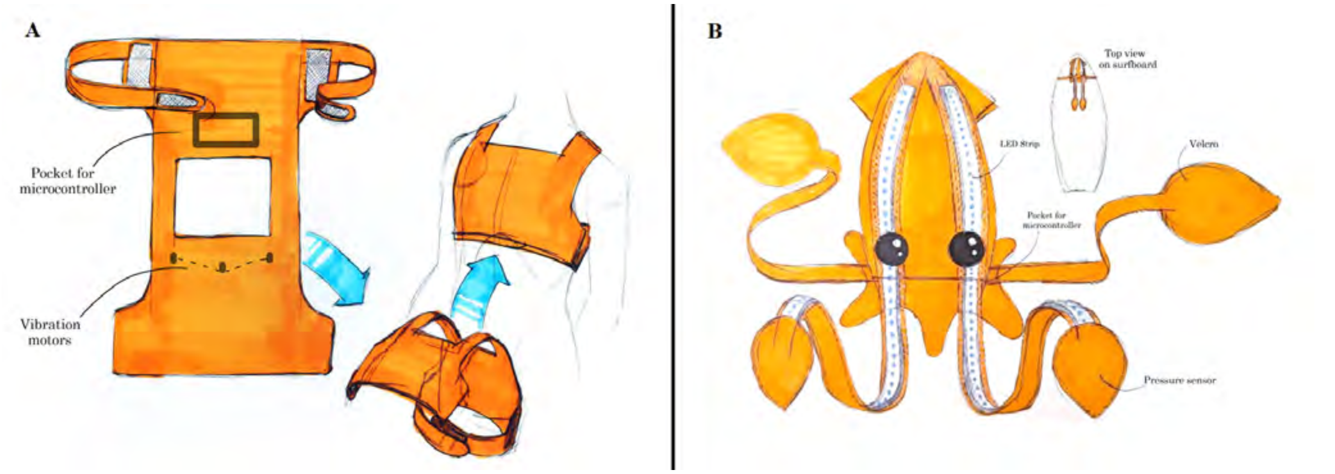

Figure 3: Design Concepts. A) A wearable size-adjustable top. B) A soft-robots in the shape of an octopus.

Figure 4: Wearable top prototyping A) The wearable top made in thermochromic fabric with colour-changing activation due to the vibration motors. B A volunteer surfer testing the top. C) the wearable top is made with expanded fabric and thermochromic fabric in the shoulder, collarbone and waist areas. D) User wearing the wearable top with embedded electronics, with colour-changing activation due to head pads.

the vibration sound could be distracting, predicting silicone waterproofing would isolate this noise. After 5 minutes of continuous use, the vibrations caused the top to change color, inspiring us to test thermal pads for inducing color change and providing thermal feedback, as has been done in prior HCI work [37, 83].

Hence, we start exploring analogous head pads. In cold water, the pads provided relief and regulated body temperature when tried on different body parts, more noticeable than in on-land tests. In line with soma design principles, we engaged an experienced surfer in this early prototyping (Fig. 4B), revealing the need for usability improvements for larger backs and rib cages, leading us to modify the top with expandable fabric and strategic thermochromic fabric placement (Fig. 4C). We found the fabric's colour change was less responsive on cloudy days but effective with direct sunlight in a cold environment (11° C), prompting us to enhance this feature using heat pads (Fig. 4D).

We waterproofed the microcontroller and vibrators using silicone and adapted its shape to the new top using 3D-printed moulds (Fig. 5A). The on-land testing revealed that the silicone was effective in reducing the noise made by the vibration motors, allowing the user to focus on the sensation of the vibrations. We tested the waterproofing on a bucket filled with water to test it safely. We then incorporated waterproofed electronic head pads to the top to be positioned on the shoulders (Fig. 4B). However, the silicone did not allow heat transmission, so we only sealed the edges of the pad.

For the soft robot prototype (Fig. 6), we used the same microcontroller and networking protocol used on the top. The head of the octopus was made to hold the microcontroller and the mobile phone, which is connected to three vibrators positioned on the octopus's short tentacles. One long tentacle has embedded the pressure sensors and the LED lights, controlled with a FLORA board (Fig 5C). Two long tentacles have velcro to be attached around the surfboard (Fig 6B). We tested this prototype on land (Fig 6A), where we realized the vibrations did not transmit on the surfboard as hard as expected, then position of the vibrations was not very differentiable. Hence, we decided to use two vibration motors on the left and right tentacles to increase the force of the vibration transmission on the surfboard. We found that the LED lights were accurately changing depending on the pressure exerted on the user's torso when laying on the surfboard in a simulated paddling position. We completely waterproofed the systems using silicone, and tested them in water (Fig. 5D) and on top of the surfboard again (Fig. 6C). We found that

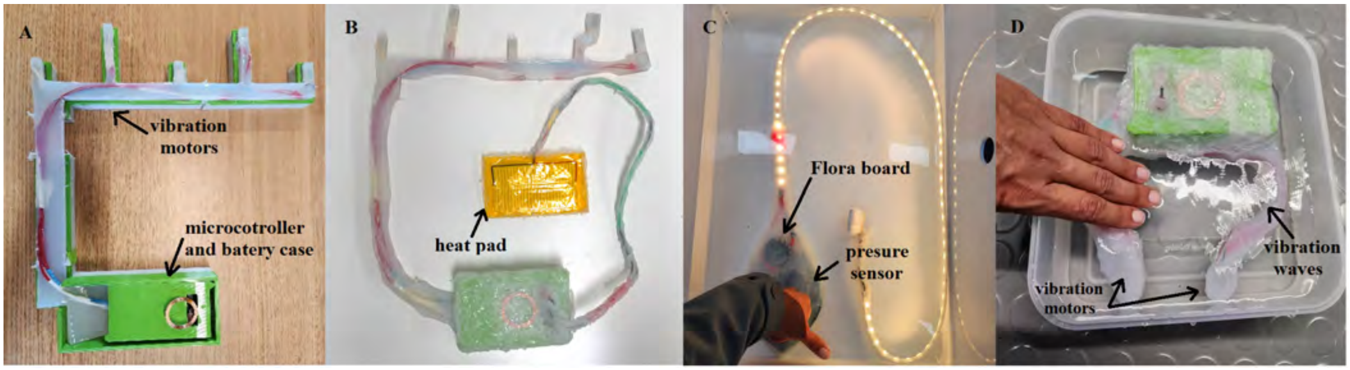

Figure 5: Electronics prototyping. A) The microcontroller and vibration motors for the wearable top are waterproofed using silicone. B) Complete waterproofing microcontroller and heat pad addition. C) The waterproofed pressure sensor for the soft robot was tested in water. D) The microcontroller and vibration motors for the soft robot were tested in water.

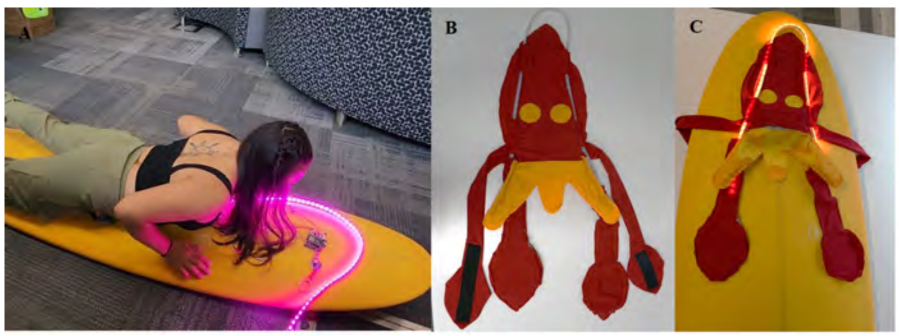

Figure 6: Soft robot prototyping. A) The electronic test on the surfboard on-land. B) Soft robot cover with the shape of an octopus, short tentacles and eyes made with thermochromic fabric, and long tentacles covered with velcro for adjustment to the surfboard C) Soft robot with electronics embedded tested on the surfboard on-land with colour changing activation due to sunlight

the vibrations created a nice sensation in the skin when submerged in the water, and the array of two motors on each side created a stronger vibration on the surfboard. These vibrations may change depending on the surfboard materials as they vary in a wide range [80].

4 CONCLUSION AND FUTURE WORK

Integrating soma design with playful design offers a unique approach to designing interactive technology for surfing's experiential aspects. Grounding the design in somaesthetics, we consider technological affordances, surfers' embodied experiences, and the dynamic water environment. This aligns with Zimmerman et al.'s principles of play design [85], emphasizing bodily engagement and sensory immersion. Using the PLEX framework's playful qualities [16, 57, 58], such as exploration and discovery, we gain valuable insights for designing interactive technology for outdoor water activities. Soma design facilitated an embodied approach to prototyping, crucial for our team, which lacked surfing experience. Initially relying on literature, documentaries, and interviews [6, 7, 74, 93], through soma design, we gained a deeper understanding through immersion in surfing experiences, shifting our perceptions of the sport and revealing insights into surfing's affordances and potential interactions between the body, technology, and water.

While soma design has enriched training in other sports [61, 88], our focus is on supporting surfing's experiential aspects, believing playful design enhances the activity's experiential and behavioral qualities [34]. We believe play has the potential to best support surfers' experiences, eliciting meaningful engagement and increased enjoyment [60]. Hence, in future work, we aim to test these assumptions by conducting a user study with the prototypes shown in this work in progress. However, the design team must first test the prototypes' usability in the ocean (e.g., ensure current resistance).

ACKNOWLEDGMENTS

I would like to thank the Exertion Games Lab's members. Additionally, all the authors would like to thank the Australian Research Council, especially DP190102068, DP200102612 and LP210200656.

REFERENCES

[1] [n. d.]. *100 Foot Wave | Official Website for the HBO Series | HBO.com.* https://www.hbo.com/100-foot-wave

[2] [n. d.]. About Wyve | Our History | French Surf Brand. https://wyvesurf.com/en/pages/about-wyve
[3] [n. d.]. Adorable baby seal shows off its surfing skills - YouTube. https://www.youtube.com/watch?v=xz2M01_9jVk
[4] [n. d.]. Blueprint Surf Is Making 3D Printed Surfboards. https://www.theinertia.com/surf/watch-gabriel-medina-warm-up-for-the-pipe-pro-in-style/
[5] [n. d.]. *Bustin' Down the Door.* https://www.thesurfnetwork.com/detail/59325c188de9f0c812f5039fa59ff1ad4f0888b5fb5b5bb0/movie
[6] [n. d.]. Edge of the Earth Ep 4. https://www.hbo.com/edge-of-the-earth/season-1/4-episode-iv-the-great-unknown
[7] [n. d.]. In Depth - A Surfing Podcast | OMBE. https://www.ombe.co/indepthasurfingpodcast?gclid=CjwKCAiAqNSsBhAvEiwAn_tmxSPlV7XY_ObJljdQr7OMHu0I5y1UVTwvPiNp-mMV5-IleIgiya719xoCeFwQAvD_BwE
[8] [n. d.]. Meet Sammy, the surfing seal from San Diego. *BBC News* ([n. d.]). https://www.bbc.com/news/av/world-us-canada-66146766
[9] [n. d.]. Stream Attacking Life Online | Download and Watch HD Movies | Stan. https://www.stan.com.au/watch/attacking-life-2023
[10] [n. d.]. Surfers for Climate. https://surfersforclimate.org.au/
[11] [n. d.]. The Surfsonar Project Prevents Underwater Collisions by Using Sonar to Detect Obstacles. https://www.hackster.io/news/the-surfsonar-project-prevents-underwater-collisions-by-using-sonar-to-detect-obstacles-d068a29b1f35
[12] [n. d.]. What the groms have got that we don't - how to have more fun | OMBE. https://www.ombe.co/guides/what-the-groms-have-got-that-we-dont-how-to-have-more-fun
[13] 2017. This Is What Happens When Scientists Go Surfing 2017. https://www.redbull.com/us-en/this-is-what-happens-when-scientist-go-surfing
[14] 2023. *Sustainable Living In A Surfer's Paradise, Day Zero, Earth Stories 2023.* https://www.youtube.com/watch?v=6G1E6m219I4
[15] Jeremy Anderson. [n. d.]. Homepage. https://xensr.com/
[16] Juha Arrasvuori, Marion Boberg, Jussi Holopainen, Hannu Korhonen, Andrés Lucero, and Markus Montola. 2011. Applying the PLEX framework in designing for playfulness. In *Proceedings of the 2011 Conference on Designing Pleasurable Products and Interfaces*. ACM, Milano Italy, 1–8. https://doi.org/10.1145/2347504.2347531
[17] Juha Arrasvuori, Marion Boberg, and Hannu Korhonen. [n. d.]. Understanding Playfulness. ([n. d.]).
[18] Joshua A. Barreiro and Rick Howard. 2017. Incorporating unstructured free play into organized sports. *Strength and Conditioning Journal* 39, 2 (2017), 11–19.
[19] Philip J. Bresnahan, Tyler Cyronak, Todd Martz, Andreas Andersson, Shannon Waters, Andrew Stern, Jon Richard, Katherine Hammond, John Griffin, and Benjamin Thompson. 2017. Engineering a Smartfin for surf-zone oceanography. In *OCEANS 2017-Anchorage*. IEEE, 1–4.
[20] Robert JW Brewin, Kieran Hyder, Andreas J. Andersson, Oliver Billson, Philip J. Bresnahan, Thomas G. Brewin, Tyler Cyronak, Giorgio Dall'Olmo, Lee de Mora, and George Graham. 2017. Expanding aquatic observations through recreation. *Frontiers in Marine Science* 4 (2017), 351.
[21] Easkey Britton. 2018. 'Be Like Water': Reflections on Strategies Developing Cross-Cultural Programmes for Women, Surfing and Social Good. *The Palgrave handbook of feminism and sport, leisure and physical education* (2018), 793–807.
[22] Anke Brocker, Jose A. Barreiros, Ali Shtarbanov, Kristian Gohlke, Ozgun Kilic Afsar, and Sören Schröder. 2022. Actuated Materials and Soft Robotics Strategies for Human-Computer Interaction Design. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts*. ACM, New Orleans LA USA, 1–7. https://doi.org/10.1145/3491101.3503711
[23] By. 2020. Surfboard LED Strips Light Up The Waves. https://hackaday.com/2020/09/10/surfboard-led-strips-light-up-the-waves/
[24] Marc Bächlin, Kilian Förster, and Gerhard Tröster. 2009. SwimMaster: a wearable assistant for swimmer. In *Proceedings of the 11th international conference on Ubiquitous computing*. 215–224.
[25] Marc Bächlin and Gerhard Tröster. 2012. Swimming performance and technique evaluation with wearable acceleration sensors. *Pervasive and mobile computing* 8, 1 (2012), 68–81.
[26] Raoni Caselli, Marcelo Ferreira, and Berenice Gonçalves. 2017. *Analysis of Tools to Measure the User Experience During the Sports Practice of Recreational Surfing*. Advances in Intelligent Systems and Computing, Vol. 496. Springer International Publishing, Cham, 71–83. https://doi.org/10.1007/978-3-319-41953-4_7
[27] Haena Cho, Yoonji Lee, Woohun Lee, and Chang Hee Lee. 2024. Thermo-Play: Exploring the Playful Qualities of Thermochromic Materials. In *Proceedings of the Eighteenth International Conference on Tangible, Embedded, and Embodied Interaction*. 1–16.
[28] Woohyeok Choi, Jeungmin Oh, Darren Edge, Joohyun Kim, and Uichin Lee. 2016. SwimTrain: Exploring Exergame Design for Group Fitness Swimming. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, San Jose California USA, 1692–1704. https://doi.org/10.1145/2858036.2858579
[29] Woohyeok Choi, Jeungmin Oh, Taiwoo Park, Seongjun Kang, Miri Moon, Uichin Lee, Inseok Hwang, and Junehwa Song. 2014. MobyDick: an interactive multi-swimmer exergame. In *Proceedings of the 12th ACM Conference on Embedded Network Sensor Systems*. 76–90.
[30] Chris. 2016. Samsung Galaxy Surfboard Prototype - Smart Surfboard. https://elitetraveler.com/features/samsung-galaxy-surfboard-prototype-smart-surfboard
[31] Laurie Clancy. 2004. *Culture and customs of Australia*. Greenwood Publishing Group.
[32] 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 (DIS '22)*. Association for Computing Machinery, New York, NY, USA, 1119–1132. https://doi.org/10.1145/3532106.3533543
[33] Kevin Dean. 2023. Next big break. https://unlocked.microsoft.com/usa-surf/
[34] Sebastian Deterding. 2016. Make-believe in gameful and playful design. *Digital make-believe* (2016), 101–124.
[35] Rebekah Diehm and Christine Armatas. 2004. Surfing: An avenue for socially acceptable risk-taking, satisfying needs for sensation seeking and experience seeking. *Personality and individual differences* 36, 3 (2004), 663–677.
[36] Steven Dow, Blair MacIntyre, Jaemin Lee, Christopher Oezbek, Jay David Bolter, and Maribeth Gandy. 2005. Wizard of Oz support throughout an iterative design process. *IEEE Pervasive Computing* 4, 4 (2005), 18–26.
[37] Tamar Dublin, Talia Sofia Ezer, and Oren Zuckerman. 2024. A Journey Inward: The Somaesthetic Experience of a Heated Walking Carpet. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems*. 1–7.
[38] Vuk Ekmecic, Ning Jia, Thomas G. Cleveland, Maya Saulino, Jeff A. Nessler, George H. Crocker, and Sean C. Newcomer. 2017. Increasing surfboard volume reduces energy expenditure during paddling. *Ergonomics* 60, 9 (2017), 1255–1260.
[39] Sara Eriksson, Åsa Unander-Scharin, Vincent Trichon, Carl Unander-Scharin, Hedvig Kjellström, and Kristina Höök. 2019. Dancing with drones: Crafting novel artistic expressions through intercorporeality. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–12.
[40] Oliver RL Farley, Chris R. Abbiss, and Jeremy M. Sheppard. 2017. Performance analysis of surfing: a review. *The Journal of Strength and Conditioning Research* 31, 11 (2017), 260–271.
[41] Chris Gibson and Andrew Warren. 2014. Making surfboards: Emergence of a trans-Pacific cultural industry. *The Journal of Pacific History* 49, 1 (2014), 1–25.
[42] Kristian Gohlke, Eva Hornecker, and Wolfgang Sattler. 2016. Pneumatibles: Exploring Soft Robotic Actuators for the Design of User Interfaces with Pneumotactile Feedback. In *Proceedings of the TEI '16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction*. ACM, Eindhoven Netherlands, 308–315. https://doi.org/10.1145/2839462.2839489
[43] José Maria Guimarães and Gabriel Pestana. 2019. Athlete-Trainer Interaction Dashboard in Performance Analysis. In *2019 14th Iberian Conference on Information Systems and Technologies (CISTI)*. IEEE, 1–5.
[44] Rabee M. Hagema, Tim Haelsig, Steven G. O'Keefe, Andy Stamm, Thomas Fickenscher, and David V. Thiel. 2013. Second generation swimming feedback device using a wearable data processing system based on underwater visible light communication. *Procedia Engineering* 60 (2013), 34–39.
[45] Jane Hart. 2019. Blue space: How being near water benefits health. *Alternative and Complementary Therapies* 25, 44 (2019), 208–210.
[46] Kristina Hook. 2018. *Designing with the body: Somaesthetic interaction design*. MIT Press.
[47] Matevž Hribernik, Anton Kos, Anton Umek, and Jaka Sodnik. 2022. Haptic user interface for biofeedback in aquatic sports: A design concept.
[48] https://www.facebook.com/rick.maese. [n. d.]. Warming oceans have created a golden age for big-wave surfing, leaving surfers conflicted. https://www.washingtonpost.com/sports/2019/05/09/warming-oceans-have-created-golden-age-big-wave-surfing-leaving-surfers-conflicted/
[49] Johan Huizinga. 2014. *Homo ludens ils 86*. Routledge. https://www.taylorfrancis.com/books/mono/10.4324/9781315824161/homo-ludens-ils-86-huizinga
[50] Kristina Höök, Martin P. Jonsson, Anna Ståhl, and Johanna Mercurio. 2016. Somaesthetic appreciation design. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. 3131–3142.
[51] Raine Kajastila, Leo Holsti, and Perttu Hämäläinen. 2014. Empowering the exercise: A body-controlled trampoline training game. *International journal of computer science in sport* 13, 1 (2014), 6–23.
[52] Raine Kajastila and Perttu Hämäläinen. 2014. Augmented climbing: interacting with projected graphics on a climbing wall. In *CHI '14 Extended Abstracts on Human Factors in Computing Systems*. ACM, Toronto Ontario Canada, 1279–1284. https://doi.org/10.1145/2559206.2581139
[53] Raine Kajastila and Perttu Hämäläinen. 2015. Motion games in real sports environments. *Interactions* 22, 2 (Feb. 2015), 44–47. https://doi.org/10.1145/2731182
[54] Joseph La Delfa, Mehmet Aydin Baytas, Rakesh Patibanda, Hazel Ngari, Rohit Ashok Khot, and Florian'Floyd' Mueller. 2020. Drone chi: Somaesthetic human-drone interaction. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*. 1–13.

[55] Wonjun Lee, Youn-kyung Lim, and Richard Shusterman. 2014. Practicing somaesthetics: exploring its impact on interactive product design ideation. In *Proceedings of the 2014 conference on Designing interactive systems*. 1055–1064.

[56] Rui Li, Zibo Cai, WeeSit Lee, and Daniel TH Lai. 2016. A wearable biofeedback control system based body area network for freestyle swimming. In *2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*. IEEE, 1866–1869. https://ieeexplore.ieee.org/abstract/document/7591084/?casa_token=Mge1pv3qYhYAAAAA:KRofw75Q9kv-45j7YsYSR8zJHD6lwZUQCnBfZFJTbdNZLwFabfBI29hDsbeyJwsALyxvMOnt

[57] Andrés Lucero and Juha Arrasvuori. 2010. PLEX Cards: a source of inspiration when designing for playfulness. In *Proceedings of the 3rd International Conference on Fun and Games*. 28–37.

[58] Andrés Lucero and Juha Arrasvuori. 2013. The PLEX Cards and its techniques as sources of inspiration when designing for playfulness. *International Journal of Arts and Technology* 6, 1 (2013), 22. https://doi.org/10.1504/IJART.2013.050688

[59] Andrés Lucero, Jussi Holopainen, Elina Ollila, Riku Suomela, and Evangelos Karapanos. 2013. The playful experiences (PLEX) framework as a guide for expert evaluation. In *Proceedings of the 6th International Conference on Designing Pleasurable Products and Interfaces*. ACM, Newcastle upon Tyne United Kingdom, 221–230. https://doi.org/10.1145/2513506.2513530

[60] Andrés Lucero, Evangelos Karapanos, Juha Arrasvuori, and Hannu Korhonen. 2014. Playful or gameful? Creating delightful user experiences. *interactions* 21, 33 (2014), 34–39.

[61] Yoav Luft, Pavel Karpashevich, and Kristina Höök. 2023. Boards Hit Back: Reflecting on Martial Arts Practices Through Soma Design. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. ACM, Hamburg Germany, 1–18. https://doi.org/10.1145/3544548.3580722

[62] Steve Mann, Mark Mattson, Steve Hulford, Mark Fox, Kevin Mako, Ryan Janzen, Maya Burhanpurkar, Simone Browne, Craig Travers, and Robert Thurmond. 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.

[63] Alberto Mendez-Villanueva and David Bishop. 2005. Physiological aspects of surfboard riding performance. *Sports Medicine* 35 (2005), 55–70.

[64] 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 (Sept. 2023), 948–975. https://doi.org/10.1145/3611056

[65] 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.

[66] Jesse D Morgan and Rosanne A Coutts. 2016. Measuring peak experience in recreational surfing. *Journal of Sport Behavior* 39, 2 (2016), 202.

[67] mosivers. [n. d.]. Surfboard LED Fins. https://www.instructables.com/Surfboard-LED-Fins/

[68] Florian 'Floyd' Mueller, Maria F Montoya, Sarah Jane Pell, Leif Oppermann, Mark Blythe, Paul H Dietz, Joe Marshall, Scott Bateman, Ian Smith, Swamy Ananthanarayan, et al. 2024. Grand challenges in WaterHCI. In *Proceedings of the CHI Conference on Human Factors in Computing Systems*. 1–18.

[69] Elena Márquez Segura, Laia Turmo Vidal, Asreen Rostami, and Annika Waern. 2016. Embodied Sketching. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, San Jose California USA, 6014–6027. https://doi.org/10.1145/2858036.2858486

[70] Elena Márquez Segura, Laia Turmo Vidal, Annika Waern, Jared Duval, Luis Parrilla Bel, and Ferran Altarriba Bertran. 2021. Physical Warm-up Games: Exploring the Potential of Play and Technology Design. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–14. https://doi.org/10.1145/3411764.3445163

[71] 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.

[72] Stina Nylander and Jakob Tholander. 2014. Designing for Movement: the Case of Sports. In *Proceedings of the 2014 International Workshop on Movement and Computing*. ACM, Paris France, 130–135. https://doi.org/10.1145/2617995.2618018

[73] Luca Oggiano and Marc in het Panhuis. 2020. Modern surfboards and their structural characterization: towards an engineering approach. In *Proceedings*, Vol. 49. MDPI, 65. https://www.mdpi.com/2504-3900/49/1/65

[74] Rebecca Olive. 2019. The trouble with newcomers: Women, localism and the politics of surfing. *Journal of Australian Studies* 43, 1 (2019), 39–54.

[75] Rebecca Olive, Louise McCuaig, and Murray G Phillips. 2015. Women's recreational surfing: a patronising experience. *Sport, Education and Society* 20, 2 (2015), 258–276.

[76] 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.

[77] Rui Pascoal, Ana De Almeida, and Rute C Sofia. 2020. Mobile pervasive augmented reality systems—mpars: The role of user preferences in the perceived quality of experience in outdoor applications. *ACM Transactions on Internet Technology (TOIT)* 20, 1 (2020), 1–17.

[78] Rui Miguel Pascoal and Sérgio Luís Guerreiro. 2017. Information overload in augmented reality: The outdoor sports environments. In *Information and Communication Overload in the Digital Age*. IGI Global, 271–301.

[79] Sebastiaan Pijnappel and Florian "Floyd" Mueller. 2014. Designing interactive technology for skateboarding. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction*. ACM, Munich Germany, 141–148. https://doi.org/10.1145/2540930.2540950

[80] Alexander Romanin, Samuel English, James Furness, Kevin Kemp-Smith, Sean Newcomer, and Jeff Nessler. 2021. Surfing equipment and design: A scoping review. *Sports Engineering* 24 (2021), 1–13.

[81] Emanuele Ruffaldi, Alessandro Filippeschi, Antonio Frisoli, Oscar Sandoval, Carlo Alberto Avizzano, and Massimo Bergamasco. 2009. Vibrotactile perception assessment for a rowing training system. In *World Haptics 2009-Third Joint EuroHaptics conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems*. IEEE, 350–355.

[82] Lucy Sherriff. 2023. Intel builds laptop into surfboard. https://www.theregister.com/2004/06/18/surf_surfing_surf/

[83] Anna Ståhl, Martin Jonsson, Johanna Mercurio, Anna Karlsson, Kristina Höök, and Eva-Carin Banka Johnson. 2016. The soma mat and breathing light. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. 305–308.

[84] Editor at SurferToday. [n. d.]. The 23-piece 3D-printed surfboard. https://www.surfertoday.com/surfing/the-23-piece-3d-printed-surfboard

[85] Katie Salen Tekinbas and Eric Zimmerman. 2003. *Rules of play: Game design fundamentals*. MIT press.

[86] Jakob Tholander and Stina Nylander. 2015. Snot, Sweat, Pain, Mud, and Snow: Performance and Experience in the Use of Sports Watches. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, Seoul Republic of Korea, 2913–2922. https://doi.org/10.1145/2702123.2702482

[87] Vasiliki Tsaknaki, Madeline Balaam, Anna Ståhl, Pedro Sanches, Charles Windlin, Pavel Karpashevich, and Kristina Höök. 2019. Teaching soma design. In *Proceedings of the 2019 on Designing Interactive Systems Conference*. 1237–1249.

[88] Laia Turmo Vidal, Elena Márquez Segura, Christopher Boyer, and Annika Waern. 2019. Enlightened Yoga: Designing an Augmented Class with Wearable Lights to Support Instruction. In *Proceedings of the 2019 on Designing Interactive Systems Conference*. ACM, San Diego CA USA, 1017–1031. https://doi.org/10.1145/3322276.3322338

[89] Robby Van Delden, Sascha Bergsma, Koen Vogel, Dees Postma, Randy Klaassen, and Dennis Reidsma. 2020. VR4VRT: virtual reality for virtual rowing training. In *Extended Abstracts of the 2020 Annual Symposium on Computer-Human Interaction in Play*. 388–392.

[90] Vincent Van Rheden, Thomas Grah, Alexander Meschtscherjakov, Rakesh Patibanda, Wanyu Liu, Florian Daiber, Elise Van Den Hoven, and Florian "Floyd" Mueller. 2021. Out of Your Mind!? Embodied Interaction in Sports. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*. ACM, Yokohama Japan, 1–5. https://doi.org/10.1145/3411763.3441329

[91] Sarina Verwijmeren, Juriena D. De Vries, and Arnold B. Bakker. 2024. Playful sport design: A game changer? *Journal of Applied Sport Psychology* 36, 1 (Jan. 2024), 45–74. https://doi.org/10.1080/10413200.2023.2185698

[92] Mackenzie E. Warner, Jeff A. Nessler, and Sean C. Newcomer. 2019. Skin temperatures in females wearing a 2 mm wetsuit during surfing. *Sports* 7, 6 (2019), 145.

[93] Matt Warshaw. 2011. *The history of surfing*. Chronicle Books.