Blindfolded in the Air: Towards the Design of Interactive Aerial Play

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The intersection of aerial acrobatics (movement on a suspended apparatus where the performer is off the ground) and interactive technology remains an underexplored area in HCI. In this autoethnographic study, we investigate the interplay between augmented eyesight and proprioception in adapting to the suspended environment. We developed a motion-sensitive blindfold mixed-reality headset application that enables wearers to transition between visibility and darkness based on their body's orientation while rotating in a two-point harness. Analyzing videos, somaesthetic maps, and interviews, we observed that our design reduces visual and social distractions, facilitating inward focus on movement and breath. However, acclimation to both physical and mixed-reality systems is necessary for people to interact comfortably. The findings extend our understanding of designing interactive real-time visuomotor couplings between movements and mixed-reality in suspended environments, offering four themes and six design considerations to support the active body, aiming to enrich the possibilities for augmented aerial play.

CCS Concepts: • **Human-centered computing → Mixed / augmented reality**.

Additional Key Words and Phrases: Aerial arts, Acrobatics, Extended Reality, Movement-based design, Suspended environments.

ACM Reference Format:
Amanda Topaz, Maria Fernanda Montoya, Rakesh Patibanda, Josh Andres, and Florian 'Floyd' Mueller. 2025. Blindfolded in the Air: Towards the Design of Interactive Aerial Play. In *Proceedings of Annual Conference on Human-Computer Interaction and Sports November 17–19, 2025 Enschede, Netherlands (sportshci2025).* ACM, New York, NY, USA, 28 pages. https://doi.org/10.1145/3749385.3749401

1 INTRODUCTION

Aerial acrobatics, a centuries-old art form, gained popularity in the 19th century and has recently experienced another resurgence thanks to Cirque du Soleil and the emergence of aerial acrobatic exercise studios around the world [24, 41, 68, 82]. We define the term "aerial acrobatics" to include any type of acrobatic performance requiring the rigging of an apparatus at height [25, 75]. An aerial apparatus can be understood as a suspended dynamic force-translating interface or a type of performance tool that allows bodily motion, interaction, and energy transfer of the performer's movements into three-dimensional, gravity-defying spatial dynamics [49]. This includes, but is not limited to, trapeze, lyra/aerial

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hoop, aerial straps, etc. [10, 49]. Aerial Acrobatics also requires an overhead structure (built or natural) that can hold a suspended being, which follows that design-specific mechanics for hanging are a necessity.

Due to its ungrounded nature, gravity and momentum play a large role as it is a type of pendulum, and there is always an added risk of falling. Falling has been found to be one of the top recurring themes of adult nightmares [38, 77]. This element of risk adds to its popularity both for the performers and the audience [41, 50]. Aerial acrobatics, in a way similar to the Olympic sport of gymnastic rings, pushes the athlete physically and psychologically, requiring strength, flexibility, with precise movements 'carefully coordinated in time and space' [25, 56], all of which underlines its capacity for embodied creativity.

In addition to its athletic demands, aerial acrobatics encompasses both performative and technical skill components. Although an aerial 'hobbyist' aims to develop physical capabilities comparable to a professional performer, they would have a different experience and understanding of aerial acrobatics shaped by a controlled environment — typically a gym equipped and insured by its operators — where safety is assumed, and audience feedback is absent. In contrast, performers engage with aerial practice in diverse settings and at greater heights, often installing their own rigging or collaborating with technical teams to meet theater regulations [25]. Awareness of safety and performance/audience aspects changes the sports experience [78].

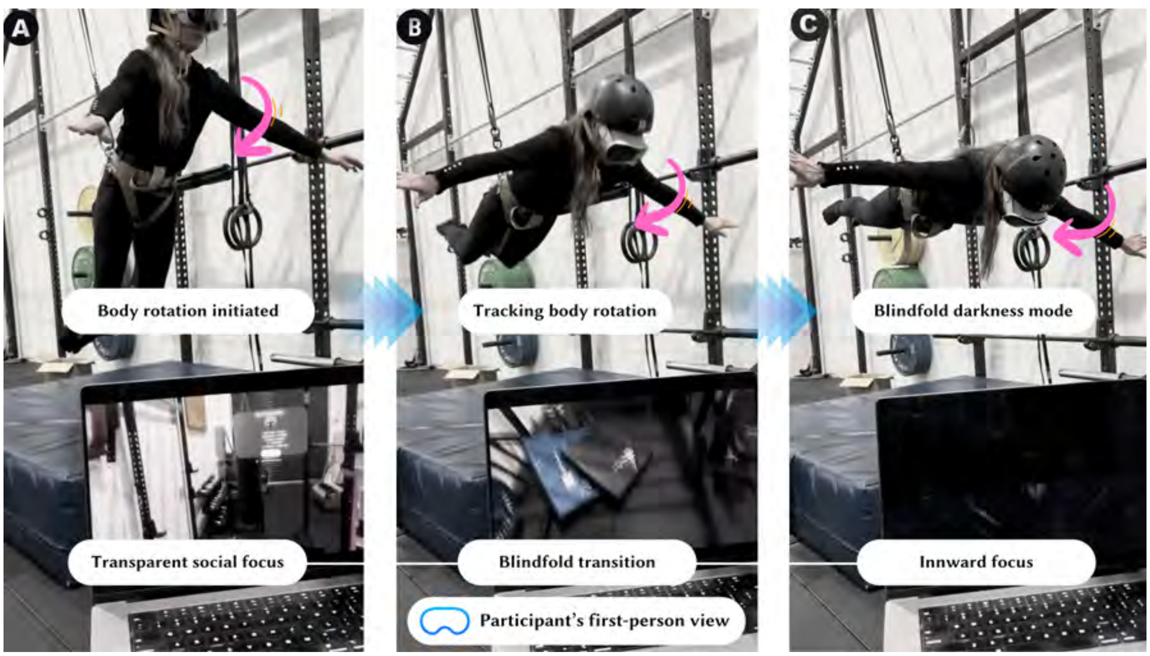

Fig. 1. A participant suspended in a two-point harness, wearing the Apple Vision Pro headset while interacting with the motion-sensitive blindfold app. (A) The participant begins to move forward, with the blindfold in transparent mode, revealing the surrounding environment. (B) As the participant continues to rotate, the blindfold partially activates, shifting their focus from the external environment to bodily sensations. (C) Upon completing the rotation to 90 degrees, the blindfold enters full darkness mode, enhancing proprioception and balance awareness. The arrows indicate the direction of body rotation, while the blue blindfold icons represent the blindfold's transition states. The laptop illustrates the participant's first-person view, displaying the gradual progression of the blindfold transition during rotation.

HCI has increasingly explored ways to support the active human body [5, 61–63, 65, 71, 74, 79]. However, the intersection of aerial acrobatic play and interactive technology remains largely underexplored, particularly in how eyesight and proprioception can be engaged to attune to a suspended body rather than one that is grounded. Being suspended poses unique opportunities, but also challenges when it comes to supporting the user with interactive technology. We are accustomed to having our weight distributed over our feet, but when this comfortable environment is removed and the weight is distributed elsewhere, such as the pelvis or hips, we may struggle to make sense of it. Similarly, when visual memory representations do not align with what we are seeing when inverted or in an upside-down position, as Karpinskaia et al. [44] noted , we can experience confusion.

When unable to establish a sensory connection through the feet, through disorientation, we may look more heavily toward our other sensory systems, such as vision or vestibular [37, 40]. At this point, one might instinctively gaze toward the forehead, expecting to see a ceiling or sky for orientation, or conversely, look toward the feet, expecting to see the ground or a floor. If additionally, one is inverted in the air or 'upside down', this automatic visuomotor reflex of looking toward our forehead will instead show us a floor, and when looking down toward the feet we will see the ceiling or sky. The incongruence can cause more disorientation. If this experience of inversion takes place on an apparatus connected to the ground, the stability of the structure will be reassuring. As part of a pendulum, you would be moving with little stability from which to draw positional data.

This paper focuses on the interplay between bodily movement and perception during aerial play, facilitated by a motion-interactive blindfold prototype to explore this experience of sensory incongruence when suspended and inverted. We designed an interactive real-time visuomotor coupling in the form of a motion-sensitive gradient blindfold in an Apple Vision Pro headset. The gradient blindfold uses the system's accelerometer and gyroscope sensors with a "pass-through" feature that allows bodily control of visual transitions between mixed-reality (transparent view, social reality) and virtual reality (darkness blindfold mode, inner self-awareness).

Participants use rotational movements (flipping) to explore their inner senses, proprioception, and the interplay of self and social judgment through shifts in visual perception. We believe that this might invite participants to safely "experience their [suspended] body as play" (rather than for play) [61], with their body as both a medium and a site of exploration. A "flip" is classified under one of the six categories of aerial movements [25]. Flipping in a two-point harness requires similar kinesthetics to aerial movements such as an inversion on any apparatus and a front hip circle (forward rotation) or monkey roll (backward rotation) around a trapeze bar or lyra [48]. The movement is also similar to a forward or back somersault underwater or in space; however drag force varies [26, 27]. As such, we feel that learning this one basic movement as a novice in a harness apparatus can be very helpful. We selected a two-point harness apparatus because it holds a user safely with little effort. We consider the webbing attached to the sides of the harness to be part of the apparatus, as these allow for varying bodily motion and interaction. Two-point harnesses have been used widely in stunt work for film [47], for training in the sport of gymnastic rings [32, 35], tumbling [1, 69], and trampoline [1], and as an aerial apparatus by Zacco Company as part of the San Francisco Aerial Arts Festival [89] and combined with bungee by Cirque du Soleil in the show "Mystere" [21].

To investigate the experience of our system, we conducted an autoethnographic study involving a multidisciplinary group of authors. Building on first-person methodologies in HCI, we aim to explore the design of novel systems to enrich aerial play.

Our collective expertise spans technology design and bodily sports such as climbing, swimming, and cycling, detailed further below. This autoethnographic approach leveraged our backgrounds to examine the system's potential to facilitate bodily awareness and modulate the dynamic relationship between self-awareness and social perception. The study consisted of two 90-minute sessions for 4 participants using the system. We collected first-person and third-person qualitative data in the form of video recordings, conducted interviews guided by the explicitation approach to elicit reflective and detailed accounts of participant experiences, and utilized soma bodily maps [6] to document shifts in nonverbal sensations and bodily awareness. A reflexive thematic analysis followed, with the authors collaboratively coding and refining insights into thematic clusters. Our findings reveal possibilities enabled by interactive technologies to enhance attunement to the suspended body. Through four themes and six practical design considerations, we demonstrate how motion, perception, and judgment converge to open new avenues for learning, performance, and design implications for aerial acrobatic play. Hence, our work makes the following contributions:

- An empirical contribution in the form of the findings of our autoethnography study. The four resulting themes could serve as a resource for interaction designers and SportHCI researchers interested in understanding the novel experiences practitioners could have while performing aerial acrobatics.
- A theoretical contribution to the ongoing body-centric HCI (e.g., [3, 4, 61, 66, 72]) discussions in HCI by providing design considerations to future design for the suspended body. We draw attention to the suspended body as a site for exploration, highlighting the potential of interactive technologies to mediate unique bodily experiences.

2 RELATED WORK

We position our work on aerial acrobatics and movement-based interaction within four key areas: First-Person Methods, which emphasize direct engagement with the body and embodied experiences; Philosophies of Embodiment and Experience with Connection to Built Environments; Designing for Aerial Play, which investigates playful and performative interactions with vertical space; and Designing for Gravity-Altered Environments, which explores the unique affordances and interactions made possible by reimagining gravitational constraints.

2.1 First-Person Methods: Embodied Experiences

The definition of embodiment in HCI often refers to Marshall and Necker, “our living, feeling, bodily entities situated in a physical world.” [58] Building on this, Levisohn and Schiphorst demonstrated the importance of embodied engagement and the movement experience in computational interaction. [51] As mentioned earlier, aerial acrobatics require precise, perfectly timed movements and often involve physical risk. Consequently, we also briefly acknowledge neurological embodiment. The field of neurology often refers to embodied cognition and unconscious body mapping (henceforth body mapping will be referred to as embodiment) as well as proprioception - which provides the brain with needed position, velocities, and forces around each joint, in order to control the body accurately [11, 36, 87], and Borghi notes that the specific type of body one possesses constrains our cognition to a certain extent [12]. We want to center the embodiment of the aerial experience in our exploration. Consequently, we decided to follow a first-person research method.

First-person research methods have been shown to be an effective demonstration of the "design sensitivities" of the aesthetics of movement [43]. They can encompass a range of approaches, such as autoethnography [29, 54]. These qualitative first-person research methods prioritize introspection, subjective experience, and embodiment, enabling researchers to translate personal experiences into actionable design insights.

For example, in her autoethnography, Dugas described ’failing beautifully’ - using experience to transform gender dysphoria into euphoria [84], Bang explored her embodied dance learning through design [9], and Mainsbridge illustrated the qualities and meanings of performance actions in live and recorded music with a personal account of working with motion detection interfaces [55]. Similarly, Mueller et al. used autoethnography to understand the experience of an adventure climb on Mt. Everest [33]. Additionally, Segura et al. emphasize movement-centered and somatic methods, highlighting the importance of bodily awareness and sensory perception in the design process [57].

For us, these writings uncover new dimensions of benefits and drawbacks to bodily engagement and technical interaction.

In our study, we draw on autoethnography to understand the more nuanced aspects as design researchers of our embodied engagement with the prototype, soma maps to capture nonverbal, open-ended insights about our bodily attunement to the suspension experience, and explicitation interviews to evoke and consolidate detailed reflections on our experiences with the motion-sensitive blindfold. Through these methods, we focus on our sensations — such as shifts in balance, proprioception, and visuomotor coordination while using the gradient blindfold and suspended in the air — that are central to our exploration of aerial play technologies. Building on this tradition of first-person methodologies in HCI, our objective is to explore the design of novel systems to enrich aerial play.

2.2 Embodiment and Connection to the Built Environment

HCI has previously embraced the work of Phenomenologist Merleau Ponty, as well as Heidegger, and the idea that all human actions are embodied actions that must be considered if we are to understand how beings interact with technology. [53, 58, 59, 61] When examining aerial acrobatics, it is necessary to give thought to how we are embodied when using the interface of an apparatus to move and achieve a desired effect while suspended, as this is proprioceptively and visually different from more familiar movement on a stable, grounded surface.

Post-phenomenology emphasized that our embodied experiences are dependent on the environment, further altered and actively shaped by the technologies within the world. As Botin and Hyams argue, architecture itself is a mediating technology, which materially shapes thought and experience [13]. While suspended as a pendulum in aerial arts, we are entangled with this structural technology that suspends and, to some extent, directs the possibilities of movement. When one is suspended as a pendulum, any movement from a beam or truss overhead can be felt by the aerial acrobat and cause a reaction to that movement. If the overhead structure appears unsound, confidence could be lowered. If a wall is close by, the suspended acrobat will see and react to the wall, not wanting to hit it. The height of the overhead structure and the apparatus may visually instill fear. Additionally, suspension creates a boundary between the acrobat connected overhead via suspension mechanics and the observer connected to the ground via gravity. With the addition of an extended reality headset, we are attempting to alter the background relations of the user and the time it takes to acclimatize to new visual perspectives in the user's environment.

Similarly, the concept of enactive interaction emphasizes the interaction of beings with their surrounding environment and built technologies [2]. Hence, we propose that considerations for aerial embodiment from a pendulum perspective would require the addition of our living, feeling, bodily entities situated both within a structural, built environment, and as connected to that built environment. Aerial acrobatics fundamentally require not just a body, but overhead structures such as ceilings, and bespoke mechanics to hang a suspended body. These physical components—ceilings, floors, and spatial configurations—can shape the execution of movement and our embodied experience.

Furthermore, for this pendulum perspective, or the experience of being embodied as a living fixture suspended and connected to the built environment, we look to Gaston Bachelard's phenomenological perspective in "The Poetics of Space", which illustrates the importance of setting our emotional response to architecture, suggesting that humans have emotional associations - personal, group, and cultural - with built environments. Drawing on methods from Merleau-Ponty's phenomenology and Jungian psychoanalysis, Bachelard addresses a human's relation to the physical world around them, our associations with space, and the boundaries of our inner and outer selves in comparison with these spaces. In the aerial arts, the physical boundaries of the ceiling and surrounding structures influence movement and evoke emotional associations tied to the lived experience of space [8].

Umberto Eco's view of architecture as a "communicator" supports this claim, [28], stating that one carries an understanding and emotional memory of the limits of a space (obstacles and boundaries) as well as the "dignity" of the design. By recognizing the phenomenological role of the built environment, we can better understand its impact on aerial play to enrich people's physical and emotional engagement. These perspectives are particularly relevant as we design for virtual environments, where people bring sensory memories of physical spaces that shape their perception, interactions, and possibilities.

Because aerial acrobatics involve risk, or the possibility of physical harm, it should also be noted that, in addition to the psychological response to the environment, there can be a natural physiological reaction to stress that occurs from the environment. A stress response characterized by novelty, uncertainty, and uncontrollability will trigger the adrenal glands to produce adrenaline and cortisol [23]. The study took place in three different spaces with differing suspension points and varying degrees of environmental control. Our research attempts to mitigate some of this stress by offering technical acclimatization.

2.3 Designing Technologies for Aerial Arts

Only a handful of HCI works have investigated the use of interactive technology in aerial arts. Segura et al. [57] explored bodystorming with a group of designers while hanging in a hammock in an "AntiGravity" class (a fitness somaesthetic practice where practitioners use a hammock to perform poses and movements) [31]. This exploration allowed designers to sensitize their bodies to the hanging position and to better understand why hanging can be interesting and exhilarating for some people. The authors focused on the advantages of being able to understand an "unusual" bodily activity as a source of inspiration for interaction design. This work taught us that a designer can learn from the hanging experience; the excitement and joy that comes from accomplishing movements you do not often perform and emotions you do not often experience, like the feeling of flying. However, what is still missing is empirical knowledge about the user's point of view regarding the design of such aerial experiences with interactive technology. Hence, we sought to expand this with findings from our study which involved a prototype. Liu et al.developed "SonicHoop" [52], an augmented aerial hoop that generates auditory feedback, allowing the performer to play music with their bodily movement. This work showed us that interactive technology, in this case, auditory stimuli, can encourage creativity in performers to explore different bodily movements perceived as play. Their study focused on creativity and performance over learning, and aerial participants were not co-authors. Rather than add more sensory stimuli such as sound, we sought to remove extraneous senses, specifically vision, to better focus on vestibular senses and proprioception during aerial play. Research also developed a VR application that was used in a number of movement purposes, including "aerial hoop", to investigate how VR might be used to improve bodily teaching and learning.[19]. Contrary to this work, we aim to explore ways to engage with interactive technology specifically for aerial acrobatics, beginning with mixed-reality.

Tennent et al. explored how virtual worlds overlaid on existing physical rides could alter the sensations of movement and deliver thrilling ride experiences with a system called VR Playground [83]. We hypothesize that, similar to this game, a mixed reality system capable of overlaying the visual experience of suspension at greater heights while still safely close to the ground, while the user could also see their apparatus, might help mentally prepare an aerial acrobat for new environments at greater heights. Rather than a thrilling ride experience, it could be a useful tool for aerial acrobatic performers who need to acclimate to new performance spaces. Our current framework is only meant as a starting point and could be developed further.

2.4 Designing Technologies for Altered Gravity Environments

As designing for aerial arts is not widely explored, we also learned from prior HCI work that has investigated bodily movement in unfamiliar environments. We refer to unfamiliar environments to those setups that altered the traditional on-land bodily movement (not carrying the body weight on the feet supported by legs), for example, work exploring bodily movement while submerged in water [85], while momentarily suspended in the air, like jumping in trampolines, or in movements where the body fights against gravity, like flipping doing a mortal jump [38]. We believe this movement is similar to the experience of aerial arts since the vestibular system is similarly affected and the awareness of the space changes. Also, the perception of gravity feels heavier because you are carrying the weight of your body in a different way, and, as well as in aerial arts, the body must find new ways to understand movement.

One example is the work of Hämäläinen et al. [38] that explored gravity as a design resource to create movement-based games. The authors analyzed digital, physical, and mixed-reality games to propose gravity design lenses for creating novel games. With the "movement diversity" lens, the authors argue that taking into account gravity constraints, such as the amount and type of support points (hands, feet) and surface inclinations (floor, wall, slide), designers can create games with a variety of movements, for example, changing gravity perception, supporting your weight in your hands, as with handstand walking. This work showed us that there is a lack of studies of gravity-based interactions with virtual environments with complex movement improvisation abilities [38]. Hence, in our work, we aim to expand this knowledge while exploring how we interact with the motion-sensitive blindfold as our gravity constraints change with the support of our weight moved from the spine, legs, and feet, to the pelvis and hips.

Mueller et al. [67] wrote of the Grand challenges in Water HCI that included ethics and overcoming aquatic environment constraints. Aerial acrobatics bring similar safety, environment, and accessibility challenges that we seek to address in this study.

Furthermore, we learn from work exploring bodily movement while submerged in water. Pell et al. [73] proposed design considerations for underwater play, considering water as a gravity-altered environment. This work suggested to us that when designing games for underwater environments, we have to consider how this environment can influence the bodily senses and the potential of the technology to support these senses. For example, as the vestibular system is affected by the water's buoyancy, the technology should facilitate bodily movement. However, what is still missing is an understanding of how technology can engage with the vestibular system in the specific case of aerial acrobatics. In our work, we utilized IMU sensors to determine our head's orientation in order to engage with the vestibular system, which is known to be affected while suspended in the air [38].

Similarly, Montoya et al. [60] explored the use of interactive technology in a gravity-altered environment of a floatation tank. (a bathtub filled with salt-saturated water that allows effortless floatation), combined with virtual reality. In this work, the virtual water and the real water of the tank complement each other to create the illusion of floating. This work exemplifies how virtual and real environments can both be used to create different playful experiences. We were inspired by the design strategy "*Designing to encourage breathing and body awareness in water experiences*," where the authors suggest combining both real-world and virtual world stimuli. Hence, in this study, we explore how combining the blindfolded virtual world with real-world bodily suspension in a harness could support breath and bodily awareness in aerial arts.

2.5 Designing Technologies that use Balance as a Play Resource

We also learned from works that have explored play in unbalanced scenarios (e.g., standing on a balance board), trying to understand the opportunities of using interactive technology [16]. These prior works argue that the resulting vertigo sensations derived from making users unbalanced, for example, by asking them to stand on one foot or through galvanic vestibular stimulation [17], can be leveraged to create novel game experiences. For example, in "Balance Ninja" [16], the researchers stimulate the users' vestibular system to create vertigo sensations that are used as game mechanics. This work exemplifies how vertigo sensations can be leveraged rather than trying to avoid them. Similarly, in AR Fighter [18], the same authors proposed how disorientation in unbalanced scenarios can be used as a game mechanic by using a head-mounted display. Here, the authors demonstrated that perceptions like disorientation, which are often unpleasant, can be transformed into an engaging way to interact with others. Disorientation is often experienced by players wearing VR headsets, which designers have used to facilitate novel ways of play like rewarding the players who are losing control of their bodies due to disorientation [18]. We relate to Balance Ninja and AR fighter as disorientation and vertigo can be experienced in aerial arts. Consequently, these works inspired us to find ways to facilitate this feeling of playfulness through technology to support unbalanced experiences, and in our design, we also utilize a headset to support a playful experience. Because designing experiences where the user is unbalanced through other means, such as suspension in a harness, is still not understood, we feel our work is still necessary.

2.6 Research Gap and Research Question

Aerial acrobatics offer rich opportunities for exploration, yet the role of interactive technologies to support "*using the body as play*" [61] safely in aerial acrobatics remains underexplored. To address this gap, we seek to investigate the interplay between augmented eyesight and proprioception in adapting to the suspended environment and pose the question: how best to design mixed-reality interactive experiences for aerial play? We aim to contribute to advancing the design of interactive technologies that enhance engagement with aerial play as discussed in sections 7 and 8.

3 METHODS

To explore the intersection of aerial acrobatic play and interactive technology, we conducted an autoethnographic study as designer-researchers, capturing first-person accounts of our experiences. Autoethnography, a well-established methodology in HCI, supports the exploration of novel technologies and their experiential implications [54, 76, 86]. Our approach to safely engage in aerial play was guided by the first author's 30 years of experience as a teacher of aerial arts. Over two weeks, two 90-minute aerial sessions for each author were conducted, gathering first-person data through multiple mediums, including first and third-person video recordings, autoethnographic reflections, semi-structured interviews, soma maps, notes, images, and discussions. This multimodal approach enabled us to document and reflect on our aerial play experiences. Following this, we conducted a thematic analysis guided by Braun and Clarke's methodology [14] over eight weeks, consisting of weekly one-hour group sessions and multiple asynchronous sessions. Through collaboration, the authors developed thematic clusters, which were refined into the themes presented in Section 6 and synthesized into practical design considerations discussed in Section 7.5. As all the participants were also authors, we acknowledge that we did the analysis of our own data and recognize this bias could be seen as a limitation. However, leveraging our varied backgrounds added tension and gave us different perspectives to address (A1 having little HCI experience and A2-A5 with no prior aerial acrobatic experience, with the exception of one AntiGravity

Yoga workshop). These contributions advance understanding of the largely unexplored intersection of aerial play and interactive technologies.

4 DESIGNING "BLINDFOLDED IN THE AIR" - AN EXTENDED REALITY MOTION-SENSITIVE HMD PROTOTYPE

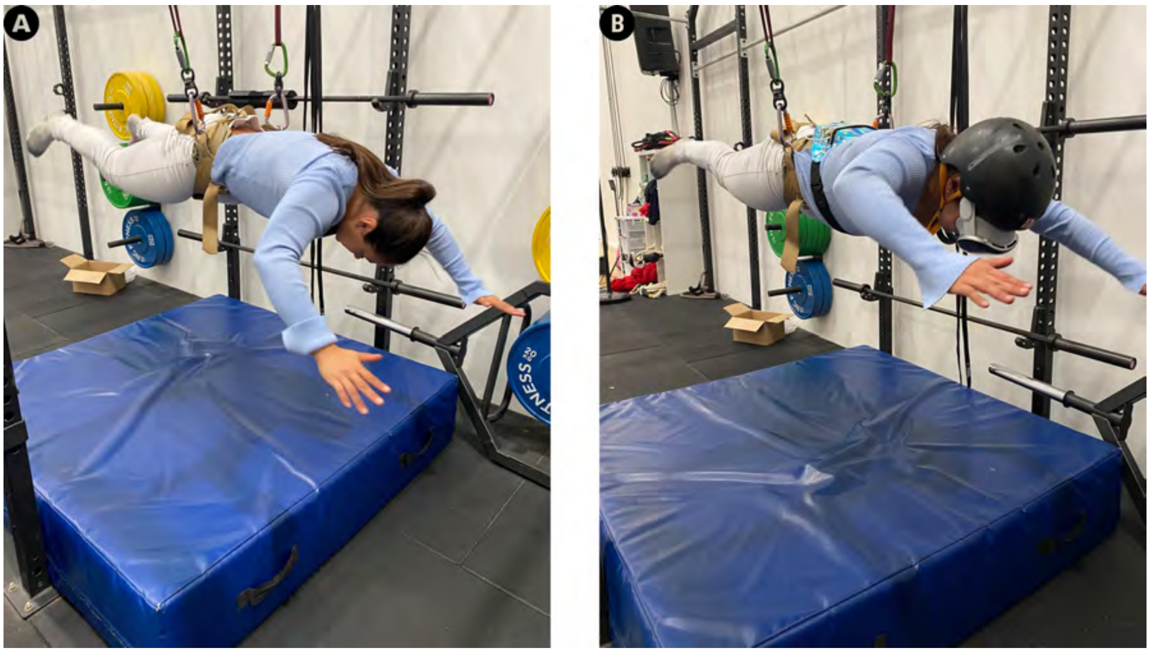

Fig. 2. Participant engaging with the "Blindfolded in the Air" motion-sensitive head-up display prototype while suspended in a two-point harness. (A) The participant explores movement in a suspended upright position without using the Apple Vision Pro, focusing on balance and coordination through natural bodily adjustments. (B) The participant transitions to a horizontal suspended posture while wearing the Apple Vision Pro, demonstrating how the technology facilitates inward focus, enhances spatial awareness, and supports proprioceptive alignment by reducing visual dominance.

The idea of the motion-sensitive blindfold mixed-reality headset was inspired by the first author's aerial arts teaching experience. Through years of working with a diverse mix of people, such as children from a variety of socioeconomic backgrounds and with and without disabilities, women and men with different body shapes, and athletes with different sports backgrounds, the first author observed that people were often lost when their feet didn't have a stable hold. In particular, the first author observed that one martial arts (Wu Style Taiji Master) and one American-style football player who were accustomed to grounded movement expressed extreme discomfort and disorientation when their feet were unsupported, even with spotting assistance. When standing on the ground, our feet reassure a connection to the surface via various sensory mechanoreceptors in the skin [39]. In their article, "Sensitivity Mapping of the Human Foot: Thresholds at 30 Different Locations", Henning and Sterzig note that these mechanoreceptors are accustomed to assisting balance control during human locomotion and are an important part of sensory input [39]. In "Transferring Qualities from Horseback Riding to Design" [42], Höök writes an anecdote of her instructor asking her to "stand up in the saddle" to encourage her to put her weight into her heels in order to trigger the proper kinesthetics for English style riding. When we are suspended, we may lack this sensory connection completely. Hence, when teaching, the first author would place her fist under a student's foot as they were learning to climb a rope or silk to comfort students, and to encourage them to use their legs and core more to assist climbing rather than only climbing with arm strength. The first author also observed that as students learned to move with feet disconnected from the floor, their perceptions of their bodies and selves shifted. Eye movement and focus are crucial to initiate movement in any sport [22]. A notable observation of the first author during instructions was that although students could follow focus cues in an upright position, when inverted and asked to "look up", all students would instinctively look towards their foreheads and the floor rather than at the ceiling, where we generally conceive "up" to be. Additionally, during adaptive climbing training, the first author discovered that blindfolded certification exercises improved her climbing technique. Without the dominance of vision, her inward focus enhanced proprioception, and her body naturally brought her hips closer to the rock wall by aligning itself vertically. This account impressed upon us the potential benefits of removing visual distractions to improve spatial awareness and body alignment through interactive technologies.

Next, we describe the technical implementation and the mechanics setup.

4.1 Implementation

"Blindfolded in the Air" is a motion-sensitive blindfold mixed-reality headset created using an Apple Vision Pro. Designed for use with a two-point harness for full-body suspended rotation, it dynamically transitions between a black virtual environment and the real world. By reducing visual and social distractions, the prototype aims to enhance inner-body awareness and enable sensory-rich, playful experiences that deepen connection to the suspended body.

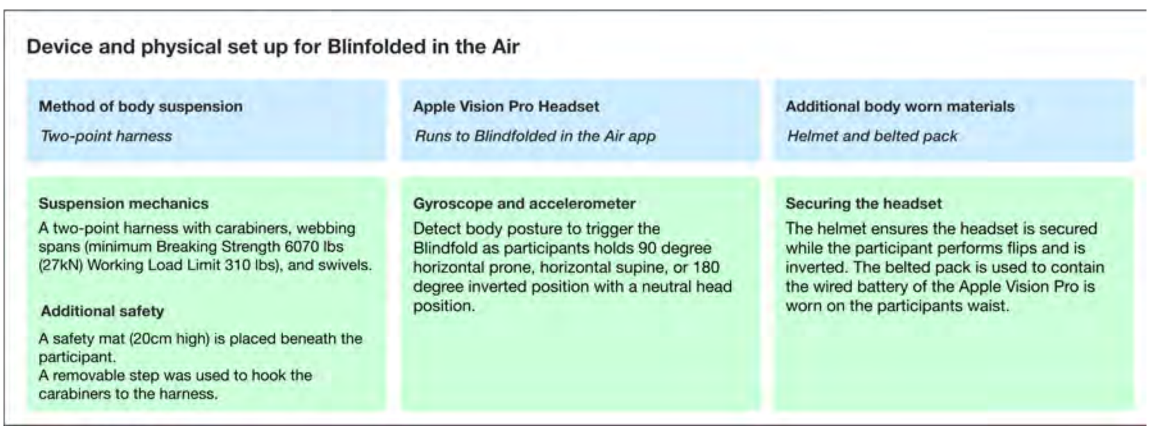

Fig. 3. This figure shows the physical setup, including the body suspension method specifics, and the digital setup, including how the Apple Vision Pro headset sensors are used to trigger the blindfold.

4.1.1 *Iterative Implementation.*

An iOS application was designed for the Apple Vision Pro that triggers a pass-through functionality as the participant rotates and holds a 90-degree horizontal prone, horizontal supine, or 180-degree inverted position with a neutral head position (Figure 2). We called this functionality a motion-sensitive gradient blindfold because it gradually increases or decreases a black virtual environment, occluding the vision of the real world.

The motion-sensitive blindfold was designed to allow visibility to be controlled by body motion, which we hoped would mitigate issues of object recognition that can be experienced when the upright frame of reference is missing

[44]. Coupling the blindfolding with suspension, we aimed to defamiliarize and remove participants completely from the "automatism of perception" [53]. As the user moves towards 100 degrees, vision slowly fades in again, and at 170 degrees, it slowly fades out as the user moves to a position of complete inversion. These transitions can be seen in Figure 1. Our intent was to support the participant shifting between the physical-social reality to a blindfold-like immersive reality of the inner sensations of their suspended body.

4.1.2 Physical setups. We chose the two-point harness [Figure 1] as an aerial apparatus, both to isolate a basic, unilateral aerial acrobatic movement (rotation) as a first point of study, as well as to ensure the safety of the researchers. When in a harness, the participant is not required to physically hold anything to avoid falling. The center of gravity in a human varies, but is generally located in the lower abdominal region near the hips [70]. This is ideally where the suspension points on the harness should be placed. There can be some discomfort with the new sensation of weight being placed on the anterior and posterior iliac spines (front and back hips).

4.1.3 Additional Participant and Technology Safety. We secured the headset by using a skating helmet. This helped to keep the device stable during rotations and provided additional safety. To safely manage the wired battery of the Apple Vision Pro, we used a belted pack worn around the participant's waist, creating a secure and stable setup that allowed the technology to stay in place throughout the experience with the wire safe from entanglement. A safety mat was placed under the participant, and proper insurance for suspended sports was held by the gyms where the study took place. A third party was present in case the participant needed speedy dislocation from the hanging points.

5 USER STUDY

This section outlines the study, detailing the participants, data collection, data analysis, suspension mechanics, and session procedure.

5.1 Participants

We are a team of HCI researchers and designers with different complementary sports backgrounds. The first author (A1) is a researcher in Applied Cybernetics and has 30 years of experience in aerial arts performance and coaching. She holds various movement certifications including Pilates Machine and Osteo-Pilates.

The second author's (A2) research involves soma design practices and has 5 years of HCI research experience using virtual reality-related technologies. She has practiced different sports (e.g., soccer, swimming) for over 15 years and competitively practiced rugby and CrossFit for the last five years.

Author three (A3) is an experienced researcher in technologies that explore the body as play, with nine years of HCI research experience. Previously, he explored the design of technological interfaces that promote mindfulness and understanding of the self. Additionally, his professional background in sports, like cricket, and running as a hobby, enriches his perspective on bodily awareness and performance. This diverse expertise informs his approach to designing interactive systems that blend playfulness with practical insights into movement and mindfulness.

The fourth author (A4) uses movement-based methodologies in technology design, focusing on interactions with agentic technologies positioned near or directly onto the body. His work includes exploring interactive mobility devices that respond to motion. Previously, he played semi-professional football and is an active CrossFit practitioner, providing diverse reference points to engage with the body and technology.

Author five (A5) is a design researcher with over 20 years of experience researching bodily experiences. As part of his creative practice, he has co-designed various bodily experiences. His research goal is to understand the design of interactive technologies to help people experience their bodies as play, not just for play. This is because he wants to help people figure out who they are, who they want to become, and how to get there. Due to time constraints, he did not partake in gym sessions.

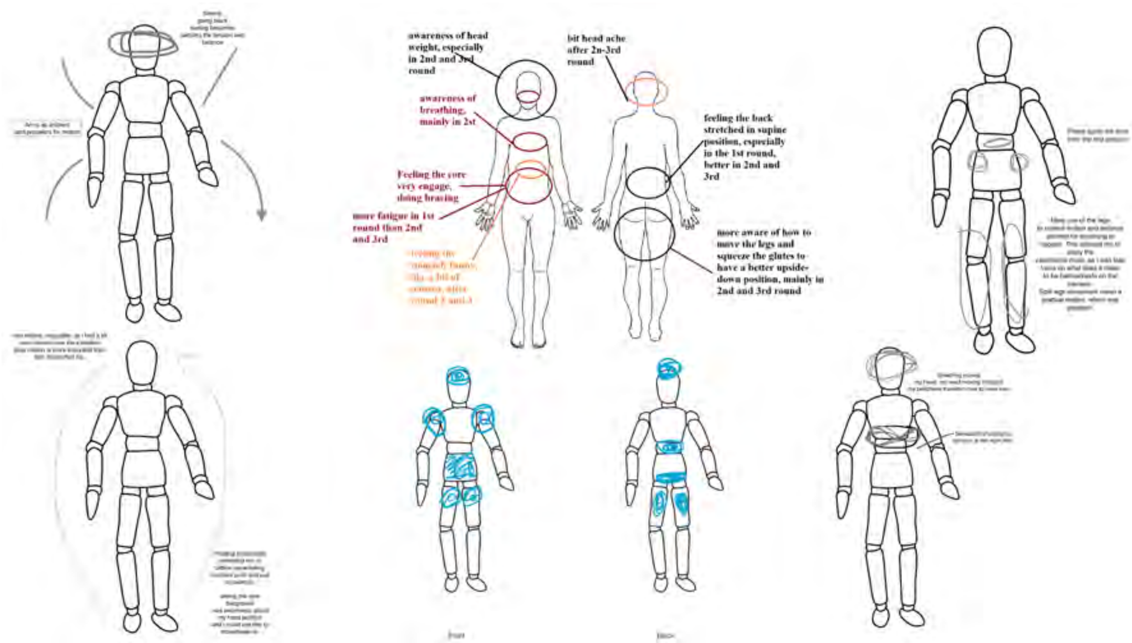

Fig. 4. A collage of the Soma maps illustrating participants' physical sensations, body awareness, and adjustments experienced during the "Blindfolded in the Air" prototype sessions, highlighting areas of tension, movement control, and sensory focus.

5.2 Data Collection

We chose a first-person research approach to center the participant's lived experience in the exploration of interactive aerial play with our motion-interactive blindfold prototype. Autoethnography allows researchers to highlight embodied feelings and experiences, as seen in Höök's work on soma-based design and Bang's exploration of Isadora Duncan's choreography through her own body [43, 86]. Given the inherent risks of aerial arts, autoethnography provides essential insights into somatic awareness—understanding the body from within—illustrating the importance of firsthand experiences. To gather participants' accounts, we utilized multiple first- person data collection approaches. Each of the authors participated in two 90-minute sessions. These sessions served as repeated technology encounters, allowing participants to move beyond the initial novelty effects and deepen their engagement by allowing them to focus on different aspects of the experience. First-person perspectives were observed using the video mirroring feature of the Apple Vision Pro, while a separate camera recorded a third-person perspective.

The participant was not allowed to view a live or video demonstration before trying the prototype. During each of the two sessions, four explicitation interviews were conducted. This method enabled participants to recount how the experience unfolded from their perspective, with researchers asking open-ended questions such as: "What happened when you mounted the harness?", "Tell me more about this," and "What happened next?" This semi-structured approach provided a scaffold for participants to articulate their experiences in detail. The first interview took place after the participants had practiced movement in the harness and lasted 5 to 10 minutes; the second and third interviews were conducted after participants had spent 5-10 minutes exploring and playing with the blindfold system while suspended in the harness; and the final interview, conducted at the end of the session, after dismounting, lasted approximately 20 minutes. During this final interview, participants used soma maps [79], shown in Figure 4, to draw details about their experiences, illustrating non-verbal information on the front and back of the body, such as sensations, strengths, movements, or shifts in bodily awareness they experienced.

5.3 Data Analysis

To deepen our designer-researcher understanding and reflection of the experience, we conducted a reflexive thematic analysis guided by Braun and Clarke [14]. Each author began by individually analyzing their data—including videos, soma maps, interview recordings, and transcripts.

Participants then engaged in cross-analysis, reviewing and coding each other's data to deduce shared patterns, overlaps, and unique perspectives. We systematically coded the data, treating all data items equally and coding individual quotes as data units. This collaborative process offered a collective space to appreciate each others' experiences, avoiding the echochamber by utilizing the tension between positionalities of the different authors. The results from these sessions were refined into thematic clusters over an eight-week period.

Through eight one-hour meetings, we reached an intersubjective consensus on the themes and actionable design insights. This iterative process allowed us to reflect on and translate our insights into interaction design considerations, advancing our understanding of designing for aerial play technologies.

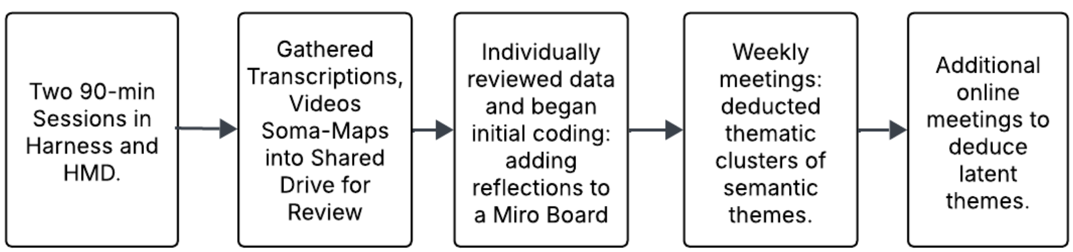

Fig. 5. Data Analysis Methods Flowchart

5.4 Suspension Mechanics

It was necessary for the overhead suspension point to be at least 4 meters tall and 2 meters wide, with enough space for a mat of at least 20cm beneath. This setup must allow the researcher to be hung without their feet touching the mat to allow complete suspension and adequate room for the shoulders when flipping. A removable step was used to hook the carabiners to the harness when commencing. We used a two-point harness, carabiners, webbing spans (minimum Breaking Strength 6070 lbs (27kN) Working Load Limit 310 lbs), and swivels (Figure 5 below).

The first author held certifications in boom lift operations, IRATA rope access certification, and Working Safely at Heights. She set up the suspension mechanics and helped the participants to secure the harness. The two-point

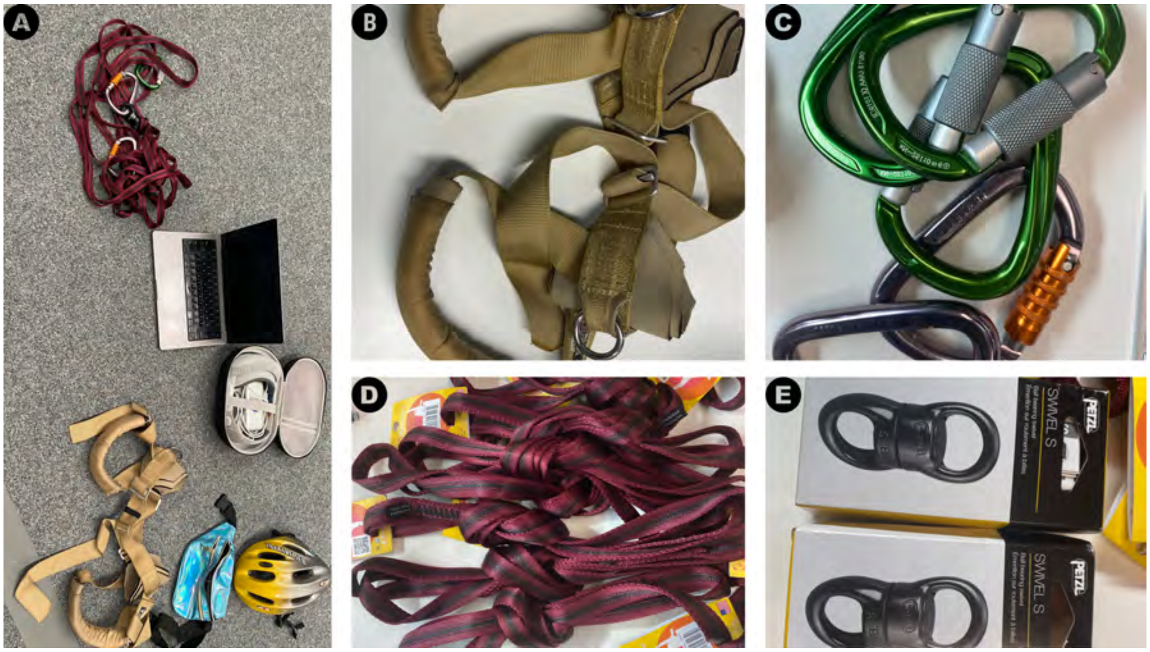

Fig. 6. Equipment, A.) Harness with Battery Holder and Helmet, MacBook Pro, Apple Vision Pro, Spans, Carabiners and Swivels B.) two-point harness C.) webbing spans (minimum Breaking Strength 6070 lbs (27kN) Working Load Limit 310 lbs) D.) professional carabiners E.) Petzl Swivels.

harness was positioned with a central fulcrum at the hips. No demonstration would be given as this could influence their exploration. There were no mirrors in the space.

The study sessions took place in three distinct environments, with two tested by individual authors and the third by two authors. Each setting provided unique acoustic, lighting, social, and mechanical conditions that shaped the experience. These different environments were chosen to contrast our first-person experience and the use of the blindfold functionality. However, rather than analyzing each setting in isolation, we approach them as a whole because what mattered was not the singular qualities of a space but how the shifting acoustic, lighting, social, and mechanical conditions together shaped the experience. The first aerial studio, with fluorescent lighting, minimized social distractions and interference from surrounding structures. The second studio provided even lighting, minimal audio distractions, and complete privacy, with only the researchers and the first author present as a guide. However, the narrow hanging points brushed the shoulders when rotating and interfered with the movement. The gym environment had a sun-filled window to the side, which interfered with the mixed-reality, background music, and occasional social distractions, as curious bystanders twice approached to observe the sessions. We believe these varied environmental factors could have influenced how participants interacted with the suspension mechanics as well as the blindfold.

5.5 Session Procedure

The first author guided every session, which consisted of four stages involving the movements outlined in Figure 6. These movements were arranged progressively, from novice to advanced, to gradually encourage participants to explore their bodies while suspended and while navigating the experience. The first author, as the instructor, provided more detailed cues to help with forward and backward rotations at the start of the session, reducing cuing towards the end to allow participants space to experiment independently after familiarizing themselves.

First stage - mat warm-up: A warm-up was carried out on the ground using a yoga mat. An abdominal, back, and core warmup is beneficial for reducing the chance of injury while in the harness. Vocabulary that was used while on the mat was then translated to the harness to help cue movement. The first author guided the ten-minute warm-up with similar movements in prone, supine, and standing positions to emulate movements that would be performed while suspended.

Second stage - harness no headset: The first author helped to secure the harness and hooked the participant into the suspended position using a removable step. Then, she guided them using verbal cues to perform the movements in Figure 2. No demonstration was given; it was up to the participants to find the movement on their own without the visual memory of seeing someone else.

Third stage - harness and headset guided: In the third stage, the user would wear the headset. It was initially necessary to recalibrate eye and hand tracking of the HMD, open the application, and manually initiate mirroring with a Macbook Pro. When this was finished, the participant could begin engaging in the rotational movements and interacting with the gradient blindfold. **Fourth stage - harness + headset free play:** After acclimation to working in a harness and using the headset, the user was free to explore movement on their own.

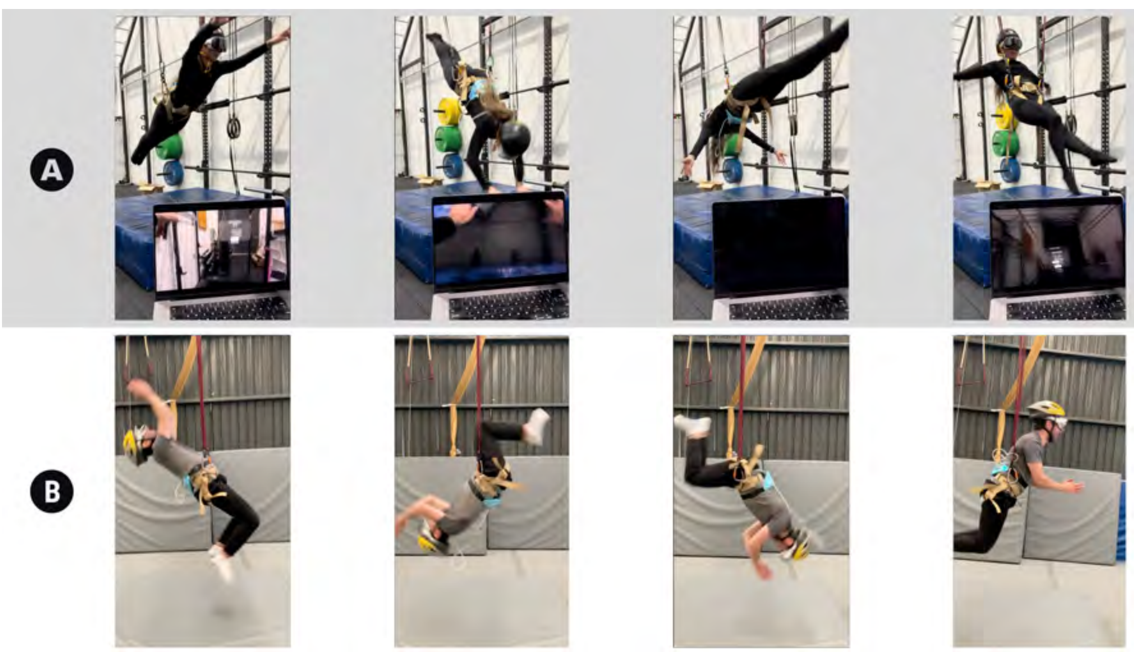

Fig. 7. (A) Participant engaging with the "Blindfolded in the Air" prototype while suspended in a two-point harness, demonstrating a forward flip of the body and visual transitions displayed on the Apple Vision Pro headset (As shown on the laptop). (B) Participant performing a backward flip and rotations using the two-point harness setup, highlighting physical engagement and aerial play facilitated by the prototype.

6 FINDINGS

Our data analysis identified 4 themes: 1) Re-embodying our Bodies in Suspension, 2) The Role of Gradient Blindfolding in Shaping Bodily Focus and Bodily Control, 3) Expanding Movement Boundaries in Aerial Play Using Mixed-Reality, and 4) Perceiving Oneself as a Performer Through the Dynamic Interplay of Self and Social Judgement.

6.1 Theme 1: Re-embodying our Bodies in Suspension

This theme presents two sub-themes examining how suspension in a harness prompted participants to rediscover their bodies in a novel aerial environment: (1) Re-embodiment due to Body Disorientation and (2) Re-Embodiment with HMD via Breathing and Head Position. We highlight how our bodily perceptions transitioned to the aerial space, adjusting to the unfamiliar sensory input, becoming aware of one's body in a new context, initially without using the headset. We believe this is important to highlight since we were interested in how our body's perceptions change when suspended with or without technology.

6.1.1 Re-embodiment due to Body Disorientation. Participants described feeling a sense of disorientation when first suspended, particularly those unfamiliar with aerial activities, as pointed out by A3: *"The connection between the hands and legs was quite disembodied. I was learning how to use them to move my body."* Conversely, A1 experienced a positive reaction: "When I hook into the harness, I feel a sense of joy and lightness." and A4 described a heightened awareness: *"It gave me a sense of expanded awareness [. . .] even a small movement of one arm shifts the balance, affecting the alignment of my entire body."* Some participants reported feeling disoriented, especially when being upside-down; however, they were able to re-embody their awareness as exemplified by A2: *"It was disorienting when I was upside down and rotating. I didn't know where I was in space, but it wasn't disorienting for my body awareness."* Over time, participants articulated how they rediscovered their body during the suspension phase, as A4 said: *"Learning to move in a floating space is strange [...]I felt a bit like an octopus, trying to synchronize my limbs to move smoothly."* By the end of the first suspension phase, participants acknowledged getting used to this new orientation, for example, for A3 felt confident: *"I now felt confident being upside-down"*. Finally, A4 mentioned the "pre-warm-up" (exercises on the floor) was key to the learning process and getting confident with use of the headset: *"The pre-warm-up before putting on the harness helped me become aware of how ready my body was to engage with the device. The warm-up plays a sensitization role, shaping how I think about and connect with my body."*

6.1.2 Re-embodiment with the HMD via Breathing and Head Position. While the harness introduced a unique set of physical constraints and sensations, participants gradually adapted and, in the second round, would wear the HMD to play with body angle position using the blindfold application. Initially, participants reported getting used to the new top-heaviness when the HMD was introduced, as mentioned by A2: *"The head felt heavy, 'cause of the helmet and the headset."* and similarly A3 said: *"With the second flip I started to notice the weight quite a bit"*. The adjustment of the headset did not allow proper fit, and this change in weight made participants perform differently: *"My hands were often on my head because the headset kept moving around"* (A1), and also created discomfort in the first session. *"I felt a bit [of a] headache after the second and third rounds[with the HMD]."* Awareness of breath then became prominent, and participants described how this led to breathing adjustments." The experience of A1 enabled her to engage her breath more intentionally, emphasizing its role in controlled movement: *"My breath helps me to slow down [...] I found myself wanting to slow my movement and breath to the speed of the gradient."* Second, participants described the role of their head posture in finding balance and adapting to being suspended. For example, A4 noted: *"There was a moment when I* *was trying to float horizontally. While making an effort to balance, I took a deep breath - the act of breathing caused a subtle movement in my head, and I accidentally entered the blindfold. It felt almost as if my breathing was controlling my eyesight. This experience reminded me of the crucial role my head's posture plays in achieving horizontal balance"* - highlighting the importance of adapting their whole body to being suspended. Similarly, A1 said: *"It helped me to know when my cervical spine was in a neutral position as opposed to extended or contracted."* In summary, all participants reported how breath and head adjustments helped re-embodiment to adapt to the aerial environment and HMD with increased confidence.

6.2 Theme 2: The Role of Blindfolding in Shaping Bodily Focus and Bodily Control

This theme examines how the interactive gradient blindfold functionality influenced participants' bodily focus and control. This theme has three sub-themes: (1) Perceiving the Gradient Blindfold as Similar to Other Low Vision Experiences, (2) The Gradient Blindfold Reducing Visual Dominance and Enhancing Bodily Awareness, and (3) Perception of Control over the Gradient Blindfold.

6.2.1 Perceiving the Gradient Blindfold Similar to Other Low Vision Experiences. Participants described the gradient blindfold as evoking sensations reminiscent of low-vision or darkness-related experiences. A2 noted how the blindfold's automatic function of gradually darkening was similar to instinctively closing the eyes: *"It feels like you're closing your eyes without thinking about it."* Participants drew personal associations with the progressive gradient to darkness, connecting it to both physical and imaginative experiences. A1 found similarities between the progressive gradient to the darkness of scubadiving, associating the dark environment with controlled breath: *"The gradient reminded me of the darkness of being underwater[scubadiving] and breathing slowly."* In a different interpretation, A4 linked the experience to a robotic shutdown, reflecting on the visual transition as a metaphor for losing power: *"I saw the transition going to black, and it made me think that if you are some type of robot, that is what you would see when you go to sleep or when your battery is going low."* These sensory shifts highlighted the unique role of the blindfold functionality in expanding participants' awareness of their bodies and shaping the surrounding space while suspended, as we show in the next subsections.

6.2.2 The Gradient Blindfold Reducing Visual Dominance and Increasing Bodily Awareness. Participants described how the gradient blindfold shifted their focus inward, allowing them to concentrate on their bodily movements. For example, A3 noted: *"It made me focus more on my body when it blurred."* A2 explained: *"The black environment helped me focus on the muscles to regain balance."* The absence of visual distractions allowed participants to better understand their movements. For example, A3 highlighted how seeing the real environment initially disrupted their focus: *"The first time I could still see the blue mat underneath, so I was focusing on the external environment rather than my body."* A4 explained: *"By being able to move more gently and using the gradient, I was able to control my eyesight and balance to achieve the rotation."*. It seems that by removing unnecessary visual stimuli, the blindfold's gradient enabled a shift in attention inward, leading to increased bodily awareness. Complementing these visual associations, the blindfold further shaped participants' sensory awareness and perception of space as exemplified by A1: *"When I used to perform, I was far above the audience. Using the blindfold application reminded me how stimulating and distracting I find the outside world. It felt very peaceful and focused to be in the virtual world alone with my body.* Overall, participants' reports suggest that removing the dominance of their visual senses, with the assistance of the gradient blindfold, helped them to gain bodily awareness in this suspended position, even for the most experienced.

6.2.3 Perception of Control of the Gradient Blindfold. Participants described mixed experiences of control when engaging with the gradient blindfold, revealing how it shaped their bodily awareness and sense of agency. Initially, the participants reported a lack of control, with the gradient influencing their movements rather than responding to them. For example, A3 noted a feeling of being controlled by the motion-sensitive gradient: *"Rather than controlling it, I felt like the gradient was controlling me, making me aware of how to move my body."* Similarly, A4 associated the experience with losing bodily control during fainting: *"It reminded me of when my body took control of a situation because I was about to faint. My body looked around to find a safe place to fall, and it walked me to the carpet, where it was safe to faint. This reminded me of that sensation where you become a passenger in your own body."* These reports highlight a moment of unfamiliarity, where the gradient blindfold imposed an external rhythm that participants had to negotiate. However, as participants grew accustomed to the harness and gradient, they played with different movements, gradually reclaiming a sense of control over the gradient. This transition from losing control to gaining control illustrates a shift in embodiment as participants learned to manipulate the systems more deliberately. For example, A1 reflected: *"The gradient feels like a dance partner."* A4 reflected: *"Engaging your whole body, using precise movements allows you to control and interact with the gradient."* This growing agency also deepened participants' connection with the virtual environment, as A3 noted: *"Controlling the gradient with body movement felt like going from the outside world to the inside world."* Overall, these reports suggest that the system supported a meaningful shift from passively losing control to intentionally gaining control over the experience.

6.3 Theme 3: Expanding Movement Boundaries in Aerial Play Using Mixed-Reality

This theme describes how participants engaged in bodily movement explorations and play to push their and the device's capabilities. This theme has two subthemes: 1) Learning to Move to Push the Boundaries of Mixed-Realities, and 2) Pushing Bodily Boundaries Through Play

6.3.1 Learning to Move to Push the Boundaries of Mixed-Realities. We noted how participants gained mastery over movement between the real and virtual world. Within the immersive system, participants gradually learned to coordinate their limbs, regulate their breathing, and stabilize their posture, all while adapting to unfamiliar sensory feedback and interaction cues. As participants progressed, this learning process evolved into a more deliberate and refined engagement with movement, marked by increasing confidence and technical skill. For example, A4 delved into the complexities of *"learning movement techniques,"* suggesting an active process of acquiring new skills to navigate the virtual space effectively, trigger, and focus on the presence of the gradient. For A2, this phase was characterized by: *"learning acrobatics and understanding the role of limbs to gain stable positions,"* highlighting the challenge of mastering bodily control in an unfamiliar, dynamic setting. The iterative nature of this process is further captured in A2's reflection on *"refining movement techniques,"* revealing a cycle of trial, feedback, and improvement. This learning trajectory was pivotal in the user's journey, as it marked the transition from initial apprehension to a growing sense of agency and control within the virtual reality environment. A1 captured this essence by stating: *"feeling the gradient arc and timing adjustments [...] I played with timing to make the gradient go in and out of darkness at an even pace with every 90 degrees."* indicating a growing awareness of the system's nuances and a conscious effort to optimize interactions with the system while suspended. Crucially, this process of skill acquisition also helped participants confront and gradually overcome psychological barriers, particularly those related to fear, risk, and bodily trust. At the start, participants reported their apprehension about taking the risk of performing in the harness. For example, A3 described confronting fear and risk: *"I was a bit afraid at the start because I didn't know how to use my body, I think my body wasn't also willing to take that* *risk."* However, they gradually felt safer after gaining confidence wearing the harness, as A4 said: *"When you are in the harness, you feel that you need to be cautious… if I could get my back and the harness to feel connecting and fine, it was almost like getting that sense of, 'Ok, I'm safe."* In addition to the harness, the HMD itself initially presented a source of unease as A1 recounted: *I found I was worried about the headset like it was one of my students. I would often reach for my head to make sure it wasn't falling off and was safe."* These accounts suggest that the learning process encompassed both motor skill development and psychological adjustment, in which participants gradually built confidence in the system's safety and their own bodily capabilities within it.

6.3.2 Pushing Bodily Boundaries Through Play. Participants engaged in playful exploration as a means of testing both their own physical capacities and the system's interactive boundaries. As familiarity with the suspended environment increased, participants began to experiment with movement in ways that extended beyond basic functionality. For example, A2 said: *"Once I was connected this time, I just went to it without fear, and the front flip was also more natural.[...]"Once I achieved the rotations, it was very fun for me"*, and A1 noted: *"I played with gradient - flipping fast enough that the blindfold wouldn't kick in. I received some tracking errors because the headset was confused with the movement."* - reflecting a transition from cautious engagement to confident play. These reports of experimentation illustrate how aerial play emerged as participants gained competence, transforming the system from an interactive tool to a space for creative movement. It seems participants noticed this potential for play from the start, since they reported associations to childhood funny moments, as mentioned by A3: *"It almost made me feel like a child again. I think that was fun. Particularly, when I used to roll in the grass downhill."* Once participants found the potential for aerial play, they were able to explore new movement patterns and test the device's responsiveness, fostering a deeper sense of interaction and self-expression. A2 recounted: *"exploring the limits of the system,"* indicating an intentional effort to understand and challenge the constraints of the interactive technology. Similarly, A4 described a more refined perspective: *"I tried using split leg movement when rotating, which causes slow acceleration - and slow in and out of the blindfold - moving from black to normal gradually. I had learned to use my legs in a different way to open a new experience."* which appears to reflect a deepening understanding of their body and the relation to the system's intricacies, allowing for more nuanced aerial play technology relation. Together, these reflections marked a shift from a focus on acquiring basic skills to a more explorative aerial play experience.

6.4 Theme 4: Perceiving Oneself as a Performer Through the Dynamic Interplay of Self and Social Judgment

Participants reflected on how they perceived themselves throughout the experience, navigating shifts between self-perception, social perception, and associated self-judgment. These reflections highlight how embodiment in an immersive, technology-mediated aerial experience can reshape the sense of self. For instance, A4 described the transformation as playful and empowering: *"Wearing all the gear transforms you into a sort of floating, superhero-like, harnessed figure. The act of dressing up in futuristic-looking technology feels fun and exciting."* Participants mentioned how this self-perception shift was further deepened through embodied preparation, as A4 noted the impact of the warm-up: *"The warm-up plays a sensitization role, shaping how I think about and connect with my body to perform."* Moreover, the interactive gradient blindfold facilitated motion-related transitions between self-judgment and social perception, enabling participants to navigate their self-image and social image fluidly. For example, A4 captured the tension between imagined identity and physical coordination: *"Once on the harness, the heroic or futuristic image [of myself] contrasts with the clumsiness of moving and coordinating my body—quite the opposite of the graceful movements I'd associate with a hero or futurist* *persona."* These shifts were influenced by their perceived clumsiness or prowess during blindfold transitions, where participants noticed how their internal and external selves negotiated. A1 noted: *"When I used to perform, I was still far above and away from the audience. Using the blindfold reminded me how stimulating I find the outside world. It felt very peaceful to be in the virtual darkness alone with my body."* A3 said: *"Learning to move and become more graceful allows me to transition between focusing inward on my body and posture—almost without judgment, only from myself—toward a more social, performative state, where I aim to display gracefulness and prowess."* This dynamic interplay between self and social perceptions, as enabled by the blindfold's gradient transition, appears to play an important role in shaping how individuals perform for others and engage with their bodies through aerial play in sport-like contexts.

7 DISCUSSION

We tested the Blindfold system on four participants who were also authors of this paper. Leveraging our varied backgrounds - athletic HCI designers with no aerial acrobatic experience, and an aerial artist with no previous HCI experience - to evaluate how a simple mixed reality application could affect aerial acrobatic practice. After engaging in cross-analysis of each other's coded data, we reached an intersubjective consensus on four themes described in section 6. We will now discuss insights and practical takeaways we found from designing, developing, and engaging with our prototype, Blindfolded in the Air, and convey our results in the form of six practical design considerations. Designers can follow these design considerations, summarized in Table 1, when creating interactive mixed reality experiences for aerial play. Consequently, our work contributes to the ongoing investigations in HCI field centered around the embodied interactions and interactive sports, drawing attention to the suspended body as a site for exploration, highlighting the potential of interactive technologies to mediate unique bodily experiences. In the next subsections, we highlight how acclimating the senses to the harness apparatus, headset, and mixed reality was an important starting point to engaging in aerial play. Overall, we feel that developing interactive aerial play design knowledge can enable our community to design for moments of increased bodily awareness in unfamiliar environments, transitions between inner self-awareness and social performance, and virtual and physical juxtapositions.

Table 1. Six Considerations for Designing Aerial Play Technologies

Design Consideration	**Description**	**Aerial Play Design Opportunity**
1. Incorporate enactive acclimatisation to prepare for aerial play in mixed reality	Aerial acrobatics using a VR headset requires physical and virtual acclimatisation	Integrate warm-up activities, time to adjust to the physical interface/apparatus, and gradual exploration of the gradient to help users adjust to the technology and aerial play
2. Support the breath	In doing aerial acrobatics, breathing plays a main role in stress control and mindful movement.	Consider how peripheral visual cues in mixed reality can guide breathing. Explore simple cues to help maintain inner focus on the body. Consider game elements to support a playful attitude
3. Correlate real-virtual world shifts with movement dynamics to facilitate bodily awareness	Using a gradual transition to mixed reality in aerial play adds a temporal and spatial awareness that can help with movement and postural cuing.	Consider the gradual introduction of the virtual elements to the mixed reality environment based on the postural behavior of the practitioners, enabling them to see a virtual reference that correlates to movement dynamics .
4. Give the user a sense of control over the system to facilitate a playful attitude	In aerial play, control over the system provides a sense of trust and safety	Consider motion-sensitive visual gradients using lightweight sensors, for example, with different colors, in response to speed, orientation, or rhythm of the user's movement, to facilitate self-explanation and playful exploration of movements
5. Increase body posture sensing accuracy.	The spine's fluid movement makes head-only sensors insufficient for posture tracking.	Add lightweight sensors to the chest and back for more accurate posture tracking and better connection to aerial play technology.
6. Assist acclimation to the unfamiliar environment by reducing visual dominance, leveraging vestibular engagement	The change of perceived gravity in a suspended position may be stressful	Consider highlighting the change and supporting the vestibular system by using subtle sensory cues, such as reduced vision or shifting pressure points in the body. This could draw attention to the body's orientation and encourage playful movement exploration.

7.1 Unexpected delays: Attuning to the Suspended Body and Mixed-Reality Experiences

Here we articulate the findings of Section 6.1, Re-embodying our Bodies in Suspension, Subsection 6.2.3, Perception of Control of the Gradient Blindfold, and Subsection 6.3.1 Learning to Push Mixed-Reality Boundaries. Firstly, we noticed that once unexpected hurdles were surpassed, such as delays due to structural/environmental limitations, technical snags, and general discomfort in the apparatus, participants discovered new ways to move and perceive their bodies as well as position themselves by playing with the interactive gradient blindfold. We discovered an interesting and common behavior that was not anticipated: holding the breath until a certain level of comfort and a specific bodily position had been achieved. This finding has similarities with existing work on strength practices, highlighting how systems can help athletes practice breathing techniques to achieve desired movement patterns [15]. In our work, we seek to expand this by showcasing how, in an unfamiliar and therefore stressful environment such as mixed-reality suspension, participants appeared to rely even more on these breathing techniques to control their movement as well as the gradient blindfold system. Hence, for future aerial play in mixed reality, designers can consider triggering subtle cues to help practitioners breathe rhythmically to control and coordinate their movements with the apparatus, similar to previous work on breathing games for relaxation [88] and peripheral breathing [81]. This is the second practical design takeaway detailed in Table 1.

Secondly, the bodies of the participants were able to acclimate to discomfort, such as the “painful” (A3) sensation in the hips due to weight being distributed from the pelvis rather than the feet, and the distracting weight of the headset. The floor warm-up and initial suspension without technology supported the adjustment to the new orientation and sensation of being suspended. This aligns with the work of Mueller et al. in Grand Challenges of WaterHCI [67], pointing out that every environment needs to have an evaluation framework to complement the benefits of engagement. In our study, we highlight the complexities of the aerial acrobatic environment and how assessment and acclimatization could be beneficial to facilitating engagement. Similarly, Segura et al. emphasized bodily sensitization to inverted positions, which our findings expand by showing that such acclimatization is especially crucial before introducing the headset. Participants reported that adjusting to the weight of the headset improved their confidence and reduced discomfort during performance. Hence, we believe that when designing for aerial arts, designers should consider incorporating enactive acclimatization as detailed in the second practical design takeaway in Table 1.

7.2 The Aerial Performer in a Mixed-Reality Experience

Based on Section 6.4, Perceiving Oneself as a Performer Through the Dynamic Interplay of Self and Social Judgment, we found that the interactive gradient blindfold influenced a sense of self in participants, revealing dynamic shifts between bodily awareness, social perception, and self-judgment. This re-embodiment in mixed reality aerial play transformed participants’ sense of self in an empowering way and was useful in rediscovering movement. The gradient blindfold provided a virtual structure and temporality that - like the walls and entrance of a cave - helped participants to understand the limits of the outside space (transparent view, structural understanding and social reality) as well as the inside space (virtual reality, dark blindfold mode) and served as a type of dimensional portal between outside, inner being, and virtual reality. This feature supported a reframing of the self, enabling participants like A4 to shift from self-consciousness to playful engagement: *“Once on the harness, the heroic or futuristic image [of myself] contrasts with the clumsiness of moving...”* . Compared to traditional performance sports, such as gymnastics or figure skating, where athletes are consistently visible and judged [7], the blindfold gradient allowed participants to navigate variable states of visibility. Our work expands prior HCI work supporting the sport performer [30], given that the blindfold’s gradient offered a design paradigm where visibility is dynamic and user-controlled, empowering participants to engage with performance on their own terms. These findings suggest that carefully designed sensory modulation can empower performers to reconfigure their embodied identities and recalibrate their presence in immersive sport-like experiences, as detailed in the third practical design consideration in Table 1.

7.3 Controlling the Gradient Blindfold in Aerial Play Using Mixed-Reality

In section 6.3 and subsection 6.3.1, Learning to move to push mixed reality's boundaries, we see the potential of using mixed-reality to self-modulate social exposure as well as add a virtual frame of reference that correlates to movement dynamics. Participants remarked on how they could control the gradient blindfold with both movement and breath, as well as how this control helped them to know if their posture was aligned at 90 or 180 degrees of rotation. Bodily control over the virtual experience is often used in exergames through motion capture systems [20]. In contrast to this work, our work system leveraged the headset IMU sensors to control shifting between the real and the virtual world, which allowed postural and bodily awareness, prioritizing focus on inner bodily perception instead of engagement with the virtual environment. Gradually occluding vision, the gradient blindfold eliminated the stress caused by the uncertainty of where to focus while suspended. Furthermore, we hypothesized that because of this gradual visual transition to darkness based on posture, the discomfort of nausea was avoided. None of the participants reported feeling nauseous after repeated engagement with the system. This confirms prior work suggesting that the vestibular system is sensitive to visual-movement uncouplings [45]. Hence, a gradual shift between the real and virtual world in mixed reality, allowing visual movement couplings, could allow bodily awareness in aerial play, as detailed in our fourth design consideration in Table 1. Participants' reflections also point to the emergence of play as a liberating force since controlling the gradient blindfold helped to remove fear. Once initial control was achieved, many engaged in playful experimentation, testing the boundaries of movement and of the system itself. We expand prior work pointing out the playful advantages of limited bodily control [34], since, in contrast, in our work, we found that for aerial play, participants were only able to be playful once they felt safe and the feeling of fear decreased as full control over their bodily experience increased. Moreover, we found our work aligns with other similar embodied play observed in parkour or freestyle BMX [46]— sports in which the performer's body responds creatively to space, since the feeling of control allowed the free exploration of movements while suspended, and play becomes a form of self-expression and self-knowledge. To achieve similar results, designers can refer to the fifth and sixth practical design considerations in Table 1.

7.4 Gravity as a Design Resource in Mixed Reality and Aerial play

Based on the results of themes in Section 6.1, Re-embodying our Bodies in Suspension and Subsection 6.1.1, Re-embodiment due to Body Disorientation, we recognized the change of bodily weight perception and perceived gravity supported embodied interaction and play in aerial acrobatics. Participants first experienced their weight and center of balance changing from the feet to the pelvis during suspension. This re-embodiment was initially disorienting; however, it eventually helped the participants to discover new ways to move their bodies. These results confirm the work of Loke et al. Making Strange, which points out that disrupting our habitual movement patterns can open new movement possibilities. Secondly, our participants reported a feeling of fun and enjoyment due to the change in gravity perception heightened with the dark environment provided by the gradient blindfold, mentioning that it was enjoyable, similar to being on a *"roller-coaster without the machine"* or *"that feeling of jumping from a cliff"*. This aligns with Hämäläinen et al.'s work exploring how gravity as a design resource can be leveraged to create movement-based games.

We aim to expand this work and consider the use of the blindfold's gradient to have heightened this resource, allowing participants to explore the limits of the system with the focus of their bodily movement. Temporarily removing vision with a gradient blindfold can remove overwhelming visual dominance and distractions, bringing more attention to the body in such a 'gravity-altered' position. Additionally, these findings align with Pell et al.'s work, who proposed design considerations for underwater play and pointed out that when designing games for underwater environments, we have to consider how this environment can influence the bodily senses and the potential of the technology to support these senses. In this regard, we sought an understanding of how technology can engage with the change of movement in this 'gravity-altered' bodily position, which affects the vestibular system in the specific case of aerial acrobatics. Accordingly, we explored the use of IMU sensors to determine our head's orientation in order to engage with the system, avoiding vestibular system disruptions. We believe this consideration supported the movement freely in the suspended position, hence allowing the free exploration that led to play. Supporting the vestibular system appeared to enhance comfort within the unfamiliar context of suspension and may contribute to more rapid acclimation in other visually or physically ambiguous environments such as underwater or zero-gravity settings. Overall, these findings underscore the potential of gravity-informed, vestibular-aware design to support embodied play and orientation in novel spatial contexts, such as aerial play. This led to the sixth design consideration in Table 1.

8 LIMITATIONS AND FUTURE WORK

We acknowledge the limitations in this study. In particular, we acknowledge that we began with a very isolated movement on a sagittal plane, speaking to the fact that aerial acrobatics often involves complex types of movements. Our system senses the body's angle in sagittal movement (front and back flips). If sensing of the body's angle during coronal (sideways) movements were added, our system could possibly be used for other aerial actions such as rolling drops in the tissú apparatus. We would encourage such developments for future work. Clark pointed out that "eye movement and focus is crucial to initiate movement in any sport." [22]. Therefore, it might have been insightful to also collect eye-tracking data throughout this research to deduce where focus shifted during this suspended rotational movement, as well as during times when the blindfold was triggered. As we were using an Apple Vision Pro with eye-tracking capabilities, this could have been easily added, and we accordingly encourage such future work. Furthermore, although the darkness worked well, we could envision amplifying the mood of the experience by adding colors to the blindfold, for example, all "blue". Future research might find such explorations insightful, and we hope that our work could scaffold such investigations. We acknowledge that we only spent a limited time with the system; hence, we encourage future work to conduct longer-term studies. More study is necessary to determine conclusively whether this application helps novice aerial artists to achieve essential skills such as a basic inversion or rotational (flipping) movement. Furthermore, we have yet to demonstrate our system to experts who were not involved in the design process. Therefore, future work may want to investigate this, and we hope that our work could structure such investigations. Lastly, we also encourage future work to safely investigate additional apparatus for aerial work and also other augmentation devices, including non-visual ones such as those that allow for augmented hearing [64] or augmented haptics [80]. Taken together, we believe that these additions could expand the application of extended reality in aerial play and possibly other unfamiliar non-gravity contexts, offering new possibilities for embodied interaction design experiences.

9 CONCLUSION

This work contributes to understanding how to design for aerial play technologies, exploring the user experience of five movement technology designers through an autoethnography study. By designing, developing, and studying a novel motion-sensitive blindfold for aerial play created in the Apple Vision Pro, we investigated how the interplay between eyesight and proprioception can attune participants to a suspended body. We also observed that a gradual, gradient blindfold facilitated ease of transition between social and inner worlds. Our findings highlight how the motion-sensitive blindfold can facilitate shifts between inner senses and body mapping, enabling people to use their bodies for mixed reality aerial play. We feel it could also help people acclimate to unfamiliar non-gravity contexts and challenging environments that lack visual or physical frames of reference. This work broadens our understanding of designing interactive real-time visuomotor couplings between people's movements and mixed-reality devices in suspended environments. By offering four themes and six design considerations to support the design for an active body, we advance the knowledge on embodied interaction in HCI and the emerging field of Sports HCI. Ultimately, we aim to expand the possibilities for aerial play, offering new possibilities for embodied learning and interactive design.

10 ACKNOWLEDGEMENTS

We thank Alexi Giovani for developing the iOS application, and Dr. Ash Lenton for valuable insights and feedback on the "Embodiment and Connection to the Built Environment" section. We also acknowledge Aerial Sports in Canberra, Monash University Gym, and Elemental Aerial Studio, Victoria for generously providing spaces to conduct our study. Florian 'Floyd' Mueller thanks the Australian Research Council, especially DP190102068, DP200102612 and LP210200656. Maria 'Mafe' Fernanda Montoya thanks DP200102612.

11 DISCLAIMER ON GENERATIVE AI

This work was created solely by the authors.

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Received 24 April 2025; revised 18 August 2025; accepted