Towards Designing Playful Bodily Extensions

Learning from Expert Interviews

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ABSTRACT

Interactive technologies offer novel opportunities for physically extending our bodies, with the most prominent examples being prosthetics along with systems emerging from the wearables community. However, most such systems appear to focus on instrumental benefits, missing out on the opportunity to use bodily extensions for play and its associated benefits (including a lower adoption barrier and the potential to reveal a broader understanding of such technologies). To begin understanding the design of playful bodily extensions, we interviewed five designers of bodily extensions that have been showcased in prestigious academic venues or turned into commercial products. Here we present themes and actionable advice from these interviews for the design of playful bodily extensions through a thematic analysis. Our work aims to support the design of future playful bodily extensions while promoting the experiential qualities of bodily extension design, with the ultimate goal of bringing more playful experiences to people's lives.

CCS CONCEPTS

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

KEYWORDS

Bodily Extensions, Wearables, Play, Games, Cyborg, Transhuman, Posthuman, Expert Interviews, Thematic Analysis

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1 INTRODUCTION

Physical artefacts with interactive technology are becoming increasingly accessible and bodily. Nowadays, human bodies are adorned with wearable sensors tracking bodily activities such as movement, breathing [99] and even brain signals [8]. This advancement towards "body-centric computing" [15, 111, 135] is not restricted to only sensing, but also includes wearables that physically extend the human body [103]. We are moving towards wearable devices that change bodies' shape and form, i.e., shape-changing body-worn devices [5, 37, 124]. In this study, we call such devices "bodily extensions" [71] and by examining them we go beyond artefacts that simply extend the body (such as spikes in a jacket or a zorb ball [4]) to those that can be activated by or independent from the wearer's bodily movement (e.g., a prosthetic arm or an inflatable skirt [124]).

Such "bodily extensions" often come in the form of prosthetic limbs, which replace a lost limb's functionality or may also be worn for cosmetic reasons and a sense of wholeness [115]. However, we aim to move away from normative assumptions regarding bringing the body to a "socially accepted" state. For example, the antenna sticking out of Neil Harbisson's head [56] that translates colours into sound (which also gives him the ability to sense infrared waves) suggests that wearing bodily extensions can go beyond replacing a lost limb or conforming to bodily norms. Instead, wearing a bodily extension can be caused by a desire to alter the existing body and evoke unusual experiences, even if worn to gain a particular capability[85]). We point to recent developments that move bodily extensions beyond the current normative bodily discourses or medical applications into art galleries and to a broader audience, allowing people to play with and through their bodies in novel ways (e.g. through commercial interactive tails one can wear "for fun", targeted at the cosplay community[1]). This paper seeks to understand the design of such playful bodily extensions.

Although previous studies have developed and evaluated bodily extensions in different contexts [43, 71, 133] including for play [57, 83, 93, 100, 118], almost no studies explore the design of playful bodily extensions by drawing on existing studies. We believe that understanding bodily extension design from the perspective of play can help lower barriers to their acceptance. Moreover, focusing on play while examining the design of these devices leads us to focus on the experiential texture of bodily extensions, rather than their utilitarian purposes [6, 16]. These experiential aspects relate closely to the phenomenological lenses of body image versus body schema [47], which provides a perspective for understanding the bodily adoption of technologies. We use the lens of these two concepts to uncover the experiential aspects of bodily extensions afforded by

[1] https://cosgear.co/products/buycostail

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play. Body schema refers to the body's inner principle for the organization of its parts; body image refers to the player's perception of the extension relative to the context, including other people, the situation, their look and feel, and their emotions [126]. Also, body schema is related to Merleua-Ponty's understanding of bodily organisation as an internal process [53, 128] while body image refers to the cultural understanding of the body [128]. Within the theory on body image, Weiss points to two sides of bodily perception; inside-out and outside-in perception [128]. As bodily extensions are visible to other people, the wearer will perceive others' reactions to the extension as well as their own perception of wearing it.

To unfold playful ways of experiencing the body through bodily extensions, we conducted interviews with the designers of four different playful bodily extensions. The interviews aimed to uncover the designers' motivations, reflections and experiences with and for designing playful bodily extensions. The interviews also focused on the experience of wearing extensions, as this was part of their design practice. Additionally, we invited the participants to join brainstorming sessions for possible future development of new designs, with the aim of bringing forth more of the designers' tacit insights. Later, we applied thematic analysis to form design themes and discuss their implications.

The scope of this article covers shape-changing computational artefacts that are attached to and extend the body both physically and experientially while yielding playful experiences. In other words, we ask *"What are the emerging practices for designing playful bodily extensions that prioritise experiential aspects?"* By beginning to answer this question, we aim to provide generative and inspirational implications for designers of future playful bodily extensions.

Our contributions are:

- A preliminary articulation of five design themes for playful bodily extensions developed through examining some of the current best practices in this emerging field.
- Sixteen design implications that can serve as inspiration and guidance for designers aiming to leverage this knowledge in their work.

Our work might be helpful for the following people:

- Design practitioners who want to create bodily extensions for play (through our design implications).
- Theorists who want to understand experiences around bodily extensions and researchers who want to evaluate playful bodily extensions (through our design themes).

2 BACKGROUND

2.1 Learning from Prior Work on Bodily Extensions

In our work, bodily extension refers to devices attached to and extending from the body, such as a robotic arm. In particular, as noted also above, we are interested in moving, interactive and shape-changing pieces.

Our work broadly relates to the wearables field since the body extensions are worn on and attached to the body. Wearables, computational devices worn on and attached to the body, represent a wide variety of artefacts, from textile-based smart clothing [82] to interactive tattoos [68]. Thus, our work draws on and can be compared to work about wearables, but focuses more narrowly on body-worn shape-changing technologies that reach out from the body. We further focus on devices that can manipulate body image and body schema, and how they do so. Most wearables are primarily for sensing [7] and are adopted into the body schema or body image. For instance, a smartwatch does not change how we perceive our body moving or existing in space; likewise, Google's Project Jacquard [101] makes its technology almost invisible, as do medical wearables hidden underneath clothes. Some wearables change body image significantly. For example, the Intimacy Dress [106], which becomes transparent based on the wearer's excitement level, probably affects how users perceive their body image, but not the body schema, because the dress is not shape-changing; thus it is outside the scope of our work. On the other hand, the inflatable skirt [124], which is computational clothing, is in the scope of our work. Thus, apart from being attached to the body and shape-changing, we classify bodily extensions as artefacts that perceptibly manipulate the body image and body schema.

Our work is also related to prosthetics. Although many studies assume that prostheses replace limbs to conform to a normative body image [81, 115, 127, 134], we posit that normativity is not possible in the fluidity of bodies [85]. Therefore, having a prosthesis represents an experientially different state. Even if the prosthesis may seem to help conform the normative understanding of how a body looks to others, it creates a fundamentally different state of being for the wearer (e.g., with phantom experiences [97]), rather than resurrecting a part of the wearer's body or functionality [85]. Prosthetics may also enhance the bodily capabilities beyond their original states, as in the case of blade-shaped running prostheses that, it was argued, helped athletes run faster and therefore rendered them super-abled [52].

We also learned from prior work around prosthetics. For example, they can be controlled via a wide range of modalities: brain signals [22, 54], motion sensors [104], myoelectric methods [31, 76] or voice-based modalities through throat microphones [77]. These control methods are inspiring, as they suggest distinct ways of communicating between the organic body and synthetic additions. Furthermore, prosthetics can enable aesthetic expressions [63, 125], such as by adorning them with jewels for a fashionable look [3] or making them resemble superhero armours to support a playful attitude [96]. We are inspired by how these works highlight how designers can use bodily extensions as a design material that transforms parts of the body beyond functional purposes and supports playfulness, as in superhero prosthetics.

We also learned from prior work that bodily extensions can add new abilities to their user's existing skill sets. For example, the modular robotic arm by Leigh et al. [71] has been used for various scenarios, such as carrying multiple items at once. In another study, Ding et al. tried to understand the value of bodily extensions as storage areas around the body [43]. Furthermore, bodily extensions have been used for educational purposes, such as balance training [133]. Another project aimed to support remote collaboration where the extended arms were controlled by another person for creating a sense of bodily collaboration [108]. Interestingly for the purpose of our investigation, Leigh et al. used their robotic arm to help play the guitar [71], highlighting that extension designers are increasingly thinking about playful applications. These prior works demonstrate

that bodily extensions serve many different purposes and interests. However, apart from instrumental benefits, two of the most critical aspects of bodily extensions are the introduction of unfamiliar experiential qualities and the modification of bodily perceptions, the main foci of our work.

2.2 Related Work on Experiential Qualities of Bodily Extensions

Bodily extensions' experiential qualities have been considered in many different contexts, especially in art practice. For example, the artist Stelarc created a performance piece concerned with the experiential qualities of bodily extensions regarding proprioception and agency [113]. He attached a robotic third arm to his right arm, controlled by other people through the internet. This project, apart from extending the body physically, played with the proprioceptive sense in that he had no control of the robotic arm's movements, yet the system employed movements relevant to his own movements. His performances addressed the unusual experiential qualities of having less agency over body movements and his perceptions of altering the body.

Another project focusing on the experiential qualities of bodily extensions is "Child Hand" [98]. In it, designers deployed a miniature hand extension that allowed users to experience what it would be like to have a grip like a child. Designers have also explored emotions that might be induced by bodily extensions. For example, Xie et al. [133] gave users a tail and investigated what emotions were induced by its movements. While these studies suggest an intriguing and unconventional experiential potential for bodily extensions, the field is still underexplored, a gap this paper aims to begin addressing.

3 GUIDING CONCEPTS

This section elaborates on the main theoretical concepts that shape our analysis: play, body image and body schema.

3.1 Play in the Context of Bodily Extensions

We focus on playful bodily extensions because in playful situations people can shield themselves from the ordinary rules and issues of life [62, 114]. Thus, we believe that in play people are more prone to exploring and experimenting with unfamiliar technologies than in ordinary situations [42]. Furthermore, play establishes a protective frame [9], which further supports a perceived safe environment for exploring novel technologies. This is important, as bodily extensions can pose physical risks, such as running into things while wearing them. They can also cause social harm, as wearing bodily extensions can make others suspicious, as in the case of wearing overtly technical extensions (with visible wires, for instance) in high-security environments like airports. Using play offers researchers and designers opportunities for experimentation and exploration without the onus of designing for functionality. Bodily extensions also work well in playful situations, as they can easily be removed when players no longer want to play [80].

Bodily play has been explored in distinct contexts such as social play [65, 90], distributed play [89], wearable play [27, 34] and exertion games [91]. The experience of playing bodily games has also been investigated thoroughly, both via research through design processes that yielded guidelines [92] and through philosophical engagements such as identifying the relation of play to the lived body and the material body (e.g., the German "Körper" and "Leib" [88].) The scope of play, in our work, mostly speaks to the Danish term "at lege (being bodily playful)", meaning being playful through bodily engagement [80]. "At lege" is a bodily attitude of exploring and experimenting with bodily perceptual stimuli without a need to reach a determinate goal or outcome and where the "doing" becomes the means in itself. In contrast, "at spille," as in "doing," entails a determinate outcome for actions, such as kicking a ball to score a goal. If one were to "be playful" with the ball, one would instead explore the perceptual stimulation of kicking and rolling with the ball. When users are "at lege," playful bodily extensions can support role-playing, with players exploring the feelings of different roles while they wear the extensions.

Role-playing offers a playful context for bodily identity play, allowing players to experiment with the look of their body by extending its physicality. Role-play, which Caillois calls mimicry [30], is the play genre in which players alter their own identity by either taking on another identity or playing an identifiable role, as in the cosplay community and various carnivals around the world (e.g., Venice and Brazil) [64]. In the context of "at lege," such play is exploring the perceptual stimulation of being bodily "extended" as an internal process affecting other bodily processes. In this process lies an exploration of the players' body images as they are contested in others' reactions. These processes are explained by Grosz [53] as inside-out and outside-in processes of altering and creating one's body image. Play offers people a frame that omits common discourses and lets them access these processes in a different way [42]. In that sense, play in our work refers to experimenting with bodily sensations without a determinate goal and in relation to identity change and role-play.

Our framing of playful bodily extensions also draws on the frameworks created for bodily play through wearables, such as the design framework playful wearables (DFPW) [26]. In its performative dimension, this framework explains how wearables can be designed to leave room for imagination such as role-playing (e.g., acting as an imaginary character) or creating a detailed and immersive fictional world through elaborate costumes in cosplay. The interactive dimension of DFPW situates playful wearables in an artefact-oriented (e.g., smart watches) or embodied dimension. The embodied dimension includes extended and tangible bodily devices, speaking to our focus. The third dimension, the social, shows that playful wearables can be designed either to facilitate relaxed (e.g., waving hands) or tight (e.g., hugging) social interactions. Parallel to the social dimension, the design framework for social wearables (DFSW) [35] also draws on wearable projects based on games and play [34, 36], especially in terms of agency and the distribution of information. These frameworks help frame bodily play through wearables (and in our case bodily extensions) with regards to performativity (e.g., identity transformation, role-play), social interaction (e.g, signalling to others, computer-mediated bodily social interaction) and agency (e.g., what and who controls the bodily extensions) and have been influential for our analysis.

Figure 1: Wigglears, which moves the ears of the wearer, is mounted on the head of the user during a meeting

3.2 Bodily Experiential Perspectives: Body Schema and Body Image

Rapp [103] understands wearables as body extensions and explains them from two different thought styles, externalist and internalist. The externalist thought style, which the author explains as the dominant understanding, sees wearables as objects, repositories, and instruments that quantify, enhance and enable bodily performances. The internalist style, which Rapp [103] advocates investigating further, "[f]ocuses on the potentialities of wearables indirectly affecting 'the human' and in integrating with their sensory and intellectual experience." We focus on bodily play as rooted in this internalist thought style and activities supporting such experiences. However, Rapp's [103] externalist and internalist thought styles are not to be confused with Grosz's [53] inside-out versus outside-in processes. While Rapp [103] focuses on design, Grosz's [53] two processes focus on experiential factors affecting our body images and lie within Rapp's [103] internalist thought style. Grosz [53] distinguishes between factors from personal versus social intercorporeal perception and how these interrelate. Thus, this paper is within the internalist thought style as we focus on body extensions' sensory and intellectual experience.

While discussions around body image and body schema are manifold [47, 48, 126], we find the understanding from de Vignemont [38] the most useful for our paper. She explains her understanding as two different body representations; "the body schema for action (that is, information about the body necessary for movements, such as posture, limb size, and strength) and the body image for perception (that is, the judgment of one's own bodily properties)." For example, prostheses both alter and affect a person's body schema for action; at the same time, they affect body image as the prostheses alter and augment judgement and perception of the body. From this view, playful bodily extensions play with bodily identities, as in cosplay and carnivals, where people wear costumes to alter judgments of their body images.

Rapp [103] argues that body extensions are often seen as instruments for improvements or to collect body data, that view relies on the externalist thought style. In this paper, however, we adhere to the internalist style, viewing body extensions as vehicles for exploration and experimentation. That emphasis also aligns well with somaesthetic appreciation, which has gotten traction in embodied HCI and prioritises bodily and sensory experiences in design [39, 61, 122]. Thus, the bodily extensions examined in this paper are not investigated for a particular purpose but for their opportunities to play with body image body schema and playful bodily sensations created as a result of the alteration of those constructs.

4 FOUR PLAYFUL BODILY EXTENSIONS

This section presents this study's four playful bodily extensions. We chose those projects because of their focus on experiential qualities, their potential for creating playful situations, the differences in where they are worn on the body and their movement patterns, and their diverse experiential targets. We determined the final set through internal discussions. We considered all projects' relation to bodily play, role-play and exploration of playful relationship between body image and body schema as important criteria for inclusion. The alternatives we considered included technologies that extend the body in virtual realities [10, 11], use external objects

Figure 2: Two players are eating food by using the robotic arm of Arm-A-Dine

such as drones for extending the body through invisible strands [69], or create immaterial extensions through lasers [123]. However, we decided to limit our scope to physical extensions, as including projects with more virtual or immaterial characteristics would complicate our definition of bodily extensions. When choosing among similar projects, we prioritised those with more playful applications. For example, we chose to analyse The Tail produced by Svanaes and Holheim [118], developed for stage performance and then used by cosplayers, instead of the one produced by Xie et al. [133], which focuses more on training and abilities.

4.1 Wigglears

Wigglears (Figure 1), which wiggles the user's ears based on biodata, explores the intersection between biodata, ear movement and playful expression [100]. The inspiration came from the fact that humans have limited control over their ears. While most ears move, only some people can control their ears consciously, and it is usually only a very subtle movement. Interestingly, animals' emotions are often conveyed from their ear movements (see [70, 105]). A person who can wiggle their ears "on command" can potentially be a source of great enjoyment for others. Wiggling ears also alter the body schema by introducing a new way of moving a body part, and the effect on body image is profound, especially when other people realise that the wearer's ears move in an unconventional way.

The system consists of two small motors attached to a headband that moves the ears. Via sensors on the index and middle finger of the user, a microcontroller (Arduino) senses galvanic skin response (GSR), which controls a set of motors moving the ears. When the user exhibits a certain level of excitement, the galvanic skin response is set to increase, causing the ears to wiggle.

Wigglears was evaluated via an autobiographical study in which the designer wore the system for a minimum of three hours per day for two weeks. The designer kept records of the experience in a diary. Two prototypes were tested this way. The records were subsequently analysed. As such, the Wigglears system was studied in the wild and through the iteration of two prototypes.

4.2 Arm-A-Dine

Arm-A-Dine (Figure 2) explores the use of bodily extensions around the social experience of dining [83]. Arm-A-Dine [83] gives users a third robotic arm that feeds another person, and investigates the practice of sharing food and eating together through playful behaviour. It also alters body image and schema, since it affects balance, ad movement and, since the arm can be controlled by onlookers, the meaning of the body to others. Each person wears a robotic arm attached to their vest and the system works in the following way:

"Once the arm picks up a particular food item, it feeds it to either the wearer or their partner. After picking up the food, the wearer's arm performs actions based on the partner's facial expressions captured by a camera attached to the wearer's vest. If the partner makes a 'sad' expression, the arm will feed the wearer. If the partner expresses 'happiness', the arm will feed the partner. However, if the system senses neither a particularly positive or negative expression, the arm will move back and forth in the middle as if to tease both participants. It then makes a random choice and feeds either the wearer or the partner [93]."

Arm-a-Dine was studied in the lab with 6 pairs, 12 participants total, between 21–27 years old. The participants, who knew each other, were asked to eat casually with no further instructions. The study was followed by a semi-structured interview.

4.3 The Tail

The Tail (Figure 3) was initially developed for theatre play. The first version was a mechanical tail for the main character in Ibsen's Peer Gynt. The result was an 80 cm–long tail worn on a belt around the hip. It was made from piano wires and 3D-printed joints controlled by two servos that were controlled externally via remote

Figure 3: The Tail with different postures [19]. Photo: Kai T. Dragland, NTNU

control. It was subsequently tried on stage in two rehearsals. However, the actor preferred to be able to control the tail himself. This was implemented in the second version of the tail, which used accelerometers and gyroscopes placed on the hip for control. The tail in that sense has been a source of bodily role-play since the body movements required to control the tail influenced body schema and how the wearer moves. This particular way of moving also affects the body image since different ways of moving might lead to voluntary identity change [66].

The designer wore the tail on several occasions and demonstrated it at a CHI conference [117, 118]. As such, the tail was studied in the wild, though the user study was not published. Nevertheless, the tail was originally developed and used for a theatre performance, which also led to several iterations of the tail including a remote control - and the removal of it. Despite there being no official records of a comprehensive user study except the report from the theatre performance for which the tail was first designed, the tail has now been developed commercially and is available worldwide.

The commercial version of the tail is described on the website like this cosgear.co[2]: *"The Costail moves according to your movements which means that if you move a lot; the tail moves a lot, and if you slow down, the tail will calm down with you. You are in total control, and with practice, you can become quite the tail whisperer. As a second option, you can loosen the chord that makes the tail move. This will reduce the movement as well. You can of course change this back later.*

Besides telling how the Tail works and moves, the above quote indicates the commercial potential for these extensions for play, including adult play [74]—confirming the need to establish best practices for designing such extensions on an informed basis [42].

4.4 Monarch

Monarch (Figure 4) is a set of shoulder pads that explores how wearable technologies can physically extend the wearer's body and allow them to play with personal expression. In that sense, although Monarch affects the body schema by making the shoulders bigger, the focus is on altering the body image for expression. When relaxed, Monarch looks like regular shoulder pads; when activated, they expand and reveal a colourful, complex pleated interior. When expanded, the shoulder pads frame the wearer's face, emphasising any difference in moods. The shoulder pads expands and contracts in response to the movement of the wearer's muscles via kinetic textile that is activated by muscle movement [57].

Technically, the shoulder pads contain two servo motors that each rotate a wire arm inside the textile—all connected to a microcontroller and muscle sensors using electromyography (EMG)—to detect muscle movement of the biceps. A laser-cut acrylic textile was used for the first version [58]. However, it was too inflexible. For the second version, the designers used digital fabric printing on cotton poplin. This resulted in reduced production time, more freedom in visual design and colour choice, and lighter weight, easing the manipulation by the servo motors. Furthermore, the system included a control panel containing an on/off switch, a calibration knob for adjusting sensitivity, and a switch that gives the user a higher degree of control.

Monarch was studied by the designers who wore it during several exhibitions [57, 58]. As such, the reports of Monarch in this paper are based on the designer's own experiences of wearing the system in the wild, not lab testing. Monarch was refined into a version 2.0 which is more comfortable and sustainable for everyday life.

5 METHOD

We conducted semi-structured interviews [73] with the designers of the four systems. Recently, HCI has moved toward taking designers' first-person experiences into account to convey design knowledge [40, 41, 75, 109]. Especially when it comes to embodied design, the designer's lived body is seen as an important resource for design, according to Höök et al. [60]. This practice speaks to the third wave of HCI [17], in which subjective experiences are of critical importance. Designers can give a detailed and nuanced first-person account of experiences that evolved through their design processes. Furthermore, those first-person experiences can be useful for empathising with users [40, 41, 75, 109]. Interviewing designers can also reveal a deep understanding of the topics they

[2]https://cosgear.co

Figure 4: Two Monarch users interacting through the bodily extension [2]. Photo: Maxwell Lander

are working on through their lived experiences and actions [84]. Furthermore, talking to designers can be very efficient, especially when seeking an initial understanding of a topic [1, 18, 92], as it allows access to otherwise inaccessible information. This difficult-to-access information is tacit knowledge [32, 49] that might be hidden in unreported and hard-to-verbalise practices (e.g., rapid iterative design processes, first-person designer tests of artefacts, or trial and error that led to certain design decisions).

We acknowledge that focusing on designers (instead of users, such as larp (live-action role-playing [78]) players or cosplayers) might not surface knowledge about usability or overall user experience. Instead, however, we reveal design practices and their possible ramifications, which we believe speaks to an underexplored area of playful bodily extensions. Future studies with users can complement our approach. Furthermore, we note that all designers wore their systems as part of their practice or observed other people who wore them, hence providing a wearer's perspective to some extent, although this cannot fully substitute for engaging with end users.

5.1 Procedure

We conducted two 1-hour interviews with the designers of Wigglears and the Tail, and a 2.5-hour session in a group interview setting [46] with the designers of Arm-A-Dine and Monarch together. Our aim was to gather all the designers to prompt discussion, however, due to the time zone differences this was not possible. We invited our participants using neutral language and did not promote them as "experts," to prevent any influence. Each interview was online and started with a 10-minute presentation by us that communicated the aim of the project and explained the concepts of body image, body schema, and play. We described all projects included in this study to the participants so that they had a shared understanding of the designs. We also gave participants the chance to ask questions regarding these topics; none of the participants disputed our definitions of body schema, image and play. The only questions we got were about learning the details of projects (e.g., their working mechanism or interaction style). The interview questions were aimed at unpacking the design process. Specifically, we asked participants to 1) describe the most important highlight of their design process, 2) the key challenges they faced, 3) the parts of their prototypes which they would like to design differently, 4) examples of occasions on which their prototypes induced playful experiences and 5) recommendations for designers who would like to design playful bodily extensions. At the end of the interviews, we left time for brainstorming about possible future playful bodily extensions that the designers would like to explore by asking them to ideate freely on the playful scenarios that playful bodily extensions can create.

#	Designer	Project	Background
D1	Anonymous Designer	Wigglears	Software Engineering Student with experience in designing the bodily extension included in this paper.
D2	Dag Svanaes	The Tail	Professor of Human-Computer Interaction at the Norwegian University of Science and Technology, focusing on embodied interaction. He has deep expertise rooted in the design of bodily technologies, a phenomenological understanding of such artefacts and working with these topics for more than ten years.
D3	Yash Mehta	Arm-A-Dine	User experience researcher focusing on playful eating experiences with the experience of designing and analysing several projects with body integration technologies.
D4	Kate Hartman	Monarch	Associate Professor and Director of Social Body Lab, OCAD which focuses on the production of social bodily artefacts. She has been designing bodily technologies for more than ten years.
D5	Izzie Colpitss-Campbell	Monarch	Computational fashion, user experience and game designer with experience in designing bodily computational artefacts for more than ten years.

Table 1: The list of the participants

5.2 Participants

We included five designers. Designers varied in their experience of designing playful bodily extensions and their backgrounds, which helped us to gain different perspectives on the topic (Table 1).

5.3 Analysis

We conducted an inductive reflexive thematic analysis (TA) on the transcriptions [20]. TA has different approaches, such as codebook, inter-rater coding or reflexive thematic analysis [21]. Although mashups between different types are possible, epistemological groundings of the combined types should not contradict each other. For example, while the inter-rater coding method prioritises the objectivity of the analysis by aiming to eliminate the bias of the analyser, reflexive TA emphasises deep and organic engagement with the data, heavily affected by the stance of the analyzer. Thus, mashing up these two methods without justification indicates a problematic analysis process.

In reflexive thematic analysis, the perspectives of the researchers who analysed the data and contributed to the creation of knowledge are of utmost importance [21]. The first author, who conducted the thematic analysis, has been working on bodily technologies and playful wearables for nine years. The second and third authors, who participated in the formation of design themes, are respectively a PhD candidate and a game designer who has worked on the bodily play for the last 10 years and is the director of a research lab that focuses on movement-based games and bodily technologies. Therefore, the analysis was driven by knowledge regarding playful wearables and bodily play.

We mostly followed an inductive reflexive thematic analysis. We did not create a prior codebook or have more than one coder. The coding benefited from the capabilities of Atlas.ti [3];and through Atlas.t, functions, our process borrowed steps from a codebook thematic analysis (in which a codebook is created prior to the analysis [21]). During the coding, by using the association functions of Atlas.ti, we already started to form relations among codes, which produced a network graph of codes and sub-codes. Therefore, although we did not create a codebook in advance, we generated a coding structure during the analysis.

The process started with uploading the interview audio files to a transcription service[4]; these were pseudonymised and deleted from the database following transcription. As suggested by the reflexive TA by Braun & Clarke [20], the first author went through the transcriptions along with the recordings and corrected the text when needed. After transcriptions were checked, the text files were transferred to Atlas.ti. The coding process followed open, axial and selective coding [131]. First, all data were inductively coded by the first author, as suggested for the open coding phase. At the end of this phase, a total of 227 codes were produced. The axial coding was done by using the Network Graph function of Atlas.ti. This process allowed us to see the main relationships between codes and demonstrated the recurring topics. The eight main recurring topics (not themes),—namely, "social interaction," "body image," "body schema," "interaction modalities," "context," "design process," "wearability" and "bodily feelings"—were transferred to Miro[5] with the sub-codes for the selective coding process. For example, the "Context" topic included 29 sub-codes. During the selective coding process, we further grouped topics to create more nuanced subtopics, namely "intrinsically playful," "socially acceptable," "daily life," "serious" and "social." Thus, before generating the themes, we had a three-level affinity diagram that included main topics, subtopics, and sub-codes.

After this multi-level coding process, we started theme generation. In the theme generation process, the codes that occurred across interviews were marked along with their frequency to understand their prevalence. In Miro, each main topic was examined by the first author based on the prevalence of the codes. While generating the themes, the first author reflexively examined the affinity diagram and re-checked the quotes assigned to codes for further sense-making. The sense-making process led to takeaways from the main topics that were summarised into a presentation that shows the possible practical outcomes and the meanings. This presentation was discussed among co-authors and the comments of each author were noted as comments in the presentation. After this meeting, by using the comments and suggested readings by co-authors, the first author worked on the main findings and the revisions on these findings led to themes. The generated themes

[3]https://atlasti.com

[4]https://temi.com

[5]https://miro.com

were again discussed with co-authors in another meeting and the co-writing process of themes started. The themes were written by all co-authors (with the lead of the first author) in an online collaborative text editor.

The "network graph" of Atlas.ti and the "thematic map" we created based on it can be examined in the supplementary material.

6 DESIGN THEMES

In this section, we articulate the design themes that we derived from the data. First, we describe the themes and discuss them by explaining the subtopics that are related to these themes.

6.1 Theme 1: Designing the Extension as a Social Organ to Facilitate Communication

Our conversations with the designers (D1, D3, D4, D5) revealed that bodily extensions could be seen as designed "organs facilitating social interaction." As such, the extensions can free up, replace or extend existing bodily social interaction mechanisms such as social gestures or physical contact. They may also facilitate or augment the social signals one can produce, such as by producing movements that correspond to reactions such as blushing. In this way, bodily extensions can augment wearers' social interaction capabilities and provide an additional mode of expression and even a new bodily language. While social communication mostly concerns body image, due to its inherent focus on being perceived and seen by others [128], here, bodily extensions also afford social capabilities that emerge through their impact on the body schema, for example, by exaggerating sensations of the body or becoming limbs reacting to social cues. The impact on body image and schema brings distinct ways of social play [65], either through self-expression (as in roleplaying) [27, 30], proximity [95] or embodied coordination [45]. To elaborate on this, we present three sub-themes: Exaggerating expressions, sensing others' social cues and exclusive (non-verbal) modes of communication.

6.1.1 Exaggerating Expressions. Extensions can exaggerate the subtle reactions or movements of our body to playfully signal to others. For example, the Wigglears system makes the subtle reactions of our body noticeable to others. The designer said: *"Cause they'll be like 'Oh, you just lost all your money [in Monopoly]' and your ears are wiggling."* This unfamiliar feeling of unintentionally revealing emotions by moving your ears (which normally do not move) makes the Wigglears appear as a novel social reaction organ. In addition, the unfamiliarity and the funny look of the wiggling ears induced playfulness. The designer explains *"And I guess it kind of drew out the fact that I was feeling something, drew all the attention towards what I was feeling and then kind of made it playful because my ears were wiggling and that's funny."* This quote also points to how bodily extensions encourage bodily experimentation leading to playfulness, and thereby, add a "safe" (if being playful is suitable) frame for the wearer to showcase their bodily expressions.

6.1.2 Sensing Others' Social Cues. Extensions can also react to cues sensed from external sources, e.g. other players. In this way, extensions can react to input that might not be easily recognizable by human perception. Arm-A-Dine, for example, explores how bodily extensions can react to external cues without needing any prompts from our bodies. In particular, Arm-a-Dine allows one's own bodily extension to react to somebody else's emotional state. In that sense, the system is a sensory addition to our body, a social organ, that scans the external environment around the body and gives reactions depending on the social situation. The designer of Arm-A-Dine explained how this combination came about: *"So it started according to the expressions of the other person. And for 10 minutes, we all, like, everyone was thinking: 'What exactly is really happening? Who is controlling the robotic arm?' And that ambiguity created so much laughter, laughs... And then we made the next prototype where my expressions control your, your arm, your expressions control my arm. And through that way, it became playful, it became an engaging social experience."* While the Wigglears explore the wearer's emotions as a means for bodily expression, Arm-a-Dine explores the bodily expression of others as a way to socially interact. Furthermore, Arm-a-Dine adds a (non-verbal) intercorporeal dimension to a social situation by mixing the expressions and reactions of two people. Here, intercorporeal refers to our ability to communicate with our bodies on an unconscious level.

6.1.3 Exclusive (Non-verbal) Mode of Communication. Extensions' behaviour can also turn into a communication method exclusive to wearers of those extensions. One of the designers mentioned that Monarch gave them an extra mode of expression while they were using it at a Halloween dance party. This allowed them to offload the responsibility of social interaction to the extension: *"It was actually really fun to put the movement on the device and take it off of me. So I could just kinda like bop in the corner, but then do weird things with these wings and in some way it became my outward, my kind of outgoingness, through a device rather than my default body."* Thus the extension functioned as an exclusive mode of bodily communication. When worn by a group, Monarch created a mutual language among wearers to communicate through the extension. The designer explains their experience from a barbecue at which multiple people were wearing the extensions: *"I felt like the people who weren't wearing them felt weird because we had this extra mode of expression that they couldn't access, you know, so, like, they couldn't respond because they didn't have this prosthetic or this extension. So it became this kind of like, not a secret, but more like an open channel of communication between those of us who were wearers and that this other sub-group didn't have access to. So it created this weird hierarchy of nonverbal communication."* Monarch, in this setting, allowed for an intracorporeal connection and hence facilitated a bodily understanding that allowed wearers to communicate in a way others could not. In the same way that such extensions can bring about bodily understanding, they can exclude those who do not wear them.

6.2 Theme 2: Allowing Varying Levels of Agency on the Extensions

User control over the bodily extensions is a critical element in incorporating them into the body. Intuitively, it seems that this incorporation should be a straightforward process, and the interaction between the body and the extension should feel instinctive. Although this is true to some extent, especially when it comes to giving users a chance to operate their extensions in the way they want (D2), taking a portion of the agency can also lead to playful

moments (D1, D4, D5) that can facilitate being mindful about one's own body or the bodies of others (D3). Thus, during the design process, it is essential to explore the different experiences facilitated by different levels of agency. Different levels of agency call for the manipulation of the body schema, mostly at unexpected times, and align with bodily play that focuses on the exploration of bodily sensations (described by the Danish concept "at lege") [80]. On the other hand, adjusting to using the extension and having a high degree of control over it might allow shifting the focus from body schema to body image, again mostly through identity change and self-expression [25, 66, 128]. We investigate this theme through three subthemes: Designing for unintentional interaction, accidental activation and high degree control for intuition.

6.2.1 Designing for Unintentional Interaction. Unintentional activations of the extensions can be designed intentionally to evoke unusual and playful bodily feelings. While using Wigglears, the designer frequently noticed the unexpected movements of the ears. According to the designer, those unintended movements attracted attention to her ears and prompted reactions. When we were ideating on other possible uses of the Wigglears, the first idea that came to mind was a *"try not to wiggle ears"* challenge, where the wearer tries to control their emotions to keep their ears stable. This idea demonstrates how trying to control the extent of agency can lead to playful moments. This is also an example of using these extensions as more gameful artefacts (with a purposeful outcome of not moving them) compared to the current playful nature that puts the emphasis on their experiential texture of being moved unintentionally.

Arm-A-Dine is the only project that explicitly takes the agency from the wearer and gives it to another person. According to the designer, this shared control with another person was part of the fun and it also created a space where the wearer was more mindful of the expectations and desires of the other person with whom they were playing. The designer of Arm-A-Dine describes the players' experience: *"It facilitated social interactions and broke down the ice, it helped them to, you know, understand or know a lot more about the person. So I would say that this also works as an agency for educating how the other person is feeling about you and how you're feeling".*

6.2.2 Accidental Activation. Playful moments can be facilitated by the accidental actuation of the extension. Although the Monarch used an interaction modality that allowed for more intentional interaction, the moments when the system was activated accidentally were described as playful. This unintentional activation sometimes prompted reactions from other wearers, especially in a group setting where others also wore the Monarch. For example, participants also started flapping their Monarchs to respond to the accidental activation of the first wearer. The designers reported that unexpected movements of the extensions created playful experiences.

Nevertheless, careful consideration of how much users can adjust the level of control can be important, because a lack of agency can sometimes lead to unpleasant experiences. For example, the designers of Monarch noticed that taking the agency away from participants might be alarming in specific contexts: "*We designed a particular control panel, which meant that there was [an] easy-access 'off' switch, you know if the things had gone crazy. Cause we found that people would get really uncomfortable when they started doing things that they didn't want it to do. So there was also, you know, like a sensitivity knob, so that they could, kind of, tweak it.*"

6.2.3 High Degree of Control for Intuition. A higher degree of control can also lead to playful experiences that are more focused on the lived experiences of bodily movement. The Tail project gave a high degree of control to the user, and the iterations in the design process highlighted this. In the first version, the Tail was controlled by remote control, which did not give the user enough control. Therefore, the designer implemented a mechanism in the next iteration that allowed users to control the tail with their hip movements. In the Tail, playfulness is defined as experiencing the tail and adjusting to it. Therefore, one of the primary aims of the design process was to make the user feel that the tail would be a part of the body over which they had intuitive control. Thus, a high degree of agency over the tail was an essential element for the experience of acquiring a new body part, which was defined as intrinsically playful by the designer.

6.3 Theme 3: Different Phases of the Incorporation Process Can Facilitate Playfulness Differently

Incorporating bodily extensions into the body schema is a process. It starts with onboarding, which is the first moment when users are acquainted with the physical entity that reaches out from their bodies. Onboarding (the beginning of the experience [14]) to play is frequently voluntary and in our study represents the intention to play. Onboarding may also be contextual; for example, the extensions can be activated when the play starts or when entering a playful context. After a moment, a learning process starts for incorporating the new body extension into the body schema and making the body interact with it; we call this the adjustment period. The final stage is concerned with removing the extension, which we call offboarding. Users may offboard when the extension is not suitable to a given context (e.g., when sleeping or when the play/game experience ends) or when the extension needs to be maintained (e.g., changing batteries). An extension might also be shared, and while one player offboards another one can onboard (and this process represents transitions among users and contexts [14]). Offboarding can disrupt the body image and the body schema, since the users may experience a deficiency after removing the extension. This theme concerns how sudden shifts in body image and schema can induce or lead to playful experiences regarding the changes in the balance of the body [29, 93] (D1, D2) while some of the effects can be mitigated with playful behaviour (D3, D4, D5). Three sub-hemes constitute this theme: Explorative joy at onboarding, feedback for adjusting to the bodily extension and feeling extensionless.

6.3.1 Explorative Joy at Onboarding. During the onboarding phase, wearing the extension for the first time can induce excitement and pleasure. The designer of the Tail described how the process of walking with the tail and understanding how the body can control it induced playful experiences: *"It is an interesting experience, just the experience of walking with a tail and to learn to master how to move it, that in itself is play."* Similarly, the first moment when users started using the robotic arm in Arm-A-Dine was also associated with

playfulness facilitated by the exploration of using the robotic arm: *"I think all of them [users] were really explorative, very expressive. They were very curious to try out different ways to figure out ways on how to trick the system, and it created a lot of joy, laughter, and anger sometimes when they didn't get the food that they wanted"*.

Acquiring this bodily extension sometimes resulted in negative feelings such as frustration. In response, the designer adjusted how challenging it was to learn to use the extension. He said that if learning how to use the extension is too hard, it may repel users and prevent further effort, whereas if it is too easy, it may result in boredom. These remarks also corroborate with the flow theory suggesting that an optimal experience could balance anxiety and boredom [33].

6.3.2 Additional Feedback for Adjusting to Bodily Extension. The next phase of incorporation is the adjustment to the bodily extension. Although extensions might become a part of the body, additional prompts might be needed to facilitate control over them. For example, the Tail designer said that he would want to improve the tail by adding haptic notifiers that would inform the user about the tail's position. Although those extensions are adopted proprioceptively after a while, since they are not part of the organic body, they might need additional feedback mechanisms such as haptics or sound that would help wearers acquire the feeling of having their body extended.

The designer of the Wigglears said that additional feedback modalities could also be used to playfully conceal the undesired effects. For example, the Wigglears' servo motors, which were positioned close to the ears, produced a noise that was not the intended experience. The designer mentioned that sometimes she realised that her ears were moving because of the noise. In the ideation process, where we were brainstorming about how to improve the design of the Wigglears, the idea of playing a pre-selected sound—maybe something funny and enjoyable and that might also resemble sounds produced by other body parts, e.g., slurping—came up as a possible solution to this issue. Secondary input and output modalities, then, may affect the experience of incorporating the extension negatively or positively and drawing on playfulness for diminishing and amplifying those modalities might add to the experience of incorporation.

6.3.3 Feeling Extensionless. The designers of Monarch and the Tail talked about the bodily experiences that can occur after removing the extensions. The Tail designers mentioned feeling "tailless" upon removing the tail after extended use. The designer of Monarch similarly mentioned that the extra mode of expression granted by this extension could be something that people get accustomed to quickly: *"One thing that I found interesting in the process was the moment when people were taking them off. Even though wearing was relatively short, just because of that physical expressiveness, they became attached to the object quite quickly. So there is a sense of loss in terms of, like we had people being 'I don't want to take it off.'"* Similar to onboarding, offboarding can induce a remarkable bodily experience, the sense of losing a body part or an augmented ability. Those transitional moments can be mitigated with pre-programmed behaviour, such as the curling up of the Tail or a "good-bye flapping" by Monarch wings (an idea coined by the authors of this paper).

6.4 Theme 4: Considering Lived Playful Dynamics of Different Contexts

While contexts such as game settings or parties may quickly render the movements of the extensions enjoyable and attractive, more serious contexts such as a lecture or work environment may not accommodate them (D1, D4, D5). Contextual changes or discrepancies mostly concern body image, and while contexts that may afford playfulness (e.g., a work environment with close colleagues) could allow wearers to express themselves more freely, non-playful contexts might make them too conscious of their body image. On the other hand, related to body schema, the bodily feelings induced by extensions might boost the experience of playful contexts (e.g., playing a board game). Furthermore, if the lived experience of context does not fit the sensations induced by extensions (e.g., unintended activation while listening to a lecture), they may cause distractions. Thus playful experience is strongly tied to being in the magic circle of play [62, 107]. Three sub-themes were generated corresponding to this main theme: Lived experience of playful and serious contexts, multiple wearers in the same context, and sudden transition among contexts.

6.4.1 Lived Experience of Playful and Serious Contexts. The lived bodily experiences induced by extensions may fit or contradict the context, independent of social acceptability. The designer of the Wigglears reported that a game context facilitated reaction from others to the wiggling movement of the ears. The ambiguity behind the wiggling ears prompted other players to deduce that the movements were facilitated by their reactions to the gameplay. In this environment, the extension led to laughter, and its movements were interpreted based on the game (e.g., losing a building in Monopoly). On the other hand, the wearer was distracted when the ears started to move during an online lecture. After noticing that the ears were moving, her attention focused on the movement. Instead of following the lecture, she tried to understand why her ears were moving. In this instance, the user's reaction to wearing the extension was not about whether it was socially accepted, but how the lived experience did not fit the context.

6.4.2 Multiple Wearers in the Same Context. When the experience induced by the extension is shared by others, playful experiences may occur in non-play contexts. The Monarch designers reported two opposite experiences that differed due to the number of people wearing the extensions. One of the designers tried out the extension in a work environment in two different setups: one setup where she was the only one wearing it and one where others were also wearing it. When she was the only one wearing it, she felt like she was disturbing others, similar to the feeling of using a loud keyboard. By contrast, when more than one person wore it, it triggered a break from work that everyone else around the wearer enjoyed. As such, when the context was not associated with play (i.e., a game or play setting) playful use of the extension was affected by the number of people wearing it.

6.4.3 Sudden Transition among Contexts. Another reported experience with the Monarch revealed how intrinsically playful environments can coexist with more neutral environments. For example, during a conference that hosted an interactive exhibition, the wearer needed to walk across other conference areas. The designer explains

this feeling: *"And just this feeling of, like, crossing the boundary from this space where it's kind of expected to, just mingling with all these other things. And it was just feeling super weird, but, suddenly the playfulness faded away and it was just strange. I think that the kind of invisible boundaries [of] play spaces are really interesting."*

6.5 Theme 5: Playing with Identities through Bodily Extensions

Identity has already been a subject for research on wearables, as they are closely connected to self-expression, fashionability, personal styles and the ability to directly alter the wearer's bodily perception [50, 121]. It also has a close connection with role-play and character identification [27]. Designers similarly mentioned instances where their extensions led to transformations in identity (D2, D4, D5), mostly through internal bodily experiences. These transformations suggest that the extensions' effect on the body schema was also quite influential. This modification in identity is also closely related to role-playing [27, 66] and bodily enactment [25, 67] for example through material properties [132]. This theme consists of two sub-themes: Transformation through movement, and attitude change induced by the behaviour of bodily extension.

6.5.1 Transformation through Movement. Controlling the Tail requires performing unaccustomed movements. The user must move their hips to activate the Tail and perform unfamiliar postures, which can yield a tension that plays on the wearer's identity. The designer of the Tail said that *"[a distinguished researcher] has a very good description in her book about her experience of trying it [the tail] out and how it sort of changed her feeling of being female."* This example points to how wearers can explore identities through the way they move [28] while wearing the extension, aside from how it alters their looks. The latter effect is well-known from the practice of wearing costumes; the former is a less familiar aspect that is more exclusive to extensions.

6.5.2 Attitude Change Induced by the Behaviour of Bodily Extension. Although Monarch did not facilitate significant posture changes or body movements, the system was still deemed to alter the identity of the wearer by changing how they usually communicated with the outside world (as in inside-out thinking on body image [128]). This alteration might also partially relate to the disinhibition effect, which suggests that individuals can behave more impulsively on online platforms due to anonymity [116]. (In this situation, the wearer is not anonymous, but may consider the extension independent from the real self). For example, one of the designers of the Monarch mentioned that the wings made her behave in a more extroverted way: *"I think even if you aren't extroverted, it almost, like, makes you that way. Cause I do not, [the other designer] or I, would identify ourselves as an extrovert..."* The designer also mentioned that they chose to develop Monarch rather than other projects because the interaction provided by the wings seemed more extroverted and more playful. This intentional choice of extroverted interaction through wings also affected the first-person experiences of the designers about how they identified themselves in social situations.

7 DESIGN IMPLICATIONS

In this section, we present practical design implications in the form of actionable knowledge, responding to prior research that has called for more actionable knowledge in design research [110]. We also point to the relation of these implications to the themes we generated, because the knowledge that led to these implications is rooted in our themes. In the "Description" column we qualitatively explain how the implications are related to the themes. In "T#" column, we visually represent how much these implications are influenced by the themes. The purpose is not to create an analytically precise mapping between themes and implications, but to give readers an understanding of the roots of those implications. Moreover, we would like to note that these implications should be considered a stepping stone. Thus, they are subject to change and expansion with the introduction of more studies to the field of playful bodily extensions and with further user tests.

Table 2: Design Implications

#	Implication	Description	T#
1	Exaggerate Emotional State through Bodily Extensions	Exaggerating the emotions of the wearer and others (*Theme 6.1.2*) through the bodily extension can lead to playful moments as explained in *Theme 6.1.1*. For example, an imperceptible change in your mood such as a sudden excitement can be embodied through the movements of the extensions, which is an exaggerated form of display of emotions. Play, enjoyment and fun provide a safe frame for designing such exaggerated behaviour.	 6.1.1  6.1.2

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#	Implication	Description	T#
2	Create Exclusive Communication Modes with Extensions	Designing signalling patterns (e.g., lights, movements, sounds) can create a playful exclusive language among wearers (*Theme 6.1.3*). The additional mode of communication provided by bodily extensions can extend wearers' abilities to both express themselves and understand others (*Theme 6.1.2*) in ways that they could not without the extensions. A playful frame provided by those extensions can help wearers open up (*Theme 6.1.1*) their communication with the support of new ways of expressing themselves.	 6.1.1  6.1.2  6.1.3
3	Make Extensions Shareable to Avoid Exclusion	If a group of people wears extensions and communicates through them in a crowded setting, others who do not have access to this mode of communication can feel excluded (*Theme 6.1.3*). Designing sharable extensions can prevent the possible social exclusion that might be felt by the others	 6.1.3
4	Use Extensions as a Separate Entity for Social Interaction	An autonomous extension, although attached to the body of the wearer, can still behave as a separate entity. In these cases, the extension itself can become an object of social interaction. For example, it might poke your body with its own agency (*Theme 6.2.1*) to make you aware of social situations which are sensed by the sensors (*Theme 6.1.2*) of the extension.	 6.1.2  6.2.1
5	Benefit from Unintentional Activations of Extensions	Activation based on unintended emotional reactions (*Theme 6.2.1*) or unnoticeable body movements can become a resource for playful experiences (*Theme 6.2.2*). Even if the extension is designed for intended activation, body sensors might be subject to accidental activation, and designers might take this opportunity instead of trying to eliminate it. For example, borderline sensor values that are not meant to activate the extension might be programmed to a behaviour that can be perceived as more playful.	 6.2.2  6.2.1
6	Allow external control for social and shared experiences with extensions	Lack of agency might manifest itself with accidental activation; however, it can also be designed for specific purposes. One such purpose was giving the agency to someone else, which resulted in the increase of shared experiences through extensions (*Theme 6.2.1*).	 6.2.1
7	Experiment with a wide range of interactions between body and extensions for benefiting full agency	In cases where full control on the extension is provided, the source of joy is experimenting with the interactive modalities between the extension and the wearer (*Theme 6.3.1).* Exploring how the extension reacts to the inputs from the body and experimenting with altered proprioception led to intrinsic playful explorations (*Theme 6.2.3).*	 6.2.3  6.3.1
8	While experimenting with lack of agency, find the right balance for not alarming players	Extensions are attached to the body and might make rather large movements. Accidental activation of a smartphone light is less critical than the activation of a robotic arm or a shoulder pad attached to the body. Thus, while the lack of agency can lead to playful moments (*Theme 6.2.1 and 6.2.2*) as also indicated in implication #5 and #6, it can also alarm players in situations when they are not able to take back control.	 6.2.1  6.2.2

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#	Implication	Description	T#
9	Have a right amount of challenge during onboarding phase	Onboarding is the phase where the wearers met with the extension for the first time. Introducing a sufficient amount of challenge that will create curiosity but not struggle could help with creating a surprising, fascinating and rewarding onboarding experiences *(Theme 6.3.1)*	 6.3.1
10	Make use of extra feedback modalities during adjustment to altered proprioception	Using artificial feedback modalities (e.g., haptic, sound) that complements kinaesthetic feedback can support the adjustment to the altered proprioception with the new extension (*Theme 6.3.2*). For example, it might be hard to notice if extension ears are moving or understand the posture of a tail, so the addition of sound, haptics or visual feedback might be needed to navigate with the altered proprioception and adjust the challenge in onboarding (*Theme 6.3.1*)	 6.3.2  6.2.3
11	Use playful interactions for offboarding to improve post-extension experience	After wearers get adjusted to expressing themselves through extensions, they might feel that they are missing a body part after the removal of the extension (*Theme 6.3.3*). Designing playful offboarding moments (e.g., a goodbye gesture) can mitigate feeling "extensionless" after removing the extension.	 6.3.3
12	Design different modes for extensions that can match the contexts and the lived bodily experiences	When the extensions are activated in inappropriate scenarios (e.g., while following a lecture), the lived experience can contradict the context *(Theme 6.4.1)* even if the extension is not visible to others. Different modes (e.g., work mode, listening mode, party mode) that would induce context-appropriate feelings in wearers can be designed.	 6.4.1
13	Design easily activated idle/off modes for extensions	Extensions may be worn in situations where the context can easily change (*Theme 6.4.3*). For example, at conventions, one might unknowingly step out of the exhibition area, leading to embarrassing situations (*Theme 6.4.1*) where the extensions or their behaviour do not fit the social context. Designing easy ways to turn off, take off or change the behaviour of extensions can help accommodate the unintentional exits from the magic circle of play.	 6.4.3  6.4.1
14	Design shared extension experiences to increase social acceptability	Shared experiences might render an extension more acceptable (*Theme 6.4.2*). If the novel experiences induced by the extension are also experienced by the others, it might lead to playful interactions among wearers, for example, in a work setting that is not inherently playful. If the extension is worn by only one person, the movement or sound might be jarring for others (*Theme 6.4.1*).	 6.4.2  6.4.1
15	Design movements that can lead to transformation in identity	Extensions can lead wearers to move in ways that they are not accustomed to. Making the wearer move differently with the extension can lead to a transformation in identity through bodily experiences (*Theme 6.5.2*). Transforming the whole posture and the rhythm of walking into a bodily enactment, for example, similar to a cat with the Tail, can lead to this transformation in identity. (*Theme 6.5.1*).	 6.5.1  6.5.2
16	Design extensions for certain types of attitude	The behaviour of the extension can also affect the mood and attitude of the wearer (*Theme 6.5.2*). For example, an introverted person might feel extroverted if the wings they wore kept flapping in a joyful manner. These kinds of playful behaviour designed for extensions can lead to shifts in how wearers think about themselves (*Theme 6.5.1*).	 6.5.2  6.5.1

8 DISCUSSION

8.1 Looking through the Lens of Body Image, Body Schema and Play

Our investigation generated themes that associate playful bodily extensions with social play, identity transformation as in role-playing and experiences relating to different levels of agency. These themes also interplay with the contextual perception of body image and different phases of incorporation into body schema. In this section, we elaborate on how the design of bodily extensions is related to body schema, body image and playful framings.

Regarding social play, *we point to the opportunity to consider playful bodily extensions for tighter social interaction—for example, to tease others physically with the extension.* Tight social interaction, which was not present in the projects we analysed, has been identified as a possible dimension of wearable play [26]. The social wearables framework elaborates on social play [35], focusing on social interaction on a broader level by emphasising the differences among the controllers of actuators (e.g., self, others, both), intentionality (intentional, non-intentional) and perception by others. While the projects here can be mapped to these different dimensions, our work extends this prior work by focusing on in-depth lived social experiences of playful bodily extensions. We highlight methods such as exaggerating bodily expressions as in Wigglears (also Implication #1), creating an exclusive non-verbal bodily language as in Monarch (I#2) or positioning the extension itself as an entity that can be interacted with socially (I#4) as in Arm-a-Dine, as mentioned in Theme 1. We also add that these extensions' exclusive communication might be exciting for the wearers but exclusionary for others (something that designers might need to take extra precautions for, as suggested by I#3).

Playing with identities was another highlight of our themes. Identity transformation is known as a valuable playful resource [27, 66], and we here point to how bodily extensions can bring about new ways of moving and proprioceptive sensations that make the wearer perceive their bodies in different ways. These experiences point to the outside-in and inside-out processes [53] of body image creation as dependent on the context (as mentioned in Theme 4), affecting other people's reactions to the extensions. As the wearer might experience new ways to express themselves and intracorporeally communicate (inside-out) and reflect on their lived experiences of being with extensions in certain contexts (I#12) as in the Tail and Wigglears, they also feel others' "judgement" of these extensions as different and misunderstood or funny (outside-in). When the extension is perceived and worn by others as well (as in the examples of Monarch or Arm-a-Dine), we also modify our bodily perception as an outside-in process that might then affect perceived social acceptability (I#14). The resulting differences in bodily perception can lead to the wearer altering their internal body image. As such, we can say that by altering their body image from the outside (for others), the wearer can alter their body image from the inside (seeing themselves as another being/character/avatar) [53]. For instance, wearing the Tail provides different movement possibilities that lead to an altered perception of one's own body image, as explained in Theme 5. In other words, the body extension changes the wearer's body schema. By doing so, it also alters the wearer's body image and how they identify with themselves or with other imaginary characters, which also comes as a design opportunity (I#15). *Previous studies have claimed that playful wearables and costumes might lead to increased identification with imaginary characters in role-playing scenarios [25], but embodied aspects of this change have rarely been explored. In our study, the identity transformation is a result of playing with the extended body, such as flapping the wings of the Monarch to induce an attitude change (I#16), adjusting to controlling the Arm-a-Dine robotic arm or exploring new ways of moving by wagging the Tail.* We add to this prior work on playful wearables that playful bodily extensions can facilitate role-play through an inside-out process of proprioceptive alteration, as well as the outside-in process of changing the body image through others' perception. We also highlight playfulness as a concept speaking to somaesthetic appreciation design [61]. The ways of extracting the playful nature of bodily extensions by altering bodily sensations correspond to several aspects of somaesthetic appreciation design. These aspects include turning inwards to make sense of any identity change with subtle guidance (as in body movements guided by the motion of the Tail) [61], and intimate correspondence in the example where the designer was bopping Monarch wings along to the rhythm of the music [61].

The design framework for social wearables also touches on different levels of agency, elaborated in Theme 2, such as who controls the wearable and how intentional it is [35]. Our systems speak to several underexplored parts of the framework. Arm-A-Dine fills an underexplored area of the design framework for social wearables since the robot arm is controlled by both the bodily movement of the wearer and the facial expressions of others (which is also one of the ways of creating the social play experiences with extensions as in I#6). This is a good example of how non-utilitarian playful explorations might yield designs that can fill underexplored design spaces. The Monarch system was also analysed by the social wearables framework and was interpreted as a wearable device that was controlled intentionally. Although this might be the purpose of the design, our interviews revealed that it is not always the case, and muscle contraction is a control mechanism that led to accidental activation. Such inadvertent activation might lead to opportunities (I#5) for play, as well as some frustration, depending on the context. Addressing this aspect might require easy on/off switches, as suggested in I#13 for not alarming players, as indicated in I#8. *Previous work hinted that the different levels of agency on body-worn systems might be a source for playfulness [35], and we add to those studies by revealing the first-person experiences of our designers and communicating nuances of these experiences in Theme 2 and in I#5, I#6, I#7 I#8. We also recommend ways to create experiences of full agency over extensions (by exploring a wide range of interaction modalities such as different sound effects or haptics as in I#7, that would also help with full incorporation I#10).*

We see that the incorporation process can be a source of playful interaction, but this process can also be supported by playfulness as indicated in Theme 3. The extensions support Rapp's internalist style [103] because they explore and experiment with subjective experiences and intercorporeal communication, which has also been discussed as part of somaesthetic experiences emerging during bodily interactions with drones [69]. We corroborate this theory and extend it by adding that playful bodily extensions do not only support the internalist style, but can actively facilitate it by supporting

novel bodily capabilities. While Wigglears and Monarch seek to augment the wearer's perceptual and expressive capabilities, Arm-a-Dine explores mixing bodily expressions and reactions into one shared, interdependent experience. Designing playful behaviour for incorporating extensions and understanding the play embedded in the process are both important considerations in supporting the internalist style. *In that sense, we suggest that the right amount of challenge might help with onboarding (I#9) and building up the internalist style interaction with extensions, while the possible feelings of being extensionless (i.e., breaking the internalist perception that was built up) during offboarding might be mitigated by adding playful behaviour to extensions (I#11).*

8.2 Ethical Implications and Undesirable Effects

Our work aims to help with designing bodily extensions by considering their experiential aspects and hopefully will lead to more awareness among designers regarding non-normative or minority bodily experiences [112] that can be induced by wearables, mechanical costumes or prosthetics. However, the merging of play and bodily extensions needs careful consideration of further unintended implications.

We acknowledge that playful bodily extensions can lead to gameful interventions. Gamefulness and gamification can have manipulative patterns [87, 120]. Related to bodily play, these deceptive patterns have been criticised in the scope of proxemic interaction and play before; that is, the reality of proxemics is ephemeral while the data about them is permanent [51]. Similarly, designing playful interactions and games around these extensions may lead to using them for extended periods, which can cause physical harm (such as strained muscles or posture problems due to the weight of extensions), similar to the mental and physical strain risks with head-mounted displays [129, 130]. Getting carried away with extensions can also cause harm to others since their movements can be unpredictable and agency over them might be limited.

Another potential risk is the creation of exclusionary games. On the one hand, designing playful activities and games with bodily extensions might seem like an opportunity for accommodating diverse body types. On the other hand, games and playful experiences designed through extensions might only be participated in by those who can afford to use those extensions bodily and economically. A similar pattern was mentioned in Theme 6.1 when it comes to creating exclusive languages through extensions, which might exclude those who do not wear them. Also, an unbalanced design of extensions in terms of capabilities might harm fair play, similar to the debates about the blade-shaped running prosthetics deemed to render athletes super-abled [52]. Possible discrimination between the people who have and do not have extensions has also been one of the main criticisms of transhuman ideals [24, 55, 59, 119].

If bodily extensions are not designed in the right way, they might hinder play at times. For instance, players may feel self-conscious about the change in their body image and thus be too embarrassed to express themselves through play. A similar effect can be observed when it comes to wearing costumes while playing tabletop role-playing games. While costuming might encourage some players to immerse themselves in the imaginary world, it can repel others who do not feel comfortable [27]. A similar negative effect might also occur with bodily extensions. Thus, designers need to understand the contexts where bodily extensions might be used; otherwise, their designs might harm the play of the experience (which was also highlighted in 6.4). Another possible disturbance to play might be caused by a sudden change in the body schema of the players. While those changes might be a resource for playful experiences as mentioned in Theme 6.3, if the activities and the surroundings of the play area are not designed carefully, large and heavy extensions such as the robotic arm in Arm-a-Dine might create fatigue (unintended fatigue needs to be avoided in bodily games [92]) and can lead to frustration rather than boosting play.

9 LIMITATIONS AND FUTURE WORK

This work is based on empirical data obtained by interviewing five designers of four different projects around current best practices, offering insights and a base for further additions and developments. We acknowledge the sample size is a limitation of this study. Although a consensus on a sufficient number of interviewees or the need to reach saturation in qualitative interviews has not been reached [13], we note that the inclusion of more experts might yield design directions we did not tap into. It is not unseen to work with such a small population in qualitative expert interviews [72, 79], due to the limited pool. To the best of our knowledge, although the implications of this work might help a wide range of fields from wearables to prosthetics, the body of work that focuses on the playful experiential aspects of bodily extensions does not extend beyond those we included in our analysis and cited in our related work section. In that sense, we included the majority of the experts from our target group in our study. We again remind readers that our findings are not conclusive guidelines but a foundation that can be built upon with larger and more inclusive sample sizes. As suggested by Baker & Edwards, we framed the data we extracted in accordance with our sample size [13], as a "preliminary attempt."

Also, designers represent one stakeholder group and the information generated through this study is one-sided and may have missed some findings that could be gained through engaging with other stakeholders (e.g., players in larp communities, cosplayers, other users, game designers, engineers, developers, businesspeople). Our work focused on the design of extensions, practices around them, and the first-person experiences of designers, who gave their accounts of different contexts and their observations on users interacting with their extensions. Including other stakeholders could complement our work, especially with distinct contextual experiences for people with different backgrounds, preferences and tastes. The inclusion of those stakeholders might also inform our work regarding the technical aspects of such extensions in different gaming contexts, additional positive play experiences, hindrances and game design practices. Hence we suggest this approach for future work and believe that our research could help structure such endeavours. Likewise, our themes and implications are not exhaustive and therefore should serve as an inspiration and discussion point for future work. The implications and themes provide a resource and starting point for leveraging the results of our investigation into design research, which can help with the further development of higher-level and more generalizable design frameworks through further research. With the development of further bodily extensions

that might also get inspiration by our work, more concrete guidelines for designing bodily extensions with clear DOs and DON'Ts, as in [92] would be the next step in creating the design space of playful bodily extensions.

10 CONCLUSION

We examined four different bodily extension projects and conducted interviews with five designers to understand how to design playful bodily extensions. Design-oriented bodily extension projects that focus on experiential, and in particular playful, qualities of extending the body are scarce, and our study can be considered the first step towards creating a more complete understanding of designing such artefacts.

Our results suggested the following themes: 1) Extensions can be considered as additional social organs, 2) different levels of agency may create distinct playful experiences, 3) playful implementations can help with the different phases of incorporation such as onboarding, adjustment and offboarding, 4) shared and lived experiences change dynamically depending on the context and 5) internalistic bodily experiences altered by extensions can lead to playing with identities. We examined themes in detail based on the information designers gave us, discussed their relationship to existing theories of body schema and image and translated them into actionable design implications. Adding to previous frameworks on playful wearables, our work presents a deeper understanding based on the first-person experiences of designers.

We believe that our results might support the fields of cyborg, transhuman, posthuman play [24, 93, 94], design and development of prosthetics [12, 97], wearables (especially shape-changing [44] and playful wearables [26]), computational clothing [23], costuming, performance and cosplay [66, 102], as well as embodied physical and virtual play [86]. With this work, we aim to support the design of playful bodily extensions, while promoting the consideration of experiential qualities in regard to designing bodily extensions more broadly, and ultimately bringing more playful experiences to people's lives.

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