Towards the Next Generation of Gaming Wearables

Oğuz 'Oz' Buruk
Gamification Group, Tampere University
Tampere
oguz.buruk@tuni.fi

Mikko Salminen
Gamification Group, Tampere University
Tampere
mikko.salminen@tuni.fi

Nannan Xi
Gamification Group, Tampere University
Tampere
nannan.xi@tuni.fi

Timo Nummenmaa
Gamification Group, Tampere University
Tampere
timo.nummenmaa@tuni.fi

Juho Hamari
Gamification Group, Tampere University
Tampere
juho.hamari@tuni.fi

ABSTRACT

Recent studies on gaming wearables show that wearables can contribute to the gaming experience by bolstering performativity, facilitating social interaction, and accommodating distinct interaction modalities. Still, these studies focused on contexts such as role-playing, casual, or festival games. Stakeholder-oriented research that explores the integration of wearables for mainstream gaming platforms such as game consoles is scarce. To fill this gap, we have conducted an exploratory study through 6 participatory design workshops focusing on different aspects of wearables with 33 participants from different stakeholders. As a result, we have created fifteen design themes and three gaming wearable concepts that led to seven actionable design implications which can be adopted by designers and researchers for designing gaming wearables.

CCS CONCEPTS

• **Human-centered computing → HCI theory, concepts and models**; **Interaction design theory, concepts and paradigms**; **Ubiquitous and mobile computing theory, concepts and paradigms**; *User interface design*; **User centered design**; **Participatory design**; **Interface design prototyping**; **Ubiquitous and mobile devices**.

KEYWORDS

Wearables, Bioadaptive, Game Research, Movement-Based Games, Costuming, Role Playing, RPG, LARP, Virtual Reality, Game Controllers, Social Interaction

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1 INTRODUCTION

One of the first examples of wearable technologies was recorded in 1970: a gambling device placed in a shoe that helps its wearer to predict the outcome of a roulette game [47]. Since then, wearables have become a part of our daily lives in many different forms, such as smart glasses, activity trackers, even gadgets that help to measure brain activity. Yet when it comes to gaming, wearables are still inching towards their maturity. Most common wearables designed for gaming have been virtual/augmented reality glasses, and they have not expanded far beyond this point in terms of commercial gaming wearables. As a result, there is a dearth of knowledge when it comes to designing wearables. This is especially true for the mainstream gaming platforms of today and the near future, namely PCs, consoles, extended reality technology, and mobile devices. This study aims to take the first step towards exploring the design of wearables specifically targeted to mainstream gaming platforms through participatory design workshops. To that end, this study extends the knowledge created by previous studies of playful wearables which focused on contexts such as Live-Action Role-Playing (LARP) Games, festival games, tabletop role-playing games (TTRPGs), and indie games into the realm of mainstream gaming.

There have been several wearables designed specifically for mainstream gaming systems. One of the first examples is the Power Glove [16] which was released for the Nintendo Entertainment System in 1989. Although its purpose was to develop a wearable controller that can be adapted to various games, it was not a huge success due to its inconsistent movement tracking. The BCON, a more recent example, similarly tries to translate feet movement into keyboard commands [24]. Other popular examples of gaming wearables include Fallout's Pip-Boy [44], Pokémon GO Plus [40], and the Nintendo Labo Robot Kit [63]. The area of gaming wearables is still an emergent field, but these examples have attracted quite a lot of interest. For example, Fallout 4 Pip-Boy Edition was reported as the fastest-selling collector's edition in history [38], while the Pokémon Go Plus sold out at an unexpected rate according to Nintendo [61]. Still, commercial gaming wearables are almost limited to these examples. Most are merely props disconnected from the game content or used as supportive devices without a major effect on game mechanics and lack versatility [27]. Due to the emergent nature of the field, design knowledge for mainstream gaming wearables is limited. This necessitates the development of stakeholder-oriented design knowledge regarding how wearables can be incorporated in games by building on the strengths highlighted in previous studies [8]. It is important to note that this research does not aim to replace existing mainstream controllers but to explore the ways of designing these alternative controllers by understanding the unique strengths and features that allow wearables to improve player experience.

The strengths of gaming wearables were previously highlighted by several studies focusing on contexts such as festival games [1, 37], LARP games [17, 48] and TTRPGs [10]. Building on those, Buruk, Isbister & Tanenbaum [8] created a comprehensive *design framework for playful wearables* emphasizing (1) performativity, (2) socialization, and (3) interactivity as the strong parts of playful wearables. Previous research also indicates that wearables are suitable for (4) collecting biometric data [69] and (5) capturing motion, especially in mobile settings or settings with unstable lighting where optical tracking is problematic [5, 79]. However, previous studies have not discussed in detail how wearables can enhance the mainstream gaming experience by listening to players and other stakeholders. Thus, this study aims to explore the integration of wearables with mainstream gaming by building on the strengths of wearables indicated by the *design framework for playful wearables* and other previous studies focusing on movement and bioadaptivity with a participatory design approach. For taking the first steps towards generating participatory design knowledge in this topic, we conducted a rigorous participatory design workshop series consisting of 33 participants in six workshops focusing on the distinct facets of gaming wearables. Consecutively, these workshops focused on *interaction modalities in gaming wearables (INT), movement of body in games (MOV), social interaction through game wearables (SOC), bidoadaptivity in games (BIO), and costumes as game controllers (COS).* The sixth workshop, *the Fusion Workshop (FUS)*, grouped the participants of the first five workshops. Ideally, each group had a participant from each workshop and different disciplines and backgrounds (e.g casual or hardcore players, designers, engineers). As a result of this process, ***our main contribution*** is (1) practical *design implications* which are created through (2) *15 key themes* and (3) *five concept designs of gaming wearables* (three presented in the paper and two in the supplementary material) which were created through the participatory design process mentioned above.

2 BACKGROUND AND RELATED WORK

2.1 Movement in Games

The integration of player movement into games has been quite a popular topic in both games research and the commercial field. Its popularity in commercial games peaked with the release of the Nintendo Wii [60] and Microsoft Kinect [53]. In the current state, we still see occasional applications in console games such as Heavy Rain [66] and Super Mario Odyssey [62]. Moreover, body movement has been the main modality for VR games. Games research includes plenty of influential works that explore body movement in many distinct facets. One of the most well-known studies is by Mueller & Isbister [56], who put forth design guidelines for integrating body movement into games. This paper discusses concrete design strategies that can help designers to understand the affordances of body movement to be used in making games. Another work by Mueller et al. [55] examines a design space for social bodily play experiences which reveals the playful opportunities between bodies. Additionally, there have been many other studies that look into the effectiveness of body movements [35], embodiment [25] and experiences through movements [54], and the influence of a second body [57]. Apart from games, somaesthetic design also has a close connection with wearables and the body. Somaesthetic design fundamentally means the design of artifacts by considering the experiential qualities of the body [28]. It emphasizes the bodily experiences that will be created through movement or other modalities. In this sense, design of wearables are closely related to somaesthetic experiences. For example, wearable animal tails and ears designed by Svanes & Solheim [76] are interesting examples that extend the body with artificial limbs, altering the perception of wearers regarding the affordances, physicality, and movement capability of their bodies (e.g., moving hips in a way that will shake the tail). In our workshops, we explored the versatile relationship between wearables and movement to ideate their role in tracking and facilitating movement in contemporary gaming systems and to sensitize the participants to this subject area.

2.2 Interaction Modalities in Gaming wearables

Movement has been the dominant interaction method in gaming wearables. Previous projects such as WEARPG [10], Hotaru [1], Mister X [52], and Human Pacman [15] benefited from wearables being attached to the body which makes them easily portable and capable of tracking body movement. Still, wearables also hold the potential to introduce many different modalities by encompassing tangible parts [9], switches and buttons [34, 79], and displays [14]. "Design Framework for Playful Wearables" [8] comprehensively examined the potential interactive modalities of wearables on a spectrum of "peripheral" and "artifact-oriented" interactions. According to this framework, wearables can provide both embodied (i.e., gestures, body-data) and embedded (i.e., touch-screens, switches, buttons) interaction. In another dimension, interaction with wearables can be tangible with physical parts such as tokens or props or completely digital through sensors. Another point emphasized by the framework is that wearables can be designed to hide or show information by altering their placement on the body (e.g., inner/outer forearm) or through output modalities such as visual or haptic modalities. Another dimension of interaction is the level of connectivity between wearables and other devices, other wearables, or the environment. Interaction modalities mentioned here are well-studied in broader contexts such as embodied interaction [19], tangibility frameworks [30] and approaches [36], spectator experiences [68], Internet of Things (IoT) [3]. However, the utilization of those modalities for gaming wearables is still underexplored and requires further research. Therefore, the INT workshop aimed to explore these different interaction modalities and their effects on various game mechanics.

2.3 Social Interaction through Wearables

Wearables have also been known to facilitate social interaction between players. There are a few studies of wearables that have developed prototypes for enhancing social interaction between users. For instance, Enhanced Touch [75] is a bracelet that encourages users to get into physical contact by augmenting the touching experience with visual feedback. Contrary to physical interaction emphasized in this project, an example that does not require physical interaction is the Social Textile Shirt [39], which focuses on ice-breaking and verbal communication by displaying interesting images for starting conversations. When it comes to games, Firefly [83] and SW4LARP [34] explore the diverse characteristics of social interactions through wearables in LARP games. These studies were expanded by Dagan et al. [18] with a social wearables framework that draws upon the knowledge and hands-on experience gained from different wearables projects, including games. Wearables were also found to be capable of providing verbal, bodily, distant, and close social interactions in games in the design framework proposed by Buruk, Isbister & Tanenbaum [8]. These studies show that social interaction is an integral part of playful wearables but have not explored how to include these affordances in mainstream gaming. To that end, social interaction became a central theme in our workshops for further exploration.

2.4 Bioadaptivity in Games

Due to their autonomic nature, various physiological signals (e.g., heart rate, skin conductivity) offer an objective measure of the psychological processes of the player [64]. Nacke et al. conducted a comprehensive study on different types of biometric sensors and their integration into a variety of game mechanics. Their study concluded that direct physiological input (e.g., muscle strain) can be mapped into operative actions, while indirect ones (e.g., heartbeat) can be used to manipulate background events or enhance dramatic effects [58]. Other studies show that the data obtained with physiological sensors can be used to increase a game's difficulty to sustain player interest (e.g., [43, 64, 67]). Another application is the use of physiological signals, such as heart-based indices to track physical activity in exercise games (exergames), such as EA Sports Active 2 [20]. Bodily signals have also been used in various relax-to-win games [72]. Due to commercially available consumer-grade electroencephalogram (EEG) headsets that measure electrical activity in the brain, there are already games that utilize this neural signal. For example, NeuroSky's The Adventures of NeuroBoy [59] requires the player's concentration (detected by the EEG) to use telekinetic powers in the game. Further examples include using body temperature as a challenge-based social mechanic [41], or respiratory control to add breathing as an avatar interaction in games [74]. Recent research projects have also looked into displaying the body data of game streamers, such as heartbeat, as a part of their stream and concluded that it can increase the connection to the audience [69, 70]. Bioadaptivity in games has been investigated in a variety of contexts, and wearables' bodily connection makes them suitable interfaces for collecting such data. Therefore, to create an informed participant group and facilitate a holistic approach to design, this study revisits bioadaptivity in a participatory design context in which players are not restricted to technical limitations.

2.5 Wearables as Performative Artifacts

Compared to other gaming devices, one of the unique properties of wearables is the fact that they are worn on the body. In the game context, previous studies have found that wearables can be perceived as costumes by players [32, 79, 80], increasing the strength of the bond between players and their avatars [10, 32]. They can also turn gaming activities into stage performances and thereby enhance the immersion experience. Examples such as Hotaru [1], WEARPG [10], and Magia Transformo [37] have explored these aspects in the context of festival games and TTRPGs. However, there is no in-depth investigation to understand how wearables can enhance character identification in mainstream gaming through costuming properties. In the COS workshop, our aim was to answer this question while sensitizing participants to costuming properties by including cosplayers in the process.

Previous studies include examples that combine wearables, games, playfulness, and related concepts, such as movement and bioadaptivity. Still, these studies propose limited knowledge in the form of actionable design implications for integrating wearables into mainstream gaming paradigms such as PC, console, and mobile gaming. Contrary to these projects, our study uncovers participatory design knowledge by distinct stakeholders such as players, game designers/developers, researchers, interaction designers, and cosplayers for designing and developing the next generation of wearables for mainstream gaming systems.

3 METHOD

We followed a Research through Design (RtD) approach that aims to contribute to the field by creating design knowledge through designing artifacts. [92]. In RtD, although results are not expected to be reproduced due to the subjective nature of the design practice, it is critical to report the method and rationale so the process can be replicated by researchers to reach the different versions of the "right design."

In our study, we thoroughly reported the design knowledge and artifacts created through participatory design (PD) workshops [2, 42] that reflect the opinions of different stakeholders. PD involves including different stakeholders in the design process. The background and involvement method of the stakeholders depend on context and necessity [6]. In our study, stakeholders were continuously involved [7] throughout two workshops with a fragmented workshop structure which we call "Atom Workshops" to ensure that all participants were informed about the potential of wearables and generate rich design knowledge to cover all distinct facets. We organized six (5+1) workshops focused on the different aspects of gaming wearables. The first five Atom Workshops included 6-10 participants that worked on a particular aspect of wearables. The last workshop was called the Fusion Workshop (FUS), it brought together all participants from the first five workshops to work collectively on a holistic gaming wearable concept (Figure 1). The Atom Workshops were similar to Dialogue-Labs' [46] method with an extended and modified structure for embodied interaction by including exercises, such as bodystorming. It is important to sensitize participants to such a multi-faceted topic [85] and previous studies have sensitized participants by employing different methods, such as games [6], role-play [86], or embodied performances [50]. In

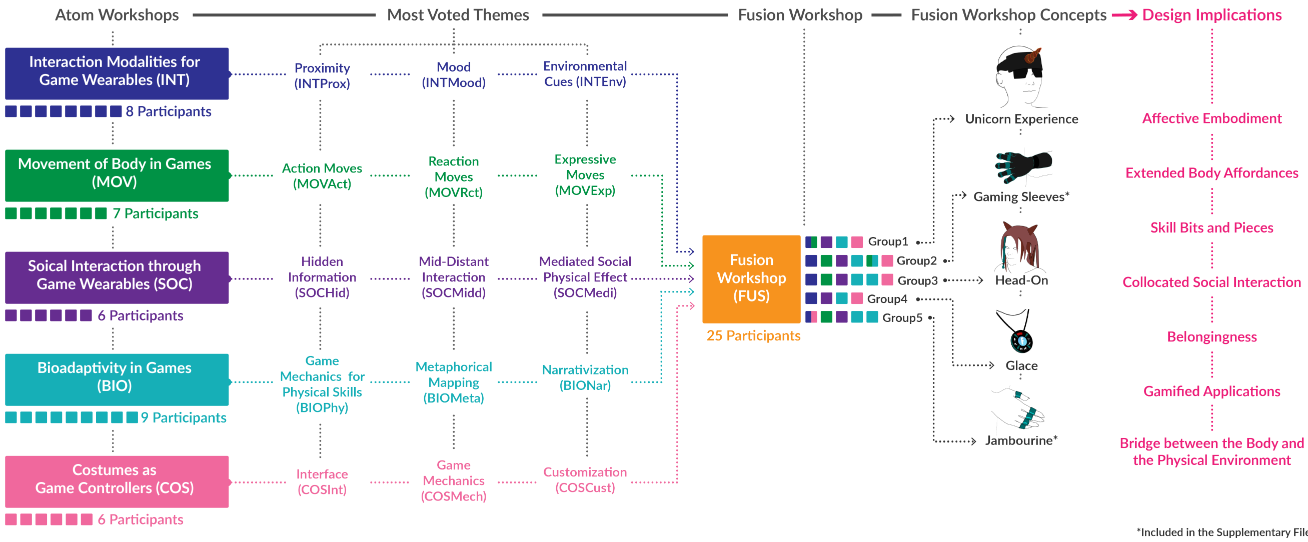

Figure 1: Overview of the Procedure and Outcomes

our case, we chose to sensitize our participants to the topic with full-day Atom Workshops focusing on the strengths of wearables. Sensitized participants came together for a more "doing-oriented" Fusion Workshop prompting creativity [6]. They used the knowledge learned in the Atom Workshops to design a unified concept that drew on popular themes.

In RtD, design knowledge can be communicated in different forms, such as strong concepts [29], annotated portfolios [21], design implications [71], or themes [65]. In our work, we present seven design implications that are mapped to the three concepts generated in FUS and fifteen design themes generated in Atom Workshops through an Annotated Portfolio. In that sense, our work is a rich source of design knowledge which can be guiding, generative and inspirational for designers and researchers who work on wearables especially in gaming and playful contexts.

3.1 Participants

33 participants partook in workshops. We sought a wide array of backgrounds to foster a participatory environment and gather input from various stakeholders. Participants included those with *game design/development and research* backgrounds, as their opinions would help to design gaming structures and experiences formed around wearables. *Interaction designers* contributed to different interaction modalities that might be administered by wearables such as embodied, tangible, andor bioadaptive modalities. Participants with *software and electronics* development background were included to shed light on the technical feasibility of the ideas. *Cosplayers* were invited for their knowledge in preparing costumes and masquerading as characters, which is unique and important for understanding the costume qualities of wearables. We also included participants with backgrounds in designing *bioadaptive technology and games* in BIO workshop and used their knowledge to apply different types of bioadaptive data to gameful technologies. Finally, we included participants without expertise related to workshop backgrounds, but who had varying degrees of gameplay experience and habits, ranging from casual to hardcore gamers. These participants represented *players.*

These workshops were conducted in February of 2019 as a part of the Design Thinking for Wearables, Body and Games course for graduate and undergraduate students at Tampere University. Participants were recruited through internal and external channels with an online application form published in social media groups related to game design, user experience design, cosplay, and through the course application system of Tampere University. Each participant, including students, submitted an application form to be placed in workshops according to their backgrounds to create a diverse environment in each workshop. Moreover, we invited participants through interpersonal connections with different expert backgrounds. Composition of the participants is listed below, and a more detailed breakdown can be reached through the supplementary material.

The study included 22 graduate students in the fields of Human-Technology Interaction (6), Game Studies (3), IT (4), Electric (4), and Biomedical Engineering (1). Eight of these graduate students had extensive professional experiences such as a UX lead position in Nokia, consultation in game companies, indie game development experience, or artistic positions in game development projects. Therefore, eight students were considered experts, ten were considered individuals with graduate-level knowledge in related fields, and four were considered players/consumers due to not having knowledge related to workshop topics. Additionally, there were six *non-student expert* participants with multiple roles in game design (4), game research (2) and development (2), psychophysiology (1), and cosplay (2). Undergraduates (5) were considered as players/consumers. As a result, there were *14 experts, 10 graduates, 9 players* involved in the workshops. Students who participated in the workshops earned two credits. We compensated the travel and lunch costs for the non-student participants.

Workshop	Most Voted Themes	Explanation
Interaction Modalities for Game Wearables (INT)	Proximity (Prox)	Proximity between wearers as an input. Speculated game mechanics include *triggering specific actions only when players are in a specific proximity to one another or notifications when an opponent is close.*
	Environmental Cues (Env)	Utilizing environmental cues or objects as an input. Examples include *detecting temperature for use as a part of gameplay* and *incorporating detected physical objects in VR environments in a digitally augmented hide-and-seek game.*
	Mood (Mood)	Utilisation of players' mood as a game input. Some ideas generated were *activating a rage mode depending on the player's stress level* and *discouraging toxic behavior by detecting voice volume with a necklace-type wearable in online games.*
Movement of Body in Games (MOV)	Action Moves (Act)	Operative moves that constitute the main mechanics such as *running, climbing, rolling, etc.*
	Reaction Moves (Rct)	Actions that are performed as a reaction to events in the game. Such as *dodging, covering, stopping, etc.*
	Expressive Moves (Exp)	Moves that can be used mainly for social interaction instead of core game mechanics. Examples include *gestures that will activate dance moves in Fortnite or celebratory gestures after a victory.*
Social Interaction through Game Wearables (SOC)	Hidden Information (Hid)	Wearables' capability of conveying information secretly. Examples include secret vibration messages, giving directions with heat, and hiding identity with a mask.
	Mid-Distant Interaction (Midd)	Similar to proximity input in INT, but also including distant social interaction. Examples generated in the workshops were *moving together as a group in a close proximity, laughter detector, and feeling vibrations according to the position of others.*
	Mediated Social Physical Effect (Medi)	Making other players abled or disabled certain types of actions. Examples were *blocking vision in VR, restricting the use of body parts, giving other players' wearables the ability to open certain doors, and distracting players by sending vibrations or heat.*
Bioadaptivity in Games (BIO)	Game Mechanics for Physical Skills (Phy)	Game mechanics designed for physical skills such as reflexive moves or dexterity, which can be altered with bio-adaptive features. *Examples were activating bullet time by focusing and triggering certain skills with high adrenaline.*
	Metaphorical Mapping (Meta)	Mapping the biosignals to metaphors in the game. For example, *breathing can be mapped to growing a tree or sending a rocket to space (each exhale can boost the rocket towards the sky), and staying calm to trigger invisibility.*
	Narrativization (Nar)	Meaningfully integrating bio-adaptivity to storylines in the game. For example, *to pass a certain point in a role-playing game, players might train their physical body to break down a door or meditate for some time to reach the desired state of mind to be allowed into a temple, altering the environment and events according to certain emotions of players.*
Costumes as Game Controllers (COS)	Interface (Int)	Using wearables as an interface that shows additional information in a way that brings the game world out from the screen to the body. *These can be collectible story items, an artifact that tells about the future, a ring that gives warning when necessary, or notified about the cooldown of a superpower and activating it through the wearable.*
	Game Mechanics (Mech)	Wearables integrated into game mechanics that are related to features/skills/states of the in-game characters. Examples include *activating different body postures by making players hold/touch a wearable attached to specific body part, activating different characters' skills depending on the worn accessory.*
	Customization (Cust)	Customizing wearables depending on the game's theme and characters. Examples include *different accessories to activate different characters, changing the look and feel by altering the material of the wearable, and embodying a character with a different skin color by changing the skin color displayed by the wearable.*

Table 1: MVTs of Atom Workshops. Themes will be referred to by their abbreviations (i.e., Narrativization in Bioadaptivity in Games: BIONar)

3.2 Procedure

3.2.1 Atom and Fusion Workshops. The structure of the first five workshops was similar with only minor differences depending on the workshop's subject. Atom Workshops began with a 10-minute warm-up exercise in which participants prepared a game card that included their name, title, and a game mechanic depending on personal information. This exercise was followed by a presentation about the topic of the workshop, schedule, and the design problem. The creation process started with a *3-12-3* [26] brainstorming session (3-minute generation of keywords, 12-minute ideation by combining keywords, 3-minute presentation). The 3-12-3 structure is an effective way to trigger participants to quickly ideate on the subject while also initiating collaboration. The concepts created in this first stage were expanded into a rich variety of ideas with a more free-form brainstorming session (45-min) managed by the workshop moderator. The morning session concluded with a lunch break. After lunch, we created an affinity diagram (30-min) [45] to categorize these ideas as themes. These themes were voted on by participants (15-min) (each participant had the right to use three votes on separate themes) and the most voted three themes were selected (as suggested by previous work [26]) to be extended into more concrete gaming concepts by creating paper prototypes [73] (30-min) and experience them with bodystorming (60-min) [49]. Bodystorming is a critical method for experiencing imaginary concepts in a real-life setting and is particularly important for topics focusing on body-related technologies such as movement-based interaction, wearables, and bioadaptivity. Each group in the workshop then presented their ideas by acting out the user-scenarios for others, after which the ideas were further discussed among participants. After the bodystorming presentations, groups discussed the effectiveness of most-voted themes (MVTs) and conducted a *$100-test* [26] by dividing their imaginary $100 among the features which represented MVTs. The prices chosen by participants refer to the value participants allocate for the incorporation of MVTs in their gaming wearables. To open the door for participants to express the rationale behind their choices, the session concluded with a wrap-up discussion which also encompassed the strengths and shortcomings of the workshop. Each workshop lasted 9 hours.

Fusion workshop focused on creating concrete prototypes and use cases. In this workshop, participants were divided into groups that included participants from different workshops and disciplines. Twenty-five participants were present in the FUS. When the groups were formed, participants shared their knowledge and experience in the previous workshop for 30 minutes. The morning session ended after a 75-minute ideation workshop where each group formed three concepts. After the lunch break, these concepts were presented to all participants to provide feedback. Following this discussion, each group selected one concept and created a paper-prototype (60-min) along with a video sketch (60-min) [91] to demonstrate the user scenario of the product. Creating video sketches is an effective practice as it allows participants to communicate their ideas quickly while realizing the shortcomings of their design during preparation. Next, groups presented their video sketches and received feedback from the listening participants. Listening participants also contributed by indicating the price (in Euros) they would likely pay for each concept. We concluded the workshop with a feedback session. FUS also lasted 9 hours.

3.2.2 After Workshop Activities. After the Atom Workshops, we asked participants to fill workshop diaries, upload the sketches of the workshop ideas, and evaluate the ideas' strengths while critically reflecting on their shortcomings. The individual diaries for each workshop helped participants to reflect on their own experiences. Similarly, FUS concepts were evaluated in terms of interaction modalities, social aspects, movement, bioadaptivity, and performative aspects. We wanted each participant to put a price tag and name the companies that would sell their concept. These individual reports provided deeper insights into each participant's vision of their concept. Each participant was also asked to evaluate the positive and negative aspects of the concepts created by other groups.

3.2.3 Analysis. The author who moderated the workshops (first author) visualized the concepts and use cases generated in FUS (Figure 2) by consulting the workshop diaries and video sketches. The MVTs were extracted from the affinity diagrams which were entered into the Miro online tool for better readability. Visualizations of the FUS concepts, affinity diagrams, and the MVTs of Atom Workshops were presented to researchers of this study who are experts on interaction and game design, marketing, computer science, psychophysiology, and gamification. This involved a 2-hour in-house workshop which generated a new affinity diagram by discussing the underlying intentions of these concepts, their broader impacts, and actionable design implications. The first author noted the occurring themes in this new affinity diagram and how each MVT and concept was related to a final set of themes which laid the foundation for the design implications presented in the last part of this paper. These implications were later examined by other researchers who were present in the in-house workshop and further improvements were made according to their feedback.

Additionally, the first author examined the video recordings of the workshops and design diaries to better understand the participants' opinions of the MVTs. All participants' comments were transcribed and tagged with thematic keywords. Video recordings for some comments was inaccessible due to recording errors. For those comments, we relied on the participants' reports in their design diaries. Results of the $100-tests were studied by the first author to determine the average prices for each MVT and FUS concept.

All in all, the MVTs and FUS concepts were used as the base of discussion for creating the affinity diagram that would inform the final design implications. All affinity diagrams from the workshops and the final affinity diagram are included in the supplementary material.

4 FINDINGS

4.1 Themes of Atom Workshops

MVTs are presented in Table 1. The following section elaborates on the broader meanings of these themes and the participants' opinions on them. This section is particularly important for the rest of the study since both the FUS concepts and final design implications were heavily guided by the themes created here. The themes not counted as MVTs are also included in the supplementary material for inspirational purposes. They are not included in the main manuscript as they did not directly contribute to the outcomes.

4.1.1 Interaction Modalities for Game Wearables (INT). In INT, we asked eight participants "How can we interact with wearables while playing games?" as the main question, along with the following sub-questions: "How can we give input to game wearables?", "How can game wearables give output to us?", "Which modalities can be more desirable for different kinds of game actions?" In the opening presentation, we informed participants about wearables, game wearables, and different types of interaction modalities such as touch, tangible, gestural, various body inputs, haptics, and more rare ones, such as gustation.

INT revealed that the ubiquitous qualities of wearables are the most remarkable feature of them. Retrieving continuous data from the environment, other wearers, and the self suggests that wearables' continuous availability and proximity to users and their surroundings are worth considering when designing game features. In the $100 test, participants favored the mechanics that encourage players to "get together ($30)," use the "proximity between bodies ($25)," and "proximity and location information of objects/NPCs in the digital world through wearables ($27)" in *INTProx*. When it comes to *INTEnv*, average prices were quite close for the features of "turning physical environment to a playground ($48)" and "altering the digital game environment depending on the real environment ($45)." For the *INTMood* theme, "changing the feeling of game to induce happiness to player ($26)," "reconfiguring the gaming environment per heartbeat of the player ($25)," and "activating the rage mode when the player is angry ($23)" were the features rated higher than the others. In INT, participants rated the different features they created in each theme. However, in other workshops, we wanted participants to rate only the MVTs and discuss the rationale behind their choice to generate a richer and more organic discussion, rather than a fragmented and categorical one.

INT was the first workshop of the series. It sparked a valuable and interesting discussion, yet participants could not go deep into specific modalities. It seemed to be difficult for participants to speculate on modalities without designing concrete game mechanics. The challenge regarding the ideation on interaction modalities in INT was due to the wide design space of interaction modalities which led to a broader discussion on wearable modalities (e.g., proximity, mood, environment sensing) that might be suitable to games rather than a specific and deeper exploration. Fortunately, due to the -oriented nature of FUS, groups produced fully-fledged user scenarios that also revealed the interaction modalities in a more detailed way.

4.1.2 Movement of Body in Games (MOV). In MOV, we asked seven participants "How can we use our body movements while playing games on current gaming systems?" and more specifically, "Which body movements can be suitable for specific actions?", and "How can these body movements increase our game experience?" In the beginning, participants were presented with the utilization of movement in different game genres and informed of the important studies that shaped the field, such as the "Movement-Based Game Guidelines" by Mueller & Isbister [56].

The first two themes of this workshop, *MOVAct and MOVRct*, suggest that being kinesthetically involved in the game with full-body controls is still preferable as long as they work seamlessly. The third theme, *MOVExp* represents expressive moves that are capable of increasing performative aspects of games without interfering with gameplay. In games like Fortnite, there are menus and buttons allocated for social expressions, such as waving or dancing. Participants speculated that these may be performed with physical gestures to increase engagement. Participants allocated an average of $37.5 to MOVAct, $33 to MOVRct, and $26 to MOVExp. Four participants asserted they would pay the most for action and reaction movements since they constitute the skeleton of the game. 2 participants allocated more for the expressive moves as they would not interfere with the play performance but can increase the character identification and social interaction.

In MOV, our take-away was that full-body game control is still desirable based on its higher price average. However, participants' input suggested that more subtle movements can still be of use to increase the gaming experience, and wearables might be ideal to capture such movements with low-cost sensors.

4.1.3 Social Interaction through Game Wearables (SOC). As a primary research question, as a main research question, we asked six SOC participants, "How can wearables support social interaction in games?" Sub-questions included, "Which social game patterns can be supported by wearables?", "How can wearables support distant social interaction in games?", and "How can wearables support close/co-located social interaction in games?" At the beginning of the workshop, participants were informed on wearables, gaming wearables, their social effects, and computer-mediated social interaction.

All MVTs of this workshop involved collocated social interaction. Although a research question for remote interaction via wearables was repeated a few times in the ideation process, ideas regarding social interaction in multiplayer online games were not proposed by participants. In SOC, *SOCMedi* is highly favored by players in $100 test with $47 average. 3 players who allocated the most expressed that it is a feature that promises various novel game mechanics. *SOCHid* and *SOCMidd* received similar averages of $26 and $27, respectively. Participants favoring these themes suggested that they can help increase the social connection between players.

Results of the SOC corroborated previous game wearables' research [1, 48] by focusing on collocated social interaction. Still, SOC adds to these by positioning bodies as platforms for which distance, orientation, and abilities can be manipulated in relation to the game mechanics.

4.1.4 Bioadaptivity in Games (BIO). In BIO, the main research question was "How can our body signals become a part of games in the current gaming systems?" Nine participants explored the sub-questions of "Which game mechanics can be created or supported by biosignals?" and "How can body signals contribute to the gaming experience in other ways?" The opening information session included various ways of collecting and measuring biosignals and examples of their use in games.

MVTs formed in BIO focused on integrating biosignals into games in quite distinct ways. *BIOPhy* mostly referred to triggering superpowers by altering body-signals. In most games, these powers might be activated after a cooldown period that can be altered by the in-game performance of the players. *BIOPhy* adds another layer to this mechanic that is mapped to the concentration or the mood of the player. Participants also found that metaphorically mapping the body-signals to game events (*BIOMeta*) may be worth exploring. Literal mapping can be considered as mapping the heartbeat of players to the heartbeat of the avatar while the metaphorical mapping corresponds to the actions that have a less direct relationship (e.g., keeping calm to become invisible) as seen in the examples in Table 1. Narrativization was also considered important by participants. Interestingly, *BIONar* reflected on the game concepts in ways that expand the game world to daily life experiences. This theme suggests that the narrative of games can be extended to our daily bodily experiences by using sensors that can track our body data continuously throughout the day.

In this workshop, average prices allocated for *BIOPhy, BIOMeta, and BIONar* were $33, $27, and $40, respectively. Four participants favored the *BIOPhy* since mechanics constitute the core part of the game and one participant thought that it might increase the novelty value. Two participants gave lower values, claiming that physical mechanics may not work well due to the detection issues and the capabilities of the human body (e.g., the difficulty of intentionally lowering one's heartbeat). *BIOMeta* was valued as a way to foster the imagination of players by one participant. Two players thought that mapping biosignals can be literal or metaphorical depending on the context. *BIONar* was favored by two participants who prioritize the storyline in games and seen as a way to meaningfully integrate biosignals into games by two others.

BIO showed that players value biometrics that are tied to game mechanics and the narrative (by extending the narrative to daily physical activities). Although mapping can change according to context, the indirect utilization of bioadaptive features as in *BIOMeta* can open new areas to explore for designing novel and engaging gaming experiences.

4.1.5 Costumes as Game Controllers (COS). COS adopted the "Costumes as Game Controllers" definition that was used by several previous works [32, 79, 80]. The main research question posed to six participants was, "How can wearables behave as costumes in current gaming systems?" Participants also investigated these specific sub-questions: "How can we design gaming wearables in a way that will increase our connection to fictional characters?", "How can gaming wearables support self-expression?", "How can gaming wearables transform us?" The workshop began with a presentation about wearables, game wearables, and specific examples that utilize wearables as costumes and transformative tools.

All MVTs of COS reflected different levels of depth regarding using wearables as an extension of the character on the body. *COSMech* focused on wearable features that can have a direct effect on gameplay while increasing the player's connection to their avatar. In one example, a bracelet must be grasped when the character is injured, forcing players to play the game with only one hand for a while. Another example includes activating skills for a duration when a specific wearable is worn (e.g., wearing a ring in a Lord of the Rings game to grant invisibility with an increased fatigue). *COSInt* reflected ideas that carry user interface elements from the screen to the body of the player. These elements do not directly affect the way the game is played but introduce interface layers that will help players to better identify with their characters. For example, wearables can inform players about the cooldown times of skills, and such skills can be activated with a gesture or by touch. *COSCust* focused on the material qualities of wearables that include features contributing to the self-expression of the user, such as changing the skin of the wearable, illusions making players feel that they are darker- or lighter-skinned, or parts that change the look and feel of the digital avatar. In this workshop, *COSMech* and *COSInt* were the most favorable themes with average prices of $41 and $40. Compared to these two, *COSCust* was considered less important by participants with an average price of $19. Comments on the customization indicated that it would be valuable as a token of self-representation in the public, but it may not be a core part of the game.

COS introduced an array of ideas that characterize different uses of wearables in ways that will strengthen the bonds between players and their avatars. Similar to the other workshops, themes that have a direct relation to the game mechanics and content *(COSMech and COSInt)* were favored more by the players than *COSCust*, which represents features that are more related to out-of-game use.

The knowledge created through the Atom Workshops was quite extensive. This information was reported with as much detail as possible, so even the small set of data can be useful for designers who read this paper. A frequent pattern in these workshops was that the design themes suggesting alteration and novelty in game mechanics and content such as *MOVAct, SOCMedi, BIONar, and COSMech* were valued highly by participants. Although valued less, it is worth noting that supportive themes such as *COSCust* or *MOVExp* were among the MVTs and may still be valuable gaming wearable features. Therefore, an ideal gaming wearable would promise improvements in the direct interaction with the game mechanics and content, while a complete design would also allow players to explore concepts such as the exploration of character identity and social connections between players.

4.2 Concepts Created in the Fusion Workshop

In this section, we will explain three of the concepts created in FUS. We show how the features of the concepts drew on the knowledge created in Atom Workshops by referring to the MVTs as suggested by the Annotated Portfolio method [21]. Two concepts were excluded from this manuscript as they did not directly contribute to the discussion in a broader sense. One of the excluded concepts, Jambourine, was a collaborative wearable instrument that was not directly related to games. The other concept, Gaming Sleeves, was a gestural glove concept that included bodily sensors but did not propose applications beyond using finger gestures, which has been tried many times in mainstream gaming by different technologies such as MYO[1] and Leap Motion[2]. Both concepts are available for examination in the supplementary material.

[1]https://developerblog.myo.com
[2]https://www.ultraleap.com

4.2.1 Unicorn Experience (Group1). Unicorn Experience (**Figure 2 - a1**) is an augmented reality headset that has a unicorn horn extension. It is played by destroying certain targets scattered around the game world by hitting them with the horn (**Figure 2 - a2**). Different horns are interchangeable, and each horn activates a different skill (**Figure 2 - a3**). The project also includes a social aspect as some targets can only be destroyed when people with different unicorn horns come together. Unicorn Experience demonstrates the transformative capabilities of wearable controllers by incorporating *COSCust, COSMech, SOCMidd, INTProx, INTEnv, MOVAct, and MOVRct* themes. Unicorn Experience is an exaggerated example of how wearables are related to self-expression. The following quote from one of the designers explains their design decisions related to these topics: *"There also lies a deeper meaning: you can be whatever you imagine no matter what other people think. The concept would have many viable possibilities for different platforms and it feeds not only your imagination but it also will challenge the "dare" aspect - do you have what it takes to play this in public?"* It transforms the player by including customizable *(COSCust)* parts that also affect the powers players can have in the game *(COSMech)*. Moreover, the horn extension affects specific action *(MOVAct)* and reaction *(MOVRct)* movements and creates in-game movements using the affordances of the physical environment *(INTEnv)*, such as pitching the heard forward, standing on tiptoes, and even jumping. These movements can vary increasingly with different shapes of head attachments instead of horns. It also adds a social layer by introducing group mechanics that depend on the proximity of players and draw on the *SOCMidd* and *INTProx* themes. The average price for Unicorn Experience was 81€ per the answers of 16 participants in FUS.

4.2.2 Head-On (Group3). Head-On is a wig that utilizes EEG measurements to transform players into their digital characters both visually and emotionally. Head-on measures brain signals to use the emotional states of players as game mechanics. For example, characters can run faster when players are more excited, or bigger fireballs can be created when players get calmer (**Figure 2 - b2**). With these features, Head-On incorporates ideas from *COSMech, BIOPhy, and INTMood* themes, and utilizes the bioadaptive data to generate game mechanics focused on physical skills such as controlling involuntary body reactions like stress. Another aim here is to foster a connection between the player and the character with an affective bond through body data and a transformative connection with the costume aspect of the wig.

Other than its bioadaptive features, Head-On also incorporates tangible interaction with different parts that reflect the movements of the digital character. For example, when players hurl their hair or hold their ear, the digital character does the same (**Figure 2 - b3**). This also extends to operational actions such as using a shield. In **Figure 2 - b4**, when the player touches or squeezes the braid, the digital character raises their shield. Here, utilization of the *MOVRct and MOVExp* themes provided a clear demonstration of how wearables can guide bodily movement without using tracking technologies. The ear in the wig not only affords movement towards the head area but also creates a material connection between the character and the player. Moreover, interaction with the braid guides the user into a posture similar to raising a shield. This aspect

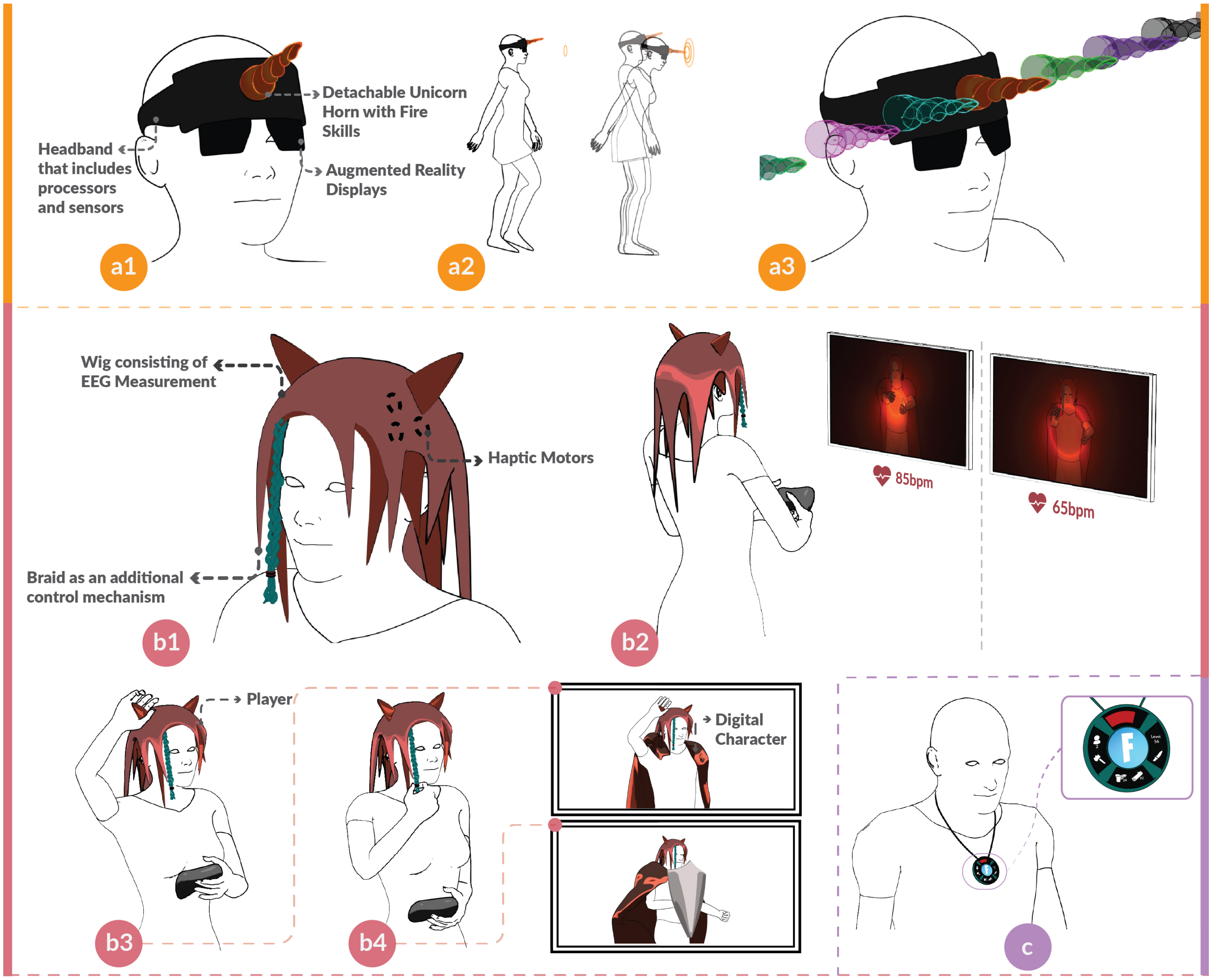

Figure 2: Concepts created in the Fusion Workshop

of Head-On shows that wearables can guide the movements of users by utilizing on-body switches, buttons, and touch areas, as well as attaching interaction areas to extensions such as braids. It also reveals the embodied interaction affordances that wearables can facilitate in games and suggests scenarios for in-game affective and expressive interactions. Designers also noted that the concept is customizable (as a feature suggested by *COSCust* theme) to embody different characters in different games as explained by one of the designers in Group 3: *"The product was thought such that a player would buy the base headset and different customizable hats/caps/wigs, representing their character in-game and possibly having additional interactions... This customization can enhance the game experience in a way that the player can identify as the character they're playing."* The average price for Head-On was 167€ (16 Participants).

4.2.3 Glace (Group 4). Glace is a wearable device that emphasizes social interaction and self-expression. It is designed to be worn as an accessory (i.e., necklace, badge) that allows players to see each other's gaming preferences and skills. In **Figure 2 - c**, one can see that this player is playing Fortnite and see specific information such as the player's ammo or experience level. Glace aims to promote engagement between collocated players and facilitate social interactions, such as requesting resources as a gift. To that end, Glace uses wearables as an interface by referring to the *COSInt* theme and creates a social sphere where people can interact with each other by glancing at their wearables as suggested by the *SOCMidd* theme. Beyond encouraging verbal social interaction, Glace was also designed with self-expression in mind. It works towards developing a sense of belonging, as put forth by one of the team members: *"The necklace allows to see and shows what games you have recently played, this allows you to 'be a part of a tribe' and be more in touch with the game."* Glace can also utilize game mechanics influenced by the players' knowledge about each other and make use of the *SOCHid* theme by showing or hiding specific information about players (e.g., the location of a player's character in a battle-royale game). According to the 16 participants, the average price for Glace was 68€.

5 DESIGN IMPLICATIONS

In this paper, we first presented the most voted themes (MVTs) of the Atom Workshops and then analyzed the concepts that were created in the Fusion Workshop (FUS) around these themes by utilizing an Annotated Portfolio [21] method. However, we also need to convey the broader meanings that these themes and concepts suggest by critically engaging with the outcomes, as suggested by RtD method [92]. Thus, our aim in this section is to interpret the outcomes which were primarily formed in the in-house workshop. Presented here is digestible and actionable design knowledge for designers and researchers who work on wearables, games, and interaction by presenting an interpretation of the complex relations between the extensive data produced in the previous sections. In each part, we will explicitly map our interpretations to specific concepts and themes along with a discussion of their relation to previous studies.

5.1 Affective Embodiment

Wearables can create affective interaction opportunities by combining tangible modalities and bodily actions. The ideas raised in *COSMech and MOVExp* were translated into the concrete concept, *Head-On*, which utilizes wearables as a tool for in-game expressiveness through its tangible parts. As indicated before by Tanenbaum & Tanenbaum [79], wearables can turn the body into a surface for switches and buttons. These switches and buttons are proposed to create affective relationships with game avatars and other digital beings by creating distinct affordances for embodied interaction. In *Head-On*, when the player rubs their ears on the wig, their avatar also starts to play with its ear in the game. Here, interaction is not as same as a motion-tracking system because tactile sensations, the material feeling and the existence of the ear, how it reacts to touch, and how touch and movement are translated to in-game action are purely expressive and designed to enhance the emotional bond with the character.

Transferring the bodily experiences of an in-game character to the body of the player promises ways to design somaesthetic experiences through guided tangible interaction, with the wearables placed on specific parts of the body. Corresponding to *Subtle Guidance*, a key quality of somaesthetic appreciation design [28], wearables for guiding specific body affordances can eliminate the tracking problems prevalent in games with motion tracking technologies and replace them with simple modalities such as switches, buttons, touch, and proximity sensors. The simplicity of these modalities (e.g. detecting on/off states) shifts the focus towards experiencing the body rather than the capabilities of the technology. By design, wearables afford body-based modalities that might not be possible or as easy through other devices.

There were also other parallel ideas to this implication proposed in Atom Workshops. In *COSMech*, players proposed mechanics such as holding an arm-worn wearable to heal the avatar and enhance the player's connection to their character. These concepts inspired further concepts in the in-house workshop, such as animal companions in the form of physical wearables that can be petted, touched, or commanded. In the light of these examples, wearables can be effective systems to enhance the affective involvement, as defined by Calleja [11], to games and characters through our bodies. *As a practical design strategy, Wearables can afford game mechanics and actions that can form tangible connections between the bodies of players and avatars and this can be used to enhance the emotional bond in between.*

5.2 Extended Body Affordances

Wearables can extend the body and change the way players move depending on these extensions. *Unicorn Experience* is a remarkable example of using the actions mentioned in *MOVAct-Rct* in a novel way by creating operational moves centered around the horn extension. As mentioned in *INTEnv*, these extensions can interact with the environmental cues that can create movement affordances that would otherwise be challenging (i.e., using your head to hit the digital environmental cues in *Unicorn Experience*).

Previous work by Svanaes & Solheim [76] suggests wearing a tail can direct wearers to move their hips and examine the movement affordances and altered proprioception induced by these wearables, but does not focus on their virtual and digital implications. Other work, such as "Light Arrays" by Wilde [88] and "Enlightened Yoga" by Vidal et al., [82] examine augmented proprioception by using projected or extended light arrays and explore non-tangible extensions of the body. Although all these works prove the capability of wearables in terms of extending the body, their exploration is limited to interaction with the real environment. However, the utilization of wearables can provide novel opportunities in virtual environments in terms of providing realistic bodily experiences of unreal situations by experimenting with the mappings between the real movement of wearables and the virtual effects perceived by players. Adding to these examples, *INTEnv* and *Unicorn Experience* demonstrated that when the extensions of the body meet the digital counterparts such as the virtual rings in the *Unicorn Experience* or other physical objects mentioned in *INTEnv*, opportunities for designing game mechanics based on the hybrid (digital-physical) proprioception can emerge and be effectively applied to augmented or virtual reality games. Expanding on the previous work, we suggest that wearables can turn into body parts extending towards the digital space and guide virtual proprioception. Therefore, our work reveals that wearables hold not only the potential to change the kinesthetic perception of the body, but they can also define and help build the proprioception in the digital/virtual space. Wearables are also costumes that transform players into their avatars and bind them to imaginary worlds [10, 32, 37]. Our findings add to this by showing that wearables can also be extensions by further transforming players kinesthetically to the imaginary characters they are playing.

In addition to showing the effectiveness of using wearables as extensions of the player's body and its affordances, this study puts forth that designers can consider the bi-directional relationship between game content and body extensions to bridge physical and virtual bodies. For example, these extended body parts can be utilized to reach specific items in the game that will turn the player into another character, not just by wearing a costume but also being kinesthetically involved [11] in the avatar without needing an external tracker or tutorial.

5.3 Skill Bits and Pieces

All themes in *COS* introduced ways to represent wearable artifacts that can reflect the superpowers of avatars. In that sense, even "wearing" or "not wearing" becomes an interaction modality that may activate or disable certain skills. These artifacts, according to the proposals of participants in *BIOPhy, INTenv or COSMech*, can be interpreted as immersive interfaces with different modalities such as touch, gesture, and tangibility, which use the skills of the avatar. The method of interaction can even be introduced as challenge-based mechanics (e.g., wearing pieces on specific parts of the body for a limited time). Previously, Buruk & Ozcan [10] and Jing et al. [37], also developed game wearables that utilize different elemental stones, robes, and hats that activate the different skills of characters. Still, in both projects, further interaction with these wearable skills was limited (i.e., they were used at the beginning of the game but were not effective later on). Participants' suggestions and concepts extended the approach by encapsulating a variety of new user scenarios.

The *Head-On* project envisioned wigs in different styles that would introduce different forms and interaction modalities for different characters. In other words, changing wigs activates new characters with entirely different skill sets. This interaction style is similar to Skylanders [84], which used tangible characters for activating in-game characters. On the other hand, the wigs do more than activate specific characters, they also introduce different types of affordances for bodily interaction. When it comes to *Unicorn Experience*, skills gained through different horn extensions also introduce the feature of creating combos when different players come together. This can be extended into exchanging horns for completing certain missions, around which game levels and social mechanics can be designed. *Skill Bits and Pieces* is also about adorning the real body of the player with imaginary powers which, in return, are expected to foster the connection with and transformation towards the imaginary world.

In terms of strengthening the bond between the avatar and the player, wearables can be considered magical platforms that sheathes the imaginary powers of characters. They also present a variety of methods to unleash these powers, including bioadaptivity; tangible, touch, gestural interaction; and even wearing/not-wearing.

5.4 Collocated Social Interaction

All themes of *SOC* focus on different ways of providing collocated social interaction. *INTProx* suggested that participants consider the proximity data between wearers as an important input source. Although the game mechanics that were produced in Atom Workshops were not explored deeply in the Fusion Workshop, *Glace* was a wearable built solely upon collocated verbal social interaction and self-expression.

Previously, verbal social communication and proximity subjects were studied by projects such as SW4LARP [48] and Hotaru [1, 33]. "The Design Framework for Playful Wearables" [8] also examined the social interaction in a continuum of relaxed and tight interactions. Interestingly, both MVTs of SOC and *Glace* concept, although focused on collocated social interaction, avoid interpersonal contact, which may indicate that *relaxed* social interaction modalities might be more suitable to mainstream gaming. Previous work on interpersonal touch-based games also indicated that social touch may create affective [12, 51, 87] or embarrassing [31] interactions between players depending on their acquaintance level and relationships [51]. Therefore, although bodily contact was among the themes created, it was not highly voted or used in the final concepts as a central theme. This decision might originate from a more general audience-oriented thinking independent from the relationship between players.

When it comes to social game mechanics, the idea of constructing games around "hiding information from other players" is an interesting one. This hidden information is considered personal, contrary to expressive knowledge according to the Social Wearables Framework [18]. However, in our workshops, when workshop participants learned that other players may be hiding information, this led to mid-distant bodily interaction in which players sought the hidden information by wandering around each other. Therefore, adding to the Social Wearables Framework [18], although hiding information might be applied to personal data, it can also generate embodied social interaction originated by this secrecy.

Although the FUS concepts did not explore them, *SOCMedi* introduced mechanics such as augmenting or impairing other players' abilities through modifying the skills associated with their wearables or by physically disabling their wearables, such as blinding their virtual reality spectacles. The reason behind not using *SOCMedi* in FUS concepts might be the challenges of creating commercially viable wearables which can restrain the physical abilities of players. Still, socially mediated dependability through wearables was a novel take and, to the best of our knowledge, was not explored by previous studies on game wearables. Further exploration might provide future competitive and collaborative social game mechanics in which players can prevent their opponents' actions or empower their team members.

These outcomes show that collocated social interaction can create new social paradigms while playing games, such as a multiplayer console game in which the proximity between two players affects gameplay. As a practical design strategy, wearables can turn bodies into platforms in which the play is affected by body proximity, orientation, and physical skill.

5.5 Belongingness

Sense of belongingness by feeling as a "part of a tribe" that was introduced in the *Glace* concept may be a promising direction for wearables. A similar effect has been explored by Tajfel, whose various experiments showed how even small and meaningless distinctions to define groups can lead to in-group favoritism, or favoring one's own group over another [77, 78]. As mentioned in the *COSCust* theme, having different customizable skins according to teams may strengthen a player's sense of belongingness by providing the chance to represent the team both inside and outside of the game.

From this point of view, these types of wearables can act like sports teams' "kits." Since the concept is closely related to e-sports, these "kits" can also be used for data collection that may help to evaluate the performance of players. This can also be extended to market to the fans of e-sports teams. These implementations may create a wider representation of e-sports across public spaces. These use-cases are quite suitable to the nature of wearables because fashionability and self-expression are integral parts of wearable design [23, 81]. Gaming wearables can be designed to reflect the gamer identity of players and facilitate a conversation around their latest games, game experiences, or favorite e-sports teams. This novel approach can combine gaming habits with social gaming identity. For example, an e-sports tournament commentator can illuminate the LEDs of players using the Raven Character in Fortnite to create a unifying experience among players. As a practical design strategy, extending the functions of gaming wearables beyond gameplay and into becoming part of player identity may increase the chance for longer wearable adoption.

5.6 Gamified Applications

Location-based games are the gaming phenomena of everyday life, and according to the findings in *INTEnv*, more precise detection of environmental objects and effects may be a strong contribution to game design. This could expand into other parts of everyday life and ideally enhance the effectiveness and experience of daily activities.

Game wearables can also be used in conjunction with applications that gamify daily activities. However, *BIONar* suggests the more novel approach of unifying screen-based games with daily activities. For example, players with a more mindful and active life can gradually improve practical skills through gameplay. More specifically, a player who develops mental strength through daily meditation would also improve their character's focus and performance when casting spells. Many more scenarios can be produced around the themes proposed in *BIO* for developing gamified applications to include gameplay experiences in everyday life. In addition to creating a sense of belongingness, extending the capabilities of wearables for gamifying everyday life may make them more adoptable. Previous work [4, 13] suggests that equipping wearables is demanding for players wearing VR trackers and is a fundamental issue that needs to be addressed in the design process. Along with developing a sense of *belongingness*, *Gamified Applications* are a novel proposition with useful contexts that make gaming wearables purposeful outside of screen time, and may remove the need to wear them only during gaming sessions. Designers should consider ways to design gaming wearables as not only part of gameplay, but part of a player's identity. However, designers should also acknowledge that this will create new concerns, such as social acceptance and fashionability [23, 81] of the wearables, that can lead to new challenges and opportunities. On one hand, players may not want to wear a device associated with gamer aesthetics, but on the other hand, this challenge can create new visual languages. This would resemble products like gaming laptops, which advertise the gamer's identity while still being suitable for professional situations, such as business meetings or working in a public environment.

5.7 Bridge between the Body and the Physical Environment

"Sensing" was a prevalent theme across all workshops. *BIO* introduced a variety of methods for meaningfully integrating the body into games through the collection of movements and biosignals from different parts of the body. Nacke et al. [58], have investigated the utilization of different psychophysical inputs through a specific game before, yet our study's participatory effort added unexplored methods and contexts for which bioadaptivity can prove useful, such as *BIOMeta.* Moreover, bodystorming for *MOVAct* revealed that different body parts can be mapped to different functions (i.e., leg wearables that will map strafing actions to legs, making it more immersive while freeing up buttons mapped to this action for other use). Additionally, *INTEnv, INTPro, and SOCMidd* emphasized the importance of sensing the surroundings of players. "Where to Wear It" [89, 90] provides body mappings with extensive information about how to design wearables for the different parts of the body. Concepts and themes presented in this paper expand this towards gameful experiences by pointing out how these different parts and environments can be sensed and incorporated in playful ways.

As the design strategy, this implication suggests that wearables can be considered bridges that connect the bodies of the players to their environment. Therefore, they become part of the body that reaches into their surroundings, senses the environment, and generates information that can be perceived through the body. Here, wearables can create closed loops between the environment and the body, which in turn can generate novel game mechanics as pointed out in *INTEnv*. *INTENv* suggests that the connection between environmental cues and the game content, such as sensing the temperature in a physical or digital environment to utilize it through wearables might be preferred by players. Other themes such as *INTProx* or *SOCMidd* indicated that sensing the objects or people around the wearable might lead to game mechanics that integrate the physical realities into digital environments. On the other hand, *BIOPhy* and *BIONar* suggested using bioadaptive features as physical challenges or as a part of the narrative by extending the game beyond the screen. The synthesis of this information implies that sensing of the body with sensors, such as heart rate monitors extends to the environment with temperature or proximity sensors. Thus, game mechanics such as altering the environment depending on the physiological data may be a valuable design opportunity. For example, in a game environment adorned with IoT devices (which is not an uncommon scenario in modern smart homes), room temperature can be increased depending on the heart rate of the player. This could present a challenge in a game where the player's goal is to lower their heart rate, which grows more difficult with increased heat. Similar challenges can be designed using the environment, for example, the proximity of every-day objects around the player.

6 LIMITATIONS

While two of the FUS Concepts (*Glace, Head-On*) were situated to be used across different types of games and genres, *Unicorn Experience* was limited to only specific applications. Although this concept can be improved in a long-term creation process, it still communicates valuable information about embodiment and playful interaction beyond games. As design researchers, our role is to interpret and report upon general outcomes through established methods of RtD, such as thematic analysis and annotated portfolios. Still, we also can observe that the versatility in customization and adaptation to wide range of game mechanics was appreciated by participants, as *Head-On* was evaluated at the highest average price of all projects.

Another limitation of this study is the number of uncertainties regarding the technical feasibility of the proposed projects, which is a prevalent concern in design speculation studies. These workshops focused on challenging the extant design space for gaming wearables, but these concepts also possessed many technical difficulties (if restricted to use only extant technologies) such as the detection of accurate brain signals when the head is sweaty. These challenges and their potential solutions will be addressed in further work which will implement prototypes based on these outcomes.

As explicated in the design implication section, the ideas created during the workshops corresponded with previous studies, specifically in the areas of pervasive, alternate reality, festival, and indie games. This study's contribution, rather than generating game mechanics exclusive to wearables, is demonstrating how these design opportunities can capitalize on mainstream games. Thus, while previous studies have demonstrated wearable-related game mechanics, this is the first time the spotlight has been cast on wearables for mainstream gaming with a rigorous participatory method. However, more granular analysis and quantitative empirical research can be conducted in the future to develop a deeper understanding of gaming wearables.

The scope of this study is limited in understanding how to design wearables as integral parts of games and playful experiences in mainstream gaming. Still, it is important to note that designing wearables is a multilayered process and will benefit from related knowledge such as wearability [22], body mappings [90], and fashionabiltiy [23].

7 CONCLUSION

In this paper, we presented the design knowledge gained from a participatory design workshop series that hosted 33 participants. The results were threefold: (1) Design implications that suggest actionable and practical design strategies for designers created through the (2) annotated portfolio of concrete gaming wearable concepts, and (3) design themes. With the ambitious structure of the workshops and participation of distinct stakeholders, this study is a first step towards understanding the perspective of various stakeholders on the integration of wearables into mainstream gaming systems such as PCs, consoles, extended reality, and mobile gaming devices.

In terms of the knowledge produced in this workshop, our scope was limited to design themes, implications, and concepts. In the future, however, we aim to create a systematic design framework with concrete design guidelines after we deepen our exploration by producing prototypes. Still, the amount of design knowledge created here possesses wide possibilities that will guide other designers. It will also serve as a valuable discussion starter by being the first example of a participatory user-oriented study that explores wearables for mainstream gaming systems. From a wider perspective, our results can also benefit the designers of other hedonic systems or services such as gamified exercise, health tracking, skill training, and so on.

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