Exploring the Player Experiences of Wearable Gaming Interfaces: A User Elicitation Study

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The design and development of playful wearable devices is a challenging and complicated problem. It entails not only multidisciplinary expertise but also a comprehensive understanding of player experience. There is a scarcity of evidence-based studies in current state-of-art literature that investigate general design practices and provide pragmatic design implications and suggestions based on solid user-centered research. To bridge the gap, we developed five experience prototypes based on the speculative design concepts from previous studies, and a Wizard of Oz experiment was conducted to elicit end users' feedback regarding general gaming experience as well as specific design themes in different gaming scenarios. The user experiment results were analyzed qualitatively following a rigorous thematic analysis, generating five major design implications as output. We believe this study will offer forward-looking insights to designers, developers and the research community, facilitating future work in this field.

CCS Concepts: • **Human-centered computing → Empirical studies in interaction design**; **Mobile devices**; • **General and reference → Design**; • **Computer systems organization → Embedded hardware**.

Additional Key Words and Phrases: wearable, gaming devices, user-centered design, wizard-of-oz, experience prototyping, thematic analysis, game design, game controllers

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1 INTRODUCTION

Playful wearable devices and wearable-based gaming are undergoing a soaring growth. According to the new market report, the global market for wearable gaming is projected to grow at a compound annual growth rate of 15.3% and is estimated to reach a market valuation of US$ 5188.9 million by the end of 2026 [1]. Typical gaming wearables include virtual reality (VR) devices (e.g., headsets, suits, backpacks, etc.), non-VR products like the Casio GD8 game watch, Pip-Boy and Pokemon Go Plus, all the way to the most recent Nintendo Ring Fit Adventure Leg Strap and brainwave game controllers by NueroSky and Nextmind. Distinguished from traditional gaming devices and consoles, the particularity of playful wearables allows them to be as close to players as a "second skin," giving rise to new types of in-game interactions, contents and also a playful experience beyond the game context. Despite its great commercial and innovation potential, when compared with the mainstream game platforms and consoles, wearables remain a niche, underexplored field.

The design and development of playable wearables is often a complicated, multifaceted challenge. It entails specialized knowledge traversing a wide spectrum of disciplines such as electronic engineering, ergonomics, biomechanics and more. At the same time, the convergence of hardware, software, contents and services have frequently extended the task of playable wearable design beyond product development. Moreover, wearables development incorporates designing complex and dynamic interactions in various gaming contexts to deliver an integrated and holistic playful experience; thus, a comprehensive understanding of user experience has become a prerequisite to devising any individual artifact or component. Although previous research, for example, [13] and [33], has proposed design frameworks and speculative design concepts for guiding playful wearable design, these studies were mostly based on ideation sessions in participatory design workshops or designerly activities such as conceptual design and design fictions.

Synergizing and reflecting on the previous research, we conducted an exploratory user elicitation study, where we involved players in different gameplay scenarios leveraging a variety of "experience prototypes" [10]. Experience prototyping usually utilizes low-tech methods and improvisation with basic materials and thus bears little resemblance to a desirable product in shape, form, size or weight. However, specifically in the phase of understanding, exploring and evaluating people's different interactions with gaming wearables in different gaming contexts, experience prototyping allows more flexible investigation with richer design possibilities at a more reasonable cost, which high fidelity prototypes can hardly provide. Therefore, we adopted this method to gain a first-hand appreciation of experiencing gaming wearables as a complex continuum of subjective and diverse contextual factors.

We followed a user-centered approach in this study. Five different experience prototypes were established according to the speculative design concepts by Jung et al. [33] that promoted the following themes: T1) Extended embodied interaction, T2) Adornment for body image, T3) Modular and multi-use adaptation, T4) Daily usage beyond gaming context and T5) Multi-sensory bodily feedback. More details can be found in Section 3. A Wizard of Oz (WoZ) experiment was conducted to elicit users' first-hand responses to specific interactions, affordances and design alternatives of gaming wearables. User feedback was collected from 15 participants with diverse gaming experiences via semi-structured interviews, and the interview contents were further analyzed with a qualitative thematic analysis. The contribution of this study is threefold:

- Through testing experience prototypes, we elicit user opinions and ideas about the design concepts previously presented in the literature
- We propose user-centered design implications that inform the field regarding the design of gaming wearables

[1] https://www.factmr.com/report/316/wearable-gaming-accessories-market

- We articulate actionable design recommendations that can be used by playful-wearables designers and researchers

2 BACKGROUND

The definition of "wearables" has shifted from technologies that are worn on the body to all kinds of technologies that are in contact with the body and facilitate personalized information processing [26, 51]. In this study, we use the term to refer to both technologies that may be worn like a jacket or are simply attached to or wrap the body like a blanket or a brooch.

In the 1990s, Gemperle et al. proposed design guidelines for wearability [23] and suggested that the physical attributes of a wearable device (e.g., size, weight, shape, etc.) and the contact with the human body (e.g., placement, attachment, sensation interaction, etc.) play important roles regarding users' wearable experience. As a fundamental basis for all wearable devices, including playable wearables, wearability needs to be ascertained from different perspectives: 1) physiological effect, 2) biomechanical effect, and 3) user-perceived comfort [37]. Later, the penetration of low-cost, tiny-volume transducers has enabled wearable devices to become an ideal medium for a body area network (BAN) [52]. In 2017, Zeagler et al. proposed a body map in [69], indicating what kind of sensors can be attached to which parts of the human body for collecting different kinds of data. A recent study surveyed different wearables and summarized their characteristics into input/output modalities, mobility and body locations [35].

Reflecting this technology-driven, multifaceted transformation in wearable design, various domain-specific applications have emerged, such as telerehabilitation [2, 53], sports and related performance analysis [21, 38, 41], physical exercises [22], education [7, 50], skill training [6], and, of course, gaming [17, 45]. Specifically for gaming wearables, several frequently seen uses of sensing technology can be identified from current state-of-art research: 1) Mapping traditional game controllers to sensor-based input/output channels, such as [42, 65]; 2) Modifying game mechanics and dynamics during runtime; for example, [22]; 3) Extending game settings from a cyber environment to a physical or hybrid environment, for example, [17, 47]. However, very few studies have revealed the underlying rationale behind the specific implementations or presented user-centered assessment results, which made it difficult to gauge how the adoption of certain functions and features will affect players' in-game experience. Moreover, along with the uptake of maturing technologies like stretchable sensors and thermal actuators, building experience prototypes [10] and testing them with end users is a substantial step toward envisioning the possible impact that the new technology trend will have on future playful wearables and the related design strategies.

Aside from its technical and functional affordances, researchers have also explored the social, cultural and aesthetical implications of wearable devices from various perspectives. Researchers studied wearables' mediation in social experience, explicitly, co-experience value in collocated interactions [20, 31, 44]. Many of the studies were conducted in the social game settings where multiple players physically co-presented, such as live action role play (LARP). Wearable devices enhance players' (usually non-verbal) social signaling, increase spectator sensitivity, and trigger social interactions either remotely or physically. Playful aspects of wearables have also been investigated by many other bodies of work, such as WEARPG [14], Magia Transformo [32] or True Colors [19]. Building on this work, Buruk et al. defined a design space of playful wearables in three planes: 1) performative, 2) social, and 3) interactive [11]. This design space was then used for investigating playful wearables for mainstream gaming based on large participatory design knowledge in [12]. Previously, a design framework for playful wearables based on hands-on experience on festival games, tabletop and LARP games was proposed in the work [13]. Jung et al. added to this study by proposing speculative design concepts to demonstrate the possible applicability of those design directions [33]. Although they did not go beyond the speculative concepts or test these concepts with end users, these studies have established a basis for further exploration of first-hand user experience.

At the same time, the convergence of fashion design and wearable technology has become a focal point in recent years. Much interdisciplinary work has investigated wearables' aesthetic affordances as computational or interactable fashion materials, such as [24, 62, 64]. Previous studies also suggested that the appearance of wearables may convey information beyond sheer aesthetic values. For example, in the context of cosplay, wearables are associated with wearers' theatrical expressiveness, community belongingness, and even daily usage as a subtle reminder of the original contents [55]. Considering that gameful and playful experiences overflow into daily life and experiences [5, 29], fashion and especially cosplay studies are closely related to playful wearable studies.

Although the aforementioned research has reflected different aspects of incomplete design knowledge of wearable devices for games and play, the major state-of-art literature in this field still anchors in single and domain-specific device development mostly based on technical prototypes. The field lacks a coherent, holistic understanding of the complex dynamics of the experiential qualities of user interactions with gaming wearables, which are co-determined by a conglomerate of hardware, software and game contexts. By intensively investigating how users engage with a rich repertoire of wearable experience prototypes under various gaming contexts, this research intends to answer some preliminary research questions and generate valuable insights for guiding pragmatic design and development practice.

3 METHOD

According to Buchenau et al., an experience prototype is "any kind of representation, in any medium, that is designed to understand, explore or communicate what it might be like to engage with the product, space or system we are designing" [10]. This method is of specific significance in the early design stage, where there is a need to understand existing user experiences and contexts as well as explore and evaluate new design ideas. In our case of designing gaming wearable devices, we have established a rich repertoire of experience prototypes in low fidelity and resolution to explore as many design directions as possible.

A user experiment based on the WoZ method was conducted [34]. The experiment consisted of two sessions, in which two independent sets of non-functional prototypes were tested. All gaming wearable prototypes were analogous objects made with simple craft materials such as Velcro, sponges, cardboard or ready-made items like gloves and jackets, and test games were simply imitated by software like Keynote and web page games. Participants' in-game interactions were simulated by two experimenters, respectively, using keyboard and mouse operations.

Note that there might be some overlap among prototypes if we only consider the electronic components required to make functional prototypes. Each prototype, however, had its own emphasis on different target users experiences, with the specific aim of directing users' attention and eliciting their feedback over certain design themes derived from concepts created by [33]:

- **T1) Extended embodied interaction** refers to how wearables can be designed in a way that reaches out from the body and guides bodily movements. Examples are a crank mounted to the arm and can be used for lowering a bridge or a cloth that can be used as a robe or a tentacle.
- **T2) Adornment for body image** means to wear game items around the body that confer in-game abilities by granting bonuses, skills and powers to the character. Skill cards that are

attached to the body for activating a specific skill and items placed on the body that also belong to in-game inventory can be examples.

- **T3) Modular and multi-use adaptation** points out the adaptability of one wearable into different game mechanics, styles and genres.
- **T4) Daily usage beyond gaming context** refers to leveraging the impacts and utilization of gaming wearables beyond the screen-time and gaming context. It includes using the data collected during daily activity as a part of in-game actions or simply being able to use the gaming wearable as a daily smart device.
- **T5) Multi-sensory bodily feedback** addresses unconventional feedback mechanisms such as temperature feedback. Although it was not specified in [33], we intended to exploit this theme by adding and testing the capability of thermal feedback.

Between the two experiment sessions, **Session I** examined four different experience prototypes, respectively *Gaming Cloth*, *Fungilainen's Mushroom cards*, *Inputs* and *Tangicubes*, in a single narrative role-playing game (RPG) and aimed to have a deeper look in T1, T2 and T3. **Session II** examined only one prototype, *Core Watch*, in four different gaming settings exploring T3, T4 and T5. See the following subsections for more details.

The reason for this division is two-fold: first, different prototypes were not tested in a single united session because they had a particular emphasis on game settings (narrative-based versus interaction-based), gameplay types (continuous play versus intermittent play) and use scenarios (multiple wearables used in one game versus one wearable used in multiple games); second, from a more pragmatic perspective, we also considered the possible mental and physical burden that a long testing session might cause to the participants. It might also be difficult for participants to recall sufficient details if all the five prototypes and five games were tested together. Therefore, to assure the experiment quality, the user test was organized in a double-session structure, with each session followed by an immediate user interview. We also note that these two sessions were not designed for comparative purposes with a control group and an experimental group but to elicit information based on different approaches and design themes.

This study employed and integrated a user elicitation approach to extract users' feedback around the aforementioned design themes. User elicitation has been commonly used to investigate users' needs and preferences regarding their interactions with technical systems and support the participatory design process; a few examples include [27, 49, 56].

3.1 Prototypes and Test Games

3.1.1 Session I. In the first session of the user experiment, participants played pseudo-RPG ***Dungeons and Goblins*** made with the presentation application Keynote. The game was about the journey of a mushroom-powered magician named Fungilainen. Players were asked to follow the game's narrative and perform actions according to the instructions on the screen to solve Fungilainen's issues by choosing and using appropriate wearable prototypes among a *Gaming Cloth*, *Fungilainen's Mushroom cards*, *Inputs* and *Tangicubes* in a situation. The game had a fixed linear story, so all the players followed the same storyline.

Here is the story of ***Dungeons and Goblins***. The player is role-playing Tampere's great wizard, Fungilainen, who uses the ancient magic inherent in wild mushrooms. The Mystical Orb beckons to Fungilainen and asks him to go to Hervanta Dungeon to find a scroll. Soon, the Mystical Orb opens the gateway, teleporting Fungilainen to Hervanta Dungeon. At the dungeon, Fungilainen faces a locked door, and the mysterious Dungeon Keeper on the other side shouts, "thou shalt not pass!" The player throws an explosive green Tangicube (Figure 1 - 4) to destroy the locked door and enters. Beyond the door, Fungilainen faces an angry Dungeon Keeper, Láthspell (another name of Gandalf in Tolkien's The Lord of the Ring meaning bad news). Láthspell casts a fireball, and Fungilainen tries to protect himself by covering his body with the Gaming Cloth (Figure 1 - 1). The Gaming Cloth protects the player for a while, but eventually, he suffers some damage. The player then drinks a health potion by holding the red Tangicube (Figure 1 - 4) close to their mouth. Meanwhile, Láthspell leaves behind a mushroom and runs away (at that moment, the experimenter throws a Mushroom card [Figure 1 - 2] in front of the player). The player acquires the mushroom and attaches it to their own body. In the display, the mushroom grows over Fungilainen's body and gives him Atomic Mushroom power. Next, Fungilainen walks along the dark passage and hears Láthspell yelling in the distance. To hide from Láthspell, Fungilainen makes himself invisible using the Gaming Cloth. Láthspell passes Fungilainen and drops another mushroom. When the player attaches the second Mushroom card to their body, another mushroom grows on Fungilainen's body, giving him the Mirror Mushroom power. Later, these two mushrooms create a mutant Magic Mushroom and Fungilainen gains "mystical power" from the mutant Magic Mushroom. Soon after, Fungilainen meets Láthspell again. The player wraps the Gaming Cloth around their arm and fires an ice missile at Láthspell. Láthspell takes damage but attacks Fungilainen with poison gas. The player tries to block the poison gas by covering their nose and mouth with the Gaming Cloth but does not act fast enough and acquires "poisoned" status. Láthspell attacks Fungilainen with the "Avada Kedavra" spell. To prevent the deadly consequence, the player uses Mirror Mushroom power to reflect Láthspell's spell. Finally, Fungilainen defeats Láthspell. Láthspell says, "I am your father" to Fungilainen. However, Fungilainen's father had passed away the previous year. After an awkward moment, Fungilainen walks along to the sound of the stream and reaches Lake Hervantajärvi. There, Fungilainen encounters a wild goblin. The goblin introduces themselves as the guardian of the scroll and attacks Fungilainen. Fungilainen counterattacks using an Atomic Mushroom. A powerful nuclear explosion occurs, but it does not defeat the goblin who stands and mocks Fungilainen. Fungilainen feeds the goblin with the mutant Magic Mushroom. The goblin is dazed and confused and runs away. However, the battle with the goblin leaves Fungilainen badly wounded. The player wraps their arm with Gaming Cloth to heal the wound. Nearby, Fungilainen finds a runestone. Three mysterious words, "wear," "crank," and "fish," are carved on the stone. Behind the runestone, Fungilainen finds a crank (at this moment, the experimenter gives the hand crank [Figure 1 - 3.1] to the player). The player attaches the crank to their arm and casts a fishing rod. After a while, the player quickly winds the crank and grabs it. A sea otter is caught on Fungilainen's fishing rod. The sea otter, in a bad mood, bites Fungilainen's arm and hangs on (experimenter attaches the fabric [Figure 1 – 3.2] to the player's jacket). Fungilainen calms the sea otter by stroking it on its arm. The sea otter relaxes, releases Fungilainen's arm, and says, "The scroll is sold out." The game ends.

The game described above took approximately 15 minutes to play. As shown in Figure 1, the first set included four prototypes:

(1) *Gaming Cloth* is a cloth-type wearable with various uses depending on which body part was covered and the method and shape of wearing it. While playing Dungeons and Goblins, participants used the Gaming Cloth as a shield to protect against a magic spell, a cloak to make themselves invisible, a hand cannon to attack enemies and a bandage to heal wounds. During the concept generation, shape recognition algorithms, stereoscopic cameras and markers were discussed as technologies that might realize the idea. However, because the purpose of the study was to explore the possibility of a design concept, not to achieve a technological implementation, an ordinary, 1 m^2 blanket was used for the experiment.
(2) *Fungilainen.* Named after the player's in-game avatar Fungilainen, a set of cards gives the magical power of mushrooms to the avatar. Following the game's narrative, players collected Fungilainen Mushroom cards and used their power to solve problems. Fungilainen Mushroom

cards had mushroom images and names printed on the front and hook Velcro glued on the back. A jacket donned before the experiment had loop Velcro, allowing Fungilainen cards to be attached. The avatar gained magical powers when the player attached the card to the jacket as instructed by the game. When gaining a new ability, the screen displayed animations and sounds of mushrooms growing on the avatar's body. In the game, players collected and used the Atomic Mushroom to create an explosion, the Mirror Mushroom to reflect the enemy's magic, and the Magic Mushroom to confuse the hostile monster.

(3) *Inputs* are a tactile gaming wearable mounted on the player's body, allowing the players to perform tactile in-game interactions on their body. Two different types of Inputs were used in this prototype. One was a hand crank, reminiscent of a fishing reel. It was tied to the participant's arm using an elastic band. The test participant performed a fishing quest in the game by rotating the crank by hand. Another prototype was a piece of faux fur that could be attached to the jacket with Velcro. Participants were asked to soothe the imaginary animal by gently stroking the fur by hand.

(4) *Tangicubes* were cubic gaming wearables of approximately 2 cm^3. In teraction occurs when the player performs certain bodily actions while holding a Tangicube. In this experiment, when the player held a red Tangicube and made a drinking action, the avatar drank a health remedy potion. If the player threw a green Tangicube, the avatar threw a hand grenade. During the experiment, the Tangicubes were attached to the participant's left upper arm. When directed, the participants detached a Tangicube and used it.

In Session I, players gained the above wearables as game items that were distributed by the experimenter during real-time gameplay. The players then used the items to perform designated operations such as casting a spell.

3.1.2 Session II. The second set of wearable prototypes was designed as one central device, that is, the *Core Watch*, which was coupled with several different peripheral attachments. The Core Watch was envisioned as an informationally and functionally centralized wearable that could also be used in a daily context, such as a smartwatch in this specific design. In the experiment, it was a multi-functional, polymorphic gaming wearable that provided versatile in-game interactions. The

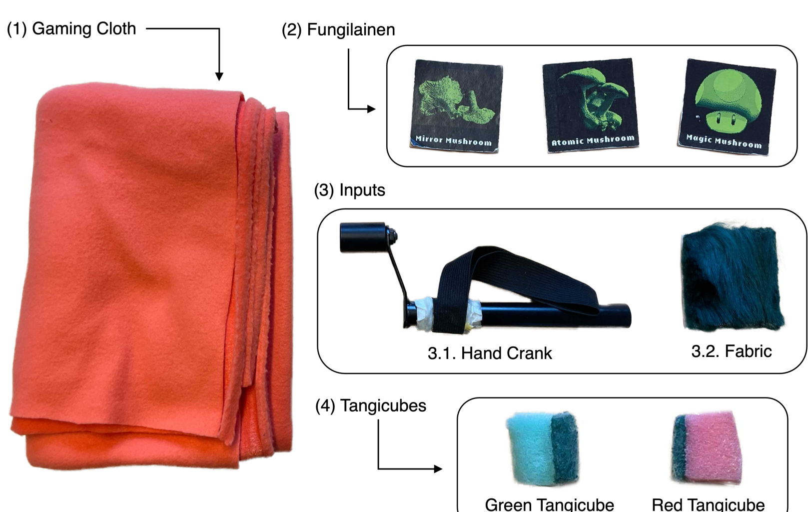


Fig. 1. Experience prototypes for the first user experiment session

assembly design of the Core Watch allowed flexible adaptation to diverse game genres and contents through a quick and simple composition of the core device with the other external gears. In this use experiment, we combined a wood cube with a rubber wristband using Velcro to resemble a watch-like wearable device. The top surface of the cube also used a Velcro strip for quickly attaching and detaching removable parts. Meanwhile, four different attachments were prepared, as shown in Figure 2:

(1) *Gauntlet.* A foam-made plate (approximately $15cm \times 7cm \times 1cm$) with a Velcro strip glued on the top surface. It is described as a panel-like extension that can be mounted directly on the surface of the Core Watch, on which removable parts such as "skill bits" (two sponge cubes, $3cm \times 3cm \times 2cm$) can be docked. It can be typically used as arm-mounted equipment for motion-based gameplay. The Core Watch was supposed to encapsulate all the basic sensors, such as an inertial measurement unit and a vibration actuator. Possible usage includes a shield in RPG games or a racket in sports games.
(2) *Glove.* A ready-made glove with a disposable heating pad inserted on the palmar side. To use the Glove, users detached the Core Watch from its wrist band and adhered it to the dorsal part of the Glove. In addition to finger tracking and gesture-based interactions, the disposable heating pad was also used to simulate thermal feedback to sensitize participants to wearables' potential to provide feedback other than vibration. The thermal interaction was designed so that participants would feel more heat when they pressed their hands together, and we designed game sequences that would correspond to increasing heat.
(3) *Staff.* A 75-cm wood stick with foam wrapping around one end, to which three different colored beads (red, green, blue) are attached. When used, the Core Watch is mounted on the top of the staff. Beads on the staff were used to simulate LED lights. During the experiment, they also acted as touchable "buttons." Because of its shape, the staff can be used as a saber, a cane, a magic wand, a stirring stick, or even a key.
(4) *Headband.* Similar to the wristband, a user could simply attach the Core Watch to the rubber headband and wear it on their forehead. The Core Watch was described as having sensors for brainwave detection as well. Given the technical restrictions of current wearable electroencephalogram (EEG) technology, the participants were informed that the headband was only for entertainment purposes and had limited accuracy compared with medical-level equipment.

Each extension was tested in a separate video game categorized in one of four different genres. The games included three self-developed demos and one online open-source game (see below). These games were selected to both exemplify a typical video game setting and use scenario and facilitate testing the target design themes without excessive difficulties in simulating users' operations under the practical limitation of the WoZ method. A participant, in turn, experienced all four games, with a short how-to-play explanation by the experimenter prior to each game. The player's journey began with wearing the Core Watch on their wrist. Next, they were asked to attach the first extension, the Gauntlet, to the surface of the Core Watch. There was no explicit restriction on the gameplay time, and the participant was encouraged to play as long as they fully grasped the ideas of the wearables and intentional interactions. After playing the first game, the player was then asked to take off the Gauntlet, remove the Core Watch from the wristband and attach the Core Watch to the Glove. A new heating pad was inserted into the Glove for each participant. Similarly, the player attached the Core Watch to the staff and headband to play the third and fourth games. The overall gameplay time lasted approximately 12 to 20 minutes. Detailed in-game interaction for each game is described below:

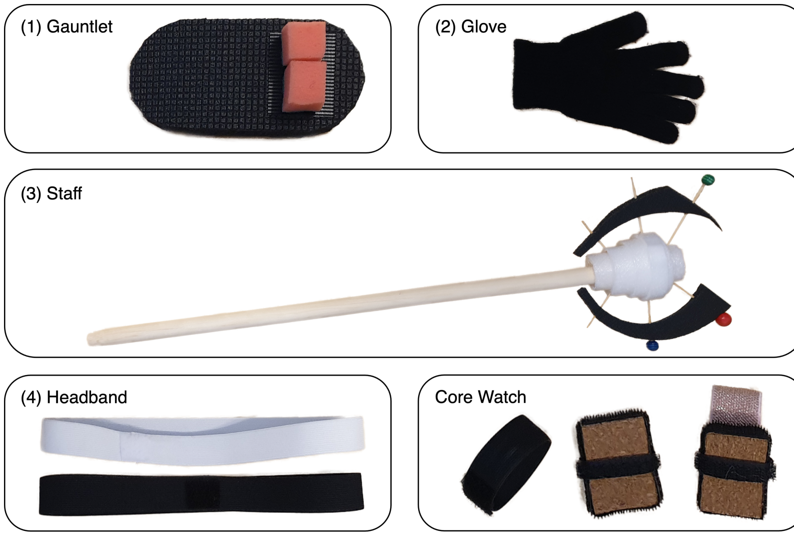


Fig. 2. Experience prototypes for the second user experiment session

(1) The first test game was adapted from a game many participants were familiar with, a ***Brick Breaker*** game. This specific game was selected and designed to showcase the embodied interaction and movement-based control introduced into a conventional video game context. Instead of mice and keyboards, the player was asked to equip the Gauntlet on the Core Watch and then swing their arm at the right time to activate a bar on the bottom of the screen and bounce back a dropping ball. While the player can move the bar left and right to catch the ball in the original game, a full-length bar instead appears each time the player swings their arm and disappears after 0.5 seconds. A "superball" mode was triggered when the player removed and threw the skill bits attached to the Gauntlet, in which the ball was enlarged and able to punch through the bricks for a brief moment.
(2) The second game, ***Gesture Ninja***, was a turn-based RPG using gesture control, the original franchise of which stemmed from the famous Japanese animation, *Naruto*. The player character was a young Ninja who had encountered an enemy soldier and started a battle. In each battle turn, the player needed to complete a sequence of different gestures within a designated time limit of 5 seconds to successfully cast a magic skill, or "Ninjutsu." Specifically, the gestures were designed so that the player needed to press their palm when casting a fire Ninjutsu, thus the heating pad inside the Glove would generate a clear heating-up feeling. If the player failed to perform the right gestures or exceeded the time limit, the game would fail, and the player had to re-challenge the gestures.
(3) In the third game, ***Sigillis*** by JUSTCAMH (https://justcamh.itch.io/sigillis), the player was first asked to combine the Core Watch with the staff to form a "magic wand." Enemy soldiers, represented by different symbols in different colors, would move from the corners of the screen toward the center to attack. Before the player's hit points ran out, they would need to switch to the same color as the enemy by touching the right bead on top of the wand and then using the wand to draw the shape of each enemy's symbol in the air to eliminate that enemy.
(4) The last game is a social or party game where multiple players compete in an ***EEG Tug of War*** by creating facial expressions according to the game's instructions (including happy,

sad, angry and anxious). For this purpose, players attached the Core Watch to the headband to locate the device in the center of their forehead. Because only one participant was present in each experiment section, one of the experimenters would play as the opponent in this game. Meanwhile, the other experimenter would judge how exaggerated the facial expressions of both players were and move the tug-of-war rope accordingly.

Information about the prototypes, test games and the corresponding design themes is summarized in Figure 3. Although concrete experience prototypes were described above, the discussion is not necessarily confined to the specific forms or implementation. Rather, the experiment participants were directed to be aware of and concentrate on the underlying core values that the overall gaming experience tried to convey: active bodily engagement, versatility in applications, body surface as interface and gamified daily context. Based on these core experiences, participants were encouraged to associate their individual experience with extended usage and application scenarios beyond the predefined test games and further elaborate on why a certain design appealed to them or not.

3.2 Experimental Setup and Process

All 15 user experiments were conducted in a laboratory environment, with each participant assigned to a one-hour slot to finish two experiment sessions with interviews after each session. We counter-balanced the sessions to eliminate possible bias due to the experimental sequence. Before each experiment, the participant was asked to sign a consent form saying that they acknowledged the video and audio recording during the experiment and the use of their experiment data for academic research purposes. Each participant received a movie ticket as compensation for participating in the experiment.

Test games in Session I and II were run on two laptops (Apple MacBook Pro, Fujitsu Lifebook) and controlled using keyboards and mice by two experimenters to simulate participants' operations. An XGIMI beam projector was connected to the laptops, and the game scenes were projected and displayed on a wall in front of the participant. To ensure the best display effect and prevent participants' attention from being distracted by the surroundings, the lights in the laboratory were turned off before each game session began and on when the session was over and the interview started. Participants' movement during the gameplay was video recorded using a Sony A7 Mark III fixed on a tripod and located at the corner of the room; an Apple iPhone 6S Plus and a Samsung Galaxy S9 were used to record the interview audio. The participants were told that they could choose to either stand or sit on an office chair to play the games. During the gameplay, they were encouraged to perform the "think aloud" [40] strategy to better disclose their opinions. They were also told to ask questions whenever they felt confused about the use of the gaming wearables. A semi-structured interview was conducted after each session, and questions concerning the participant's overall gaming experience during the experiment, opinions on wearable prototypes as well as specific design themes were asked. Interview questions are listed below in Figure 4.

3.3 Participants

Experiment participants were volunteers recruited from across the authors' institution, most of whom were university students and staff. Prior to the user experiment, volunteers were asked to fill out an online application form that collected information including age, gender (as recommended in the Guideline G3 of [61], open-ended text boxes were used to collect gender data) and individual experience specifically regarding gaming and wearable devices. In total, 15 participants took part in the study (eight women, seven men). The average age of the participants was 26.7, ranging from 20

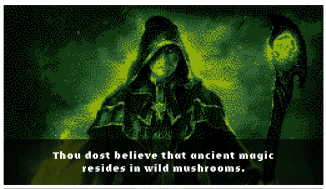
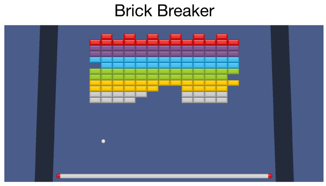
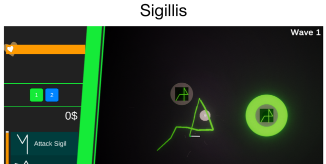
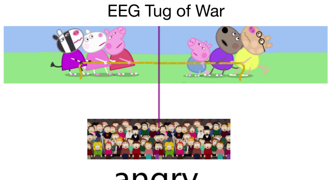
Session I				
Prototype	**Game**	**Development Platform**	**In-game Interaction**	**Tested Theme**
Gaming Cloth	Dungeons and Goblins  	Keynote	Covering Body with Gaming Cloth, Covering Nose and Mouth with Gaming Cloth, Wrapping Arm with Gaming Cloth	T1, T3
Fungilainen			Picking up Fungilainen Cards, Attaching Fungilainen Cards on the body, Showing Fungilainen Cards to the Screen	T1, T2
Inputs			Attaching a Crank on the Arm, Winding up Crank, Stroking a Furry Fabric attached on the Arm	T1, T2, T3
Tangicubes			Throwing a Tangicube, Holding a Tangicube close to the mouth	T2
Session II				
Prototype	**Game**	**Development Platform**	**In-game Interaction**	**Tested Theme**
Core Watch + Gauntlet	Brick Breaker 	Unity	Swinging Arms, Throwing Skill Bits	T3, T4, T5
Core Watch + Glove	Gesture Ninja 	HTML5	Hand Gestures	
Core Watch + Staff	Sigillis 	Web Open Resource (https://justcamh.itch.io/sigillis)	Drawing in the Air, Touching	
Core Watch + Headband	EEG Tug of War 	HTML5	Facial Expressions	

Fig. 3. Table of Experience Prototypes and Corresponding Games for Test

Interview Question	
Session I	***Session II***
Q1. How was your overall gaming experience?	Q1. How was your overall gaming experience?
Q2. What do you like and dislike about the game? why?	Q2. Which game do you like and dislike the most? Why?
Q3. What is the game item you liked the most and why?	Q3. What do you think about the daily usage feature of the prototype?
Q4. Do you have any idea to improve gaming items you used?	Q4. What do you think about the feature of thermal feedback?
Q5. Do you have any further comments or questions?	Q5. What do you think about the overall assembly design for versatile applications?
	Q6. If the prototype was a real product, how much are you willing to pay for it?
	Q7. Any further comments of advice for improving the prototypes?

Fig. 4. List of Interview Questions Asked in the User Experiment

to 38. The participants reported diverse gaming experience: five people claimed themselves as casual players, five as hardcore players and three as non-players with no game playing experience. Two people did not answer the entry survey. The average gaming time was 5 hours/week. Four people reported having related experience with wearable devices, and nine had no wearable experience. Two people reported playing games using wearable devices, explicitly with VR headsets.

3.4 Data analysis

The audio recorded during the experiment was transcribed using an automated service[2]. Then, the files were divided among the authors and checked one by one to spot errors in the transcription and to familiarize themselves with the data. Following, two independent coders used a qualitative analysis software, MaxQDA[3], to conduct open coding as suggested by [67]. Both coders' results were compared, and conflicts were resolved with the involvement of the third author via group discussion and negotiation. The coding was done according to the conventions of inductive reflexive thematic analysis [8]. Specifically, all authors coded the first three interviews and discussed the coding scheme that emerged. After the coding scheme was established, two coders independently coded the data and added subcodes as they emerged. The resulting code set included 285 codes.

This study aimed to generate a designerly understanding of the user data. Thus, although we adopted steps from the inter-rater coding [9] thematic analysis approach, it was more to have a shared understanding of the data as a design team rather than to provide a bias-free objective understanding as in the usual practice. In that sense, our epistemological stance does not contradict the reflexive thematic analysis [9] conventions because we did not simply rely on inter-rater scores but discussed every interview with three authors to develop a shared interpretation of the data.

The coding process, as seen in Figure 5, followed the process of open, axial and selective coding [67]. As the design team, we maintained the granularity and details in our first pass by inductive open coding. After the open coding, we moved to the axial coding stage, where we grouped these codes under similar themes with an affinity diagram [43]. The affinity diagram resulted in 21 main topics and 67 sub-topics (Figure 5 - a). Certain topics, such as daily usage or multi-sensory feedback, presumably emerged because the study aimed to collect information about these specific themes. To better understand the prevalence of these themes, we revisited the data and, using the code relations

[2]https://www.temi.com
[3]https://www.maxqda.com

matrix function of MaxQDA, created a thematic map of connections between the main themes (Figure 5 - b). After streamlining the map to the strongest connections based on the frequently overlapping codes (e.g., focusing on codes that overlapped in the interviews of more than eight participants), we created the second version of the thematic map (Figure 5 - c). We extracted every quotation that corresponded to these overlaps, and the three authors examined each quotation to draw insights. Then, we again discussed and highlighted the recurring and unique patterns across different theme connections and started the selective coding phase. In this stage, by examining the connections between the strongly interlinked themes and the quotations related to them, we extracted five main themes that are presented in the form of design implications in this paper (Figure 5 - d). This thematic analysis process is shown in Figure 5, which gives an overview of the whole process. The supplementary material provides a detailed unpacking of the process with high-resolution pictures.

The thematic analysis process also needs to acknowledge the standpoints and perspectives of the analyzers [9]. The design team that analyzed the data is comprised of three designers. One designer is a Ph.D. student with an industrial design background and UX design experience, and one is a postdoctoral researcher with research experience in interactive systems and industry experience in game development. The final analyzer is a postdoctoral researcher with nine years of experience in playful wearable design. The implications and recommendations generated based on the user data have been shaped by the perspectives and vision of analyzers.

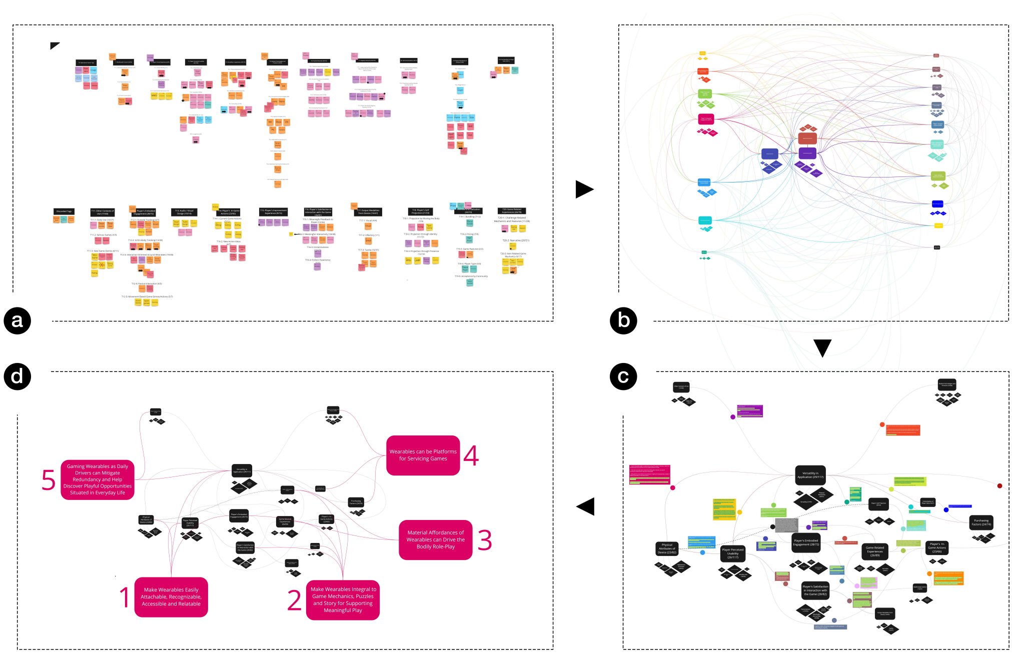


Fig. 5. The process of thematic analysis: a) generating main topics and sub-topics by reorganizing the codes through affinity diagraming, b) revealing the connections and intersections between these topics using MaxQDA's Matrix of Code Relations, c) Streamlining the data in a way that would show only the strong connections, d) Generating five main themes after re-examining and reflecting on the quotations attributed to strong connections

4 DESIGN IMPLICATIONS

Here we introduce design implications extracted through the thematic analysis of the semi-structured interviews. In this section, each implication is explained around the smaller themes that give a detailed account of users in our study with example quotations. Later, we examine each implication in relation to the existing work, previously coined theories and design knowledge to articulate the parts that add to the previous studies, possible contradictions and confirmations. Finally, we conclude each design implication with actionable recommendations that designers can directly apply to the design process. The design knowledge conveyed in this chapter conforms to the expected dimensions from design implications, such as being generative, inspirational, based on data, actionable and in relation to the extant literature [59].

4.1 Make Wearables Easily Attachable, Recognizable, Accessible and Relatable

This implication concerns designing usable gaming wearables that can be seamlessly integrated into the gameplay. The main findings that led to this implication were the importance of ***easy attachability*** to body surface, recognizable ***tactile and visual design*** and ***relatable mapping and accessibility*** to body locations.

Many participants expressed that using the body as a surface to store wearable items and designing wearables that are easily attachable to the body can both be enjoyable for players and prevent possible inconvenience when the wearables are not in use. For example, *Gaming Cloth* has been praised for the cleverly designed diversity; however, it has been found bulky and redundant when it is not in use (P14 - *"...cloak was fun. I just should have actually made it into a cape or something so it would feel more real. But I was just holding it in my hands, and that ... killed the mood a little bit."*). Similarly, we needed to store the additional *Inputs* modules when they were not in use. Designing better attachable features was recommended by players, and being able to attach and store items on the body was also found enjoyable (P15 - *"Actually that potion [Tangicubes] was the best... I do like the idea of storing an item on your body and being able to use that."*). Creating body surfaces that enable easy attachment and detachment would allow wearables to contribute to versatile interaction with games.

Attachability, however, should also be supported by allowing players to *recognize* different types of wearables placed around the body. A few players expressed the importance of recognizable materials, while some commented about the body location where wearables were attached. Although several players reported that attaching wearables to the body was useful, they also faced problems while using *Fungilainen's Mushroom cards* or the *Tangicubes* cubes because they could not easily recognize which specific item needed to be used. This was partially caused by some in-game actions that were found irrelevant to the items they mapped and partially caused by the hard-to-recognize tactile and visual properties of some items. For example, *Fungilainen's cards* were attached to the player's chest area, which meant the player had to look away from the screen to identify the correct card. P18 said, *"...if it asks me to throw a mushroom and then I have to look for the card, and then it doesn't make that much sense ... So if I would see an actual mushroom and could take it and throw it, then that would be great."* Depending on the body parts to which these wearables are attached, the material properties play an important role in uninterrupted gameplay. If they are placed on a less visible body part such as the chest like *Fungilainen's cards*, tactile or auditory qualities need to be carefully designed, and the information they hold might be low in complexity. If they are in more visible parts, such as the forearm, they might carry more complex information (e.g., health level, inventory items), and the visual properties could be more important.

Another point about better recognizability raised by many players was the meaningful mapping of items to different body parts, game actions and the consideration of accessibility of the body parts.

More relatable mapping and accessibility to body parts were deemed important considerations for seamless gameplay (e.g., mapping arrow selection closer to a player's back, which is a common place to store arrows). For example, P18 said that she liked the throwing part, but then she thought that the *Mushroom cards* simply did not make sense the way *Tangicubes* did for this action. P24, by addressing the body locations to which items can be attached, said, "*It'd be good to have it on both sides [of the body], to attach the thing... And if you want it to have more possibilities, you could have one on the shoulders, too.*"

4.1.1 Discussion. Wearables are one of the primary topics of ubiquitous computing and calm technology principles [66]. They were originally positioned as interfaces that do not interfere with users' attention, and being available only when needed was considered important. However, current paradigm shifts in human–computer interaction (HCI) suggest that engaging ubiquitous computing does not only answer the needs of users but also cultivates creativity and playfulness [57]. Compared with wearables for other purposes, gaming wearables may possess more dynamic than calming interactions. As exemplified by concepts such as *Gaming Cloth* or *Tangicubes*, while playing games with wearables, players may need to interact with wearables frequently, dynamically, at a fast pace and in diverse ways.

Attachments, placement and accessibility, revealed as important dimensions in our study, are also critical aspects of wearability [23][4]. Wearability guidelines suggest that wearables need to be designed in a way that would provide convenient attachment to the body. The attachment systems should accommodate different sized equipment and be stable. These recommendations also seemed applicable and relevant for gaming wearables. However, gaming wearables differ from conventional wearables in how they are used during gameplay. The user elicitation study with our experience prototypes suggests that the interaction with wearables can be quite dynamic and versatile. Players attached, detached, threw, reattached, and changed the location or the fitting (i.e., different ways of using *Gaming Cloth*) of the wearables. *Thus, our study adds and highlights an important difference between gaming wearables and wearables designed for other purposes. While wearables are usually designed to stay stably on the body, for gaming wearables, attachment design should not only lead to stability but also allow dynamic interaction and versatility where wearables can be frequently detached and (re-)attached.*

The placement dimension of wearability guidelines suggests that areas with similar size, low movement and flexibility with a larger surface area are more suitable for placement of wearables. In the context of gaming wearables, another consideration for the placement is the mapping of the in-game action. For example, if the wearable directs the player to shoot an arrow, it might make more sense to place the arrow selector closer to the shoulders, while a wearable piece mapped to a sword can be placed around the waist. A study by Buruk et al. [12] suggested that mapping wearables to different body parts can create affective relationships with in-game characters. *For this reason, appropriate mapping, apart from creating this affective connection, can also help with quick, easy and usable interaction with gaming wearables.*

Finally, a study by Tanenbaum and Tanenbaum [63] proposed using wearables as buttons or switches scattered around the different locations on the body surface to guide a variety of body postures. The concepts of *Fungilainen* and *Tangicubes* were aligned with this idea. Testing these wearables showed that, although using the body surface in a versatile manner might create richer in-game interactions, the physical design of wearables in terms of material, texture or color should support these mechanics for uninterrupted gameplay. *Therefore, while designing wearables that can*

[4]Wearability guidelines include 13 dimensions such as proxemics, sizing or thermal. However, we only focus on three of the 13 because the evaluation of other guidelines is neither relevant nor possible with low-fi experience prototypes

be used as bodily buttons or switches, visual, tactile, auditory or kinesthetic access [69] to different body parts should be carefully considered and tested.

4.1.2 Prescription.

- Consider the body as a surface where in-game items can be attached to increase bodily engagement and immersion.
- Design easy attachment and detachment mechanisms for accommodating dynamic and fast-paced placement of wearables on the body.
- Be mindful of the meanings and accessibility of the different body parts to provide more usable interactions.
- Experiment with the recognizability of the devices through visual and material modifications.

4.2 Wearables Could be Bodily Gateways Opening to Mechanics, Puzzles and Story for Supporting Meaningful Play

Wearables can be elements that connect specific parts of the body to the game content and allow using different body parts to interact with the game beyond movement. Most participants expressed and created ideas regarding how gaming wearables can be integral parts of game design by making critical information discernible, being elements of *puzzles or challenges* and contributing to the feeling of *self-improvement* through role-playing and stories.

Using wearables as an active part of in-game puzzles or challenges can lead to meaningful bodily play. Players especially appreciated the *Inputs* concept that needed different types of attachments to progress in the game. For example, P26 said, "*The crank is useful in many, many ways, for example, if you need to lower or draw a bridge or open a valve or something like that.*" Also, players found it enjoyable to use *Tangicubes* as an in-game item or configure the *Gaming Cloth* in different ways to gain abilities and progress in the games. It prompted a possible use of wearable controllers to design game mechanics that use information, such as the wearables' location on the body or different types of form factors (as in the *Gaming Cloth*) to progress in the game.

Another way of integrating wearables into game design is to use them for ***critical in-game feedback.*** Our questions regarding the thermal feedback (Session II, Q4) opened the discussion on how different types of tactile feedback can be relevant to gameplay. While visual and auditory modalities are frequently used for this kind of critical information, we have also witnessed the emerging commercial-grade haptic feedback coming into play. Games, especially on console systems such as Nintendo Switch or Playstation 5, have introduced advanced ways of using these types of feedback, that try to reproduce the physicality of the imaginary world of games in the real world. Our study tried to expand the boundaries of tactile modalities with temperature feedback. Although players found this addition had the potential to add to the overall experience and immersiveness of gameplay (P21 - *"I really felt like I was in there almost with the feedback of hot and cold."*), a few players also demanded the exploration of ***better integration with gameplay scenarios*** (P27 - *"Oh, I guess when you're dying in the game, you would be close to red, and when you're kind of healthy maybe, I don't know fresh or, no, you don't feel anything."*). In this sense, one way to integrate wearables into meaningful play is by using body-integrated feedback to make in-game events discernible.

Some players also commented on the use of wearables to induce a feeling of ***self-improvement*** both for players' own and their character's skills. In a previous study, Jung et al. [33] suggested that the attachments to the body can activate specific skills for in-game characters. The players in our study stated that the addition of these skills could be perceived as self-improvement both by the direct growth of in-game character and a reflection of improved gaming skills. Some players found upgrading the abilities of the character or activating power-ups by using wearables pleasant

(P30 - "*... and then you need to wrap [Gaming Cloth] around your wrist as well. That it gives you extra strength. I find it really nice...*"). Several other players favored games in which they believed they could improve their skills (P16 - "*When you play games, you get points, you might get some kind of type of adventure, or you're going to succeed in them. That gives the reward. But, getting better by yourself too [gives the reward].*"). Thus, gaming wearables can be effective for inducing a sense of improvement by progressing *Skill Bits* concept introduced by previous studies [33]. However, the game mechanics around these wearables should be designed in ways that will improve the physical, mental or social gaming skills (as also defined as one of the elements of game mechanics by Schell [60]) of players, especially for challenge-based or competitive gaming.

4.2.1 Discussion. Wearables have been suggested to enhance the immersiveness of games, especially by fostering the relationship between the imaginary character and the player by being perceived as character costumes [14]. Their value regarding the diegetic positioning (being embedded in the fiction [36]) in the game world to foster the immersion has been a subject of several projects [1, 32]. However, those studies focused on the self-expression, character identity and costuming characteristics of wearables. Participants' comments suggest other ways of altering the diegetic roles of wearables and related interaction modalities leading to meaningful play [58]. Turning a simple cloth piece into a magical in-game item in the *Gaming Cloth* or enhancing the sensory experiences with temperature feedback in the *Glove of Core Watch* revealed novel ways of integrating the body into games that go beyond the theories such as "Körper" and "Leib" that focus on sensations and capabilities of the body [48]. Our observations show that wearables can help integrate the body to games beyond movement by turning parts of the body into controllers, which can be interacted with through different modalities such as touch and tangible. They also can strengthen the feeling of character and self progression in games by forming a bodily connection. This corroborates with previous studies that speculate that wearables can help with character identification [14] and affective relationships [12] with characters. Our finding also adds to those studies by proposing progressing in the story, passing the levels of the game, and bodily identification with the progression of the in-game character.

In terms of bodily sensations, apart from "cosmetic effects" (with the words of P16), players have indicated the importance of integrating wearables as a part of the meaningful play. Meaningful play in this sense can be considered in a more evaluative way by focusing on the qualities of *discernible* and *integrated* [58]. Apart from becoming additional interface elements, wearables can communicate critical information by adding to *discernible* features that can affect the overall game design and become *integrated* (e.g., programming temperature feedback to inform about incoming enemies). *Our study suggests three directions to involve wearables in the meaningful gameplay: First, they can be integral parts of the puzzles and challenges that progress the game; second, they can expand the capabilities of bodily feedback to make in-game events discernible; third, they can contribute to the sense of self-improvement both in and out of the game.*

4.2.2 Prescription.

- Consider the bodily feedback as part of the meaningful play by thinking about the integrated and discernible roles of tactile cues such as temperature feedback.
- While designing game mechanics, different relationships between different wearables and body parts can be considered as part of puzzles and challenges (e.g., wearing an item on the head for a flashlight or the obligation of quickly swapping an item between body parts).

- Consider how wearables can reflect the improvement of in-game characters to the real body and skills of the player.

4.3 Material Affordances of Wearables Could Drive Bodily Role Play

Altering game mechanics and actions depending on the ***material affordances*** can guide different types of body movements. The best example in our study is the utilization of *Gaming Cloth* as an invisibility cloak. To activate invisibility, players need to cover their whole body with the cloth by hiding behind it. This simple interaction creates many other dynamics, such as a crouching posture for the body and the configuration of the wearable as a blanket that covers the player. When the head is also covered, the obstruction of the screen creates dynamics such as slightly uncovering the eyes to check what is going on in the game. The requirement of hiding under the blanket created many other sets of actions that can turn this simple action into a theatrical performance. P26 noted, (*"...the way I was forced to interact with the game. It felt like more theatrical than, I don't know, what I'm used to. Like hiding under the cloth, for example."*). Other bodily interactions, such as rolling the crank, soothing the otter or throwing the cubes, also exerted and moved the body in a way that absorbed the players into the game, according to several players (P18 – "*I think it was really fun to do the throwing parts and stuff like that ... if I was just pushing buttons, it probably wouldn't be exactly the same. So there wouldn't be the athletic part."*).

4.3.1 Discussion. Previous studies claimed that the wearables could create affective connections with the characters by facilitating somaesthetic experiences through subtle guidance [12, 28]. Users indicated that wearables facilitated specific types of movements and postures, which corroborates this information. Our study suggests that player actions induced by playful wearables led to an enhanced role-playing experience through guiding different varieties of movements and postures. As interfaces related to self-expression, wearables can lead to performative in-game actions [20, 32]. These performances can especially be beneficial to sustaining attention to the gameplay in social settings [14]. In our studies, the material affordances of wearables (e.g., the softness and flexibility of the textile in *Gaming Cloth*, the furry texture of a module in *Inputs*) and the game actions configured around them led the players to interactions they described as "theatrical performances." They both created an imaginary connection to the avatar because they were perceived as costumes and guided the body movements and feelings through tactile cues, bespoke interactions and placement on different body parts. *In this direction, designing gaming wearables by considering their costume-like qualities has been already addressed by several previous studies [13, 30]. We add to these findings by suggesting that bodily reactions stemming from material features, such as flexibility, softness or texture, can also play an important part in bodily role play and theatrical performances.*

4.3.2 Prescription.

- Think of designing wearables in ways that can facilitate theatrical bodily actions through their material affordances such as softness, flexibility or texture.
- Try to form relationships between the look-and-feel of wearables and the body movements that they facilitate for an improved role-playing experience.

4.4 Wearables Could be Platforms for Servicing Games

One discussion point regarding "wearables as service" was about the ***downloadable contents (DLCs)***, which was prompted by our question regarding modularity (Session II, Q5). One participant worried that such gaming wearables could be sold with diminished features, and a full experience can only be reached with additional modules (P21 - *"...modularity has become a huge problem because it becomes like a DLC in physical life. Like, if you want to play one game, you have to buy loads of* *stuff for this."*). Another participant emphasized that even if the wearables adapt to different games through different modules, the base module should provide a satisfying experience for reaching a wider target audience (P14 - *"...for example, with Wii, you just have this one [mimicking holding a Wii Mote], and with that, you do pretty much everything."*). Most participants deemed the main advantage of modular design as wearables' ability to adapt to different kinds of functions, allow involvement of different body parts in the game and adapt to different games and actions. We previously saw that game consoles such as Nintendo Wii produced different types of extensions for adaptability to different game genres (i.e., steering wheels, weapons, swords). These additions, however, have never been obligatory but are rather positioned as extensions that improve an already-satisfying player experience. Thus, although gaming wearables, as in the example of *Core Watch*, can be extended to other controllers, props and environments, the base device should be designed to provide a rich versatility in terms of adaptation to different games, game actions and body parts.

Another discussion point under this theme was regarding increasing ***wearables' role in a bigger gaming ecosystem***. Many participants mentioned the utilization of our prototypes in the context of extended reality applications. One participant put forth a vision where wearables can become the main computing devices with which the majority of our daily interaction with computers can happen with the advancing game streaming services (P26 - *"...I know so many people who use [wearables] in very many different ways. So why not gaming? And because the consensus seems to be that the gaming's future will be in streaming, then, the different platforms will lose their importance."*). P16 proposed adding an extra display to the *Gauntlet of the Core Watch* for more detailed interaction with games, such as the management of inventory. Ideas regarding the positioning of wearables in many different ways and in relation to many other devices suggest platform independence. Wearables, being light, attached to the body and always around, could be considered capable nodes that carry game and player information across places, games, devices and body parts. Specifically, with the widespread use of game streaming technologies, wearables' ability to present game content that would change over contexts, locations, bodily interaction and connected devices might be their strong suit.

4.4.1 Discussion. Currently, it is increasingly common to implement features that require further payment from users to see the full content of the game or increase their performance to compete with higher-level players. These features usually are considered in the scope of "games as a service" [18] and are called downloadable content, in-game purchases or micro-transactions. These features have turned games into services where monetization relies on the continuous engagement of players. Although they can be suitable for certain types of games, such as massive online games, they are also perceived negatively by the players when the core and the additional content are out of balance [68], and they are considered one of the dark patterns in game design. Our tests surfaced that the modular design of wearables, in addition to improved adaptability and scalability, can also lead to practices that exploit players' desires for novel gaming experiences. We have identified some of the ways in which wearables can be integrated into game mechanics and mainstream gaming. Our implications hint at desirable playful experiences through wearables and ethical design practices. Designers and developers should be mindful of providing core features that can offer those experiences in a satisfactory way. Additional parts of modules can expand the game experience but should not be a prerequisite for fully enjoyable gaming moments. *Our findings indicate that when positioning a wearable as a gaming wearable, even if its features compete with other regular wearables such as smartwatches, the core device should facilitate interaction with a variety of game genres and interaction modalities. Additional modules for different games would be welcome as long as the core device induces a satisfying gaming experience.*

Another concept is the migration toward cloud-based systems (such as GeforceNOW[5] or Google Stadia[6]) where games can be streamed to users who do not have systems with powerful processing and graphic power. Wearables, similar to other mobile devices, can be a subject of these kinds of services. A strong part of wearables, compared with other types of devices, is that they can add the bodily aspect to streaming services. The movement, activities, locations or bodily data collected from wearables might be used as real-time gameplay elements (e.g., starting a streaming service when a player is in the real-life location of an in-game place and adorning the activity with gameful elements). *The smaller form-factor and the bodily interaction modalities exclusive to wearables can make them suitable candidates for servicing games with novel game mechanics integrated with bodily activities and mobility.*

4.4.2 Prescription.

- Players appreciate the modularity of wearables if it enhances the versatility in terms of applicable game genres and in-game interactions; however, be cautious regarding the negative aspect of "physical DLC."
- Wearables that are complementary to other gaming platforms, such as extended reality or traditional game consoles, can be a game service platform that interacts with those ecosystems.
- Wearables can provide alternative presentations for games by drawing on different locations and involvement of body parts across a variety of game genres and interactions.

4.5 Gaming Wearables as Daily Drivers Could Mitigate Redundancy and Help Discover Playful Opportunities Situated in Everyday Life

The Core Watch prototype and its modules were designed based on the Gaming Core concept of [33] for all-day usage. The question regarding the daily use (Session II, Q3) allowed us to explore this dimension in detail to discover design opportunities.

Several users mentioned that having their gaming wearables as regular smart watches or smart trackers would help with the possible feeling of ***redundancy of wearing them*** only while playing the game (P23 - *"Yeah. I think it's a good idea. And like comfortable not having to change between equipment."*). Another important point was that some participants considered having an integration to games as an **added value** to daily wearables (P21 - *"I use mine [smart watch] every day, and they are very useful, and the fact that I can just plug it out and use it for entertainment or some other perspectives, I think, it's now with that implementation, it has the potential to replace smartphones ."*). Redundancy and the effort of wearing items only for playing games could be eliminated by positioning gaming wearables as daily drivers, but would the overall interaction with gaming wearables be different than that with regular smart watches or trackers?

One example given by a participant was controlling the curtains in an apartment in a playful way with wearables. This is an indication that gaming wearables can also have value for non-game interaction (P18 - *"...controlling, for example, stuff in your apartment like curtains... you can point and do stuff like that."*). Although controlling smart home systems through wearables is currently possible with apps such as Samsung Smart Things [7], the addition of the playful layer gives hints about how the interaction between a gaming wearable and other connected devices could be different than other types of wearables. A gaming wearable could configure daily playful opportunities, for example, unlocking a smart lock with a specific knocking pattern, role-playing a wizard who can suddenly raise the smart blinds with a spell word and a gesture, or turning the house into a horror scene by flickering or turning off smart lights depending on the location of the

[5]https://www.nvidia.com/en-us/geforce-now/
[6]https://stadia.google.com/
[7]https://www.samsung.com/us/support/troubleshooting/TSG01003208/

wearer. This interaction with nearby devices could also be used for configuring the environment with gameful interactions. In the smart curtain example, the ambient light could be adjusted to follow gameplay scenarios or used as a pervasive game element by itself.

4.5.1 Discussion. Although wearables have the advantage of always being available and attached to the body, if they are not designed to be used throughout the day, the discomfort of wearing them may reduce their appeal to users. Previous studies suggested that wearables offered as part of a gaming system, like the markers for HTC Vive VR environments, were deemed a burden by players because they had to be worn in every game session [4, 16]. Drawing on this information, we speculate that wearables have the potential to both support gaming activities in daily life as well as remove the need to wear them only while playing games. *Designing wearables so they offer a seamless transition between in-game and out-game situations could help mitigate the burden of wearing them only for gaming moments and support playfulness in other aspects of daily life.*

Abandonment has been an issue for smart wearables and trackers, according to the previous studies [39]. Considering gaming wearables as a part of the daily interaction portfolio, as some participants considered them an added value, might decrease the abandonment rate by making wearables more effective with added gaming functions. Apart from integration to gaming, as also articulated by several participants, gaming wearables can form playful interactions with other objects outside of gaming contexts. This can also create opportunities to increase the play potential [5] in daily life by integrating wearables that can seamlessly add computational capabilities to the immediate periphery. This can also hint toward the use of existing smart wearables in creative ways (e.g., integration of force feedback [25], heart-rate display for games [54]) to foster playful moments in daily life. Based on the opinions of our participants and the literature on wearables, we infer that *a daily wearable designed to capture the playful opportunities in everyday life can render wearables more engaging and thereby decrease the likelihood of abandonment and the redundancy feeling when wearables are worn only during gaming.*

4.5.2 Prescription.

- Configuring daily uses for a gaming wearable can overcome the redundancy of wearing it only during gameplay.
- Adding playful features to existing wearables can diversify the ways of using them that may help with abandonment
- With the increasing presence of the Internet-of-things-enabled devices, wearables can translate the location, body movements or the biodaptive data of the users into daily playful interactions.

5 LIMITATIONS AND FUTURE WORK

As with other experience prototyping-based research, the experience prototypes and the WoZ method have some innate limitations. First, experience prototypes are usually not able to precisely present the product-level look and physical traits like weight or materials. We were not able to test features that may greatly influence the user experience of the final products. Second, testing with real-time action games would dramatically increase the hurdle for experiment operators to perform the WoZ method, as it entails immediate and accurate recognition, reaction or sometimes even predictions to provide in-time feedback to users' movements. Many participants also left negative comments concerning the EEG-based competition social game because they did not feel that the interaction was "meaningful enough" to them. This was because a function like EEG-based competition was more difficult to simulate than the other games. Some participants reported that they did not like the EEG tug-of-war game itself; however, they were able to imagine that the function could be useful in other gaming scenarios. Due to the participants' lack of deep engagement with the topic, we did not report any implications with potential bio-adaptive features involved, but we plan to explore it in future studies with high fidelity prototypes. Because the aim of our study was to extract preliminary user experience knowledge regarding playful wearables to guide the development of future high fidelity prototypes, we do not see this as a substantial drawback. Third, although due to the structure and nature of our study, the ideas and feedback given in our studies extended to a wide range of platforms (from VR headsets to portable game consoles), the prototypes that the participants experienced were screen-based games and tangible wearable devices. Thus, the experimental setup might have failed to generate ideas for other types of platforms.

As for the ethical aspects of the research, we were unable to include participants with minority bodies[3] in this user experiment, which is currently out of the scope of this study. The authors are aware of their obligation to increase the overall inclusiveness and equality of playable wearable design, and we plan to include a user group of people with minority bodies in the co-design and evaluation process of higher fidelity prototypes in our future research. Specifically, one speculative design direction is to investigate the possible compositions of gaming wearables and existing assistive devices like hearing aids, wheelchairs and such, as also suggested by some previous studies [15, 46].

Finally, we need to emphasize that this study aims to be exploratory, generative and inspirational rather than descriptive. None of our findings put forth claims of observable and measurable improvements in player experience; instead, the work suggests possible avenues where gaming wearables can advance the game design. In that sense, knowledge created in this study offers inspirational and contextual design directions but does not claim these are the only ways of designing gaming wearables. A similar research process with different games and authors with different backgrounds is likely to expand this field further.

6 CONCLUSION

In this study, we tested two different sets of experience prototypes of gaming wearables, designed based on the design themes and speculative concepts of Jung et al. [12, 33]. Our study included 15 participants and five prototypes in five WoZ simulated games in a one-hour session. In the following semi-structured interview, the user elicitation approach was utilized to probe user feedback on the design themes embodied by those prototypes. A rigorous thematic analysis was applied to the interview data that generated five design implications. We further solidified these design implications by scrutinizing them in a wider research context with reference to the overall body of literature, thus gaining a more extensive insight for guiding further design and development of playful wearables.

Our design implications suggest that 1) making wearables that are easily attached to the body, recognized and used seamlessly is important for smooth gameplay; 2) wearables can be positioned as physical items that can be a bridge among game story, mechanics, puzzles and the player's body; 3) material affordances of wearables can guide body movements toward increasing role-playing experience; 4) wearables can become game service platforms that can accommodate streaming services, player data and expansions to different games and 5) positioning gaming wearables so they can be used in daily life might help with the redundancy of wearing them only during gaming and help create and discover play potentials in everyday life.

With this study, we have examined recent design concepts of playful wearables under varied gaming scenarios. The first-hand user experience elicited will enhance the research horizon within this domain. The implications we extracted provide both in-depth information regarding the expectations of end users and players from the gaming wearables and pragmatical design directions that can be applied to non-game wearables to adorn them with the advantages of playful interactions.

We believe that our contribution will be helpful to researchers and designers in the areas of wearables, playful environments, extended reality, and games and play.

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