Towards Designing Bodily Integrated Play

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ABSTRACT

There is an increasing trend in utilizing interactive technology for bodily integrations, such as additional limbs and ingestibles. Prior work on bodily integrated systems mostly examined them from a productivity perspective. In this article, we suggest examining this trend also from an experiential, playful perspective, as we believe that these systems offer novel opportunities to engage the human body through play. Hence, we propose that there is an opportunity to design "bodily integrated play". By relating to our own and other's work, we present an initial set of design strategies for bodily integrated play, aiming to inform designers on how they can engage with such systems to facilitate playful experiences, so that ultimately, people will profit from bodily play's many physical and mental wellbeing benefits even in a future where machine and human converge.

CCS CONCEPTS

• Human-centered computing → Interaction design

KEYWORDS

Bodily integration; play; cyborg; transhuman; whole-body interaction

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1 INTRODUCTION

When it comes to interactive technology, we notice an increasing trend in utilizing it for bodily integrations, most popular today probably comes in the form of technologically augmented limb prostheses. A popular recent research example is the MetaLimbs system that allows users to control two artificial arms using their legs [72]. Productivity is increased when the user uses his/her own arms in one task and the additional arms in other tasks, for example, when soldering. Another set of examples are "ingestibles", digital devices that are ingested [39, 50], such as a smart pill that wirelessly transmits body data for health objectives. There are also RFID tags that are implanted into the user's hand to assist with various mundane tasks like opening of doors without searching for keys [27].

These tangible interactive systems extend the human body's capacity through bodily integration, where the computer is intertwined with the human body. Bodily integration is building on the trend that the computer is moving closer to the human body [121], increasingly blurring the boundary between the machine and the human body. The result is that the computer is closely coupled with the user, known as human-computer integration [93]. A focus on *bodily* integration is crucial as it not only allows us to interact with computers in novel ways, but also might help us in understanding our bodies better, and hence, ultimately ourselves [65].

Of course, wearables are also a form of interfaces that are close to the human body. They are also characterized by availability [14], and we stress the temporal as well as corporeal availability of bodily integrated systems, i.e. I might take my smartwatch off at night as well as my prosthetic limb, however, removing implanted devices is not an easy undertaking. As such, wearables are only temporarily close to the human body, whereas bodily integration systems can be temporarily close, but can also be permanent. Furthermore, unlike wearables, they are not just extensions to the human body but are integrated with the body [51]. As developers create systems (e.g. [66, 103]), aspects around culture (e.g. [37]), ethics (e.g. [38]) and philosophy (e.g. [71]) are being considered. Despite these advances, we find that there is little structured design understanding when it comes to using these bodily integrated systems to facilitate playful experiences. We believe the unique characteristics of these systems – extended physical capacity, integration with the body, bodily and temporal availability – offer novel opportunities for play.

We note that prior works mostly focus on the productivity of the bodily integrated systems (e.g. [46]). We suggest examining this trend also from an experiential

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perspective, as we believe that these systems offer opportunities for engagement with the human body through play. Several artists have engaged with these systems and suggested potential for their playfulness. For example, Moon Ribas developed a “seismic sense” by implanting an online seismic sensor into her elbow that allows her to sense earthquakes [70]. She is not a seismologist but an artist using her extended physical capacity in public performances that suggest the experiential potential of these technologies. Similarly, Stelarc used an artificial third hand in his performance art [78], where he engages in at least three “play” aspects [91]: expression (self-expression through artistic performance), subversion (letting others control his third hand through electric impulses) and eroticism (the artist is naked). Playfulness can be described as a mindset whereby people approach activities with an attitude similar to that of paidia, as something not serious, with neither a clear goal nor real-world consequences [89]. We can say these artists use their bodily integrated systems for a more paidia-type [89, 90] experiential engagement.

This article contributes to an understanding of bodily integrated play by articulating strategies for designers when developing playful bodily integrated systems. Medical practitioners might also benefit from our work, as many current bodily integration systems are derived from the medical domain which increasingly acknowledges the importance of considering the patient’s user experience (assuming that play could enhance it). Our work might also be used in other fields outside HCI to inform discussions on bodily integration that currently neglect the practicality of engaging with such technology. Besides, our work can spark conversations by serving as a critical probe that highlights the experience people have with existing systems today. Lastly, our work will be useful for researchers interested in analyzing bodily integrated systems, especially when it comes to an understanding of their experiential potential. Using past systems as examples, we derive a set of initial design strategies in the form of intermediate design knowledge [31] (table 1).

Table 1. Design strategies for bodily integrated play
Support users in playfully exploring the bodily integration to learn more about their bodies
Highlight opportunities for play resulting from the bodily and temporal availability
Facilitate self-expression through bodily integrated movement
Initiate playful social interaction through bodily integration technology
Facilitate reflection on both having and being an integrated body
Challenge cultural norms around the body through bodily integration

These strategies provide a starting point for designing bodily integrated play. As technical developments emerge, they would benefit from a more structured understanding of their experiential potential. If we continue designing such systems without considering their experiential potential, users will be deprived from the opportunity to benefit from the engagement of their bodies through play. Therefore, with our work, we hope we are building an initial understanding of how to design bodily integrated play experiences so that ultimately, people will profit from bodily play’s many physical and mental wellbeing benefits even in a future where machine and human converge.

2 RELATED WORK

Our work on the human body, play and technology was informed primarily from embodiment [20], whole-body interactions [22] and playful ubiquitous computing including pervasive games [58, 61]. With more games pervading everyday life (including pervasive games [58]), we believe that games enabled by “always available” technologies can be a key aspect of contemporary life. Understanding contemporary life involves understanding bodily experiences as proclaimed by Van Manen [55]. Extending this to HCI, Dourish [20] and Klemmer [122] argued that the “body matters” [122], however, practical details on how to design technologies that integrate with the human body are still missing. Benford et al. [8] proclaimed that the consideration of bodies could be developed further with the advent of advanced sensor systems. However, the authors only consider sensors external to the human body such as cameras, leading to frameworks around sensed bodily play [63, 75]). We propose that sensors integrated with the human body afford additional opportunities to facilitate play.

There is also work on how technology could be used to promote physical activity. However, this work often focuses on instrumental objectives such as improving health (e.g. [15, 41, 84, 88]). Mueller et al. [65] introduced an experiential perspective from sports philosophy, while Loke et al. [53] and Wilde et al. [87] suggested an experiential perspective from dance. Similarly, Tholander et al. [83] proposed an experiential perspective from endurance sports. These works highlight that seeing the human body not just from a productivity perspective, but also from an experiential perspective can have personal outlook, expressive and value facilitating benefits, to which we subscribe through our focus on play. Relatedly, Andres et a. have investigated how a notion of bodily integration can support eBike cycling activities . Other past projects that investigated bodily design from an experiential perspective include Segura et al. who proposed that bodily play can be facilitated through interactive objects [75]. However, the authors only looked into portables. We argue that technology that is integrated with the human body affords additional ways to play, and hence, we extend their work with considerations on integrated technology. Höök et al. proposed that designers should consider the "pulsating, live, felt body" [30, 126] but focus on meditation in their design practice.

When it comes to the human body and game design, several researchers [36, 61, 63, 40] have already proposed design strategies. They have proposed a relationship between sensor fidelity and the opportunity for self-expression [36, 92]. However, with traditional systems, users often have the chance to compensate for limited sensor fidelity: e.g. in a camera-based game, players can step closer to the camera to make up for limited fidelity. In contrast, with bodily integrated systems, players often lack this agency. Hence, by only engaging with existing bodily play theory designers might miss critical aspects, such as a player-computer integration [93] where players experience their bodies as play, rather than play with their bodies [62].

Research in games and play around wearables has pointed to the experiential aspects that emerge if we carry technology with us (e.g. [107-110]). Their availability allows users to play anywhere away from a desktop. Bodily integrated systems also share this feature. However, unlike wearables, bodily integrated systems cannot easily be removed from the body; hence any nudging to play is not easily ignored. Our work highlights both opportunities and challenges associated with such availability. We also learn from playful approaches in ubiquitous computing research, for example, see the work on combat play that allows for full-body immersion via means of a sensor-equipped mattress [94] or sensors attached all over the human body for contact play [95]. These works suggest that ubiquitous computing can facilitate novel play experiences, such as a large number of sensors facilitating full-body play. We believe that bodily integrated play with its unique characteristics, such as always on and integration with the body, can similarly enable novel play experiences.

Research around on-skin interfaces [105] highlights that novel opportunities emerge when the computer and the human body integrate: our work builds on this by explicitly considering the malleability of the human body [106], i.e. we consider the user experience when we put technology into our body, whether by piercing the skin or swallowing technology (see our example systems below). The result can be quite visceral experiences, as prior work on games with blood already suggested [125]. Relatedly, research prototypes such as the "possessed hand" [111] and exo-interfaces [112] have explored opportunities for self-expression (such as when learning a musical instrument) and play (a fishing game) when the computer and the body integrate. These works have demonstrated that bodily integrated play is possible; however, a structured understanding of how to design such associated experiences is still missing. Prior theoretical research on play also guided us, in particular, we refer to the Plex framework [91] that highlights the consideration of factors such as self-expression and social effects (which we discuss in our strategies below), however, how to facilitate them using these novel technologies is yet to be articulated.

Overall, we note that despite the advances in our understanding of the coming together of the human body, technology and play, it has been pointed out (e.g. [52, 56]) that our knowledge on how to design for this coming together is still underdeveloped. We argue that game designers can benefit from considering emerging technologies that allow for bodily integration as an opportunity to facilitate novel playful experiences. Furthermore, integrated technology developers might, in turn, benefit from looking at game design as an opportunity to facilitate playful experiences. Nevertheless, concrete strategies on how to engage with this opportunity are still missing. We aim to address this gap by offering an initial understanding of how to design bodily integrated play.

3 BODILY INTEGRATED SYSTEMS

We now present several bodily integrated systems that exemplify our thinking. We selected two of our works [50, 96], one commercial product we have previously engaged with and two external examples. We chose these systems because they a) allow us to detail practical insights gained from our design practice, b) are possible with today's technology, allowing for the examination of the resulting user experience (such as through formal studies), c) were designed for play or we were able to find instances where people have used them for play or more broadly for experiential purposes, and d) cover a large range of bodily integration approaches, highlighting the wide spectrum that is available for designers. We acknowledge that we often tried to make our examples even "more" integrated and push the boundary further in regards to how the human body and the machine could integrate, however, did not always find this practically possible.

The advantage of including external examples is that it allows demonstrating that a) our strategies are valid not just for our work, and b) technologies are readily available for designers to experiment with today. We do, however, acknowledge the limitation that at least for the external examples, we are not able to offer a first-person perspective [62, 119] as we have not yet studied the user experience ourselves and rely on external resources such as online (we have, however, conversed extensively with people wearing implantables, see below). Nevertheless, we believe our work, seen together, can serve as a valuable springboard for future investigations by offering a first initial structured understanding of how to design bodily integrated play.

3.1 Guts Game

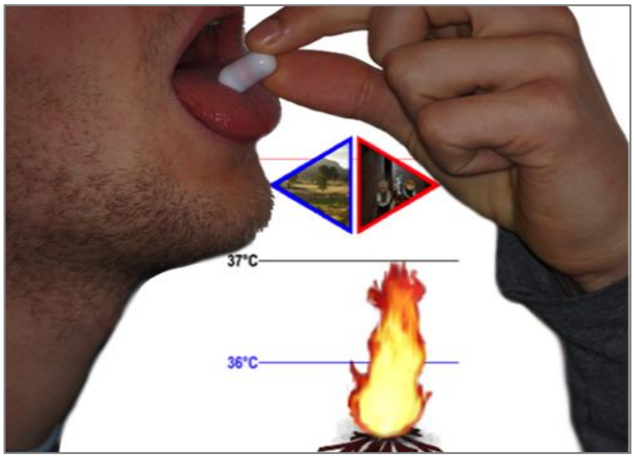

Figure 1. The Guts Game – a game using ingestible sensors.

The Guts Game (fig. 1) [50] is a two-player game that uses ingestible sensors. Two players swallow an ingestible temperature sensor each that measures their body temperatures every 10 seconds and transmit the data to a smartphone. Throughout the game, players complete various challenges given such as guessing their own temperature or changing it to a value selected by either the system or their partner. The Guts Game mobile app displays a flame to represent their body temperature and rewards points for successful task achievements. During gameplay, players can send pictures to each other and discuss how they manipulated their body temperature by either eating hot or cold food or performing physical activity. The game ends when a player excretes the sensor.

3.2 Arm-A-Dine

Figure 2. Arm-A-Dine – a playful experience around feeding food using a robotic "third" arm.

Arm-A-Dine (Fig. 2) [96] is a two-player interactive, playful eating experience. Each participant wears a robotic arm attached to a vest, acting as the wearer's third arm for feeding. The use case scenario is a casual eating experience while standing up, as often experienced in conference settings. With the robotic arm attached to a vest worn by the body, participants need to move their bodies to align the arm's gripper with the food on a table. Once the arm picks up a particular food item, it feeds it to either the wearer or his/her partner. After picking up 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 particular 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. We acknowledge that our robotic arm lacks the sophistication of many of today's prosthesis, in particular in regards to its control scheme, however, it highlights the opportunity to control additional limbs via rather "unusual" bodily input, here emotions implied through facial expressions. Players can deliberately make facial expressions in order to control the arm, however, the arm also reacts to implicit expressions, which we believe occur often as part of a social eating experience. A study [96] suggests that the integration of the robotic arm can facilitate social interactions, promote bodily engagement, fuel laughter and discussions around food as well as how people eat in social settings.

3.3 xNT Implantable

Our next example is the "xNT" NFC chip that people voluntarily implant themselves (often employing a piercing studio) for non-medical purposes [7,16]. The company that sells the xNT presents it as a substitute for carrying keys, unlocking a computer and accessing one's car [24]. The xNT uses 13,56 Mhz and has 880 bytes of memory also enabling the use of an Android phone to read out one's VCard details by just holding it above the implanted spot (most often the hand). We chose the xNT chip as designers can easily order it online and try it out today.

3.4 Atalante Exoskeleton

The Atalante Exoskeleton is an exoskeleton designed to enable a person with impaired mobility to stand up, walk, and freely move around again [86]. In 2019 the product was going through clinical trials and hence is not yet commercial, which is the case with most powered exoskeletons [2]. So, unfortunately, designers cannot experiment with one right away. Nevertheless, the market for such devices is set to grow soon [25]. We are using this exoskeleton to exemplify our thinking today and assume it might apply to many other exoskeletons that emerge in the future.

3.5 Bebionic Bionic Hand

The Bebionic Bionic Hand is a commercial myoelectric-controlled prosthesis designed to help amputees [66]. The bionic hand enables to conduct several tasks that would otherwise not be possible, such as typical hand and finger functions from different grips to throwing a ball. Some of the afforded capabilities are not possible even for people without a disability, such as maintaining a constant gripping force [1]. We include such prostheses as they are increasingly discussed in the mainstream media (partially due to the popularity of the Paralympics), bringing people outside "regular" body norms into the discussion. This could be a welcoming change, as people with disabilities have mostly been seen as disadvantaged and are rarely discussed in the bodily play literature, as previously pointed out [98, 99].

4 DESIGN STRATEGIES FOR BODILY INTEGRATED PLAY

Based on our experiences of designing, exhibiting and reflecting on the above systems, we articulate an initial set of strategies for designers of bodily integrated play experiences, building on our prior work around bodily play that touched upon some of the emerging underlying technologies already [124]. These strategies are presented in the form of intermediate design knowledge, although we acknowledge that we did not follow the process described by Höök and Löwgren [31] as our work evolved much more organically. The strategies have emerged through an iterative process rooted in the practice of a design research lab in which thinking about them has influenced our design practice and vice versa, an approach previously successfully deployed [8, 64]. For example, our thinking in regard to "exploring bodies" (see strategy 1 below) gained from the Guts Game has led us to reconsider the use case context of Arm-A-Dine. Insights from studies further refined the strategies. We also held unstructured collaborative embodied sessions; many of them resembling embodied design methods such as "material props in context" and "object theatre" previously identified by Wilde et al. [117]. Through this, we found that as many technologies are inside the human body, they are harder to enact on than wearables; nevertheless, we aimed to discuss and refute theory and design explorations "on the cheap". For example, by mounting robotic-arms on our bodies using duct tape or swallowing vitamin pills and pretending to sense temperature data using non-contact laser thermometers inspired by Wizard-of-Oz techniques. We acknowledge such a process is "messy", however reflective of design practice. As such a process has been previously used to develop a framework about bodily sensing [8] and bodily play [64], we believed it could also be fruitful here. We acknowledge that other approaches towards identifying strategies for the design of bodily integrated systems could complement our approach. Furthermore, we also acknowledge that our set of strategies is not an exhaustive list, but rather a starting point aimed at guiding future work. Nevertheless, we hope our work is still useful as it provides a first guide to how bodily integrated play can be achieved.

4.1 Support Users in Playfully Exploring the Bodily Integration to Learn more about their Bodies

This strategy is concerned with the extent to which the system supports users in playfully exploring the bodily integration to learn more about their bodies. We see exploration as a key element of play [91] and point here to the opportunity to regard play as a way trying to figure out "how things work" [113], here, how one's own body works, facilitating learning about one's own body. We think that playfully learning about one's body in the constructionism learning tradition [68] is important as we believe that gaining an increased understanding of one's body through playful engagement can lead to an increased appreciation of one's body, subsequently facilitating a better self-understanding [65]. As such, bodily integration play can help "figuring out how my body and my bodily integration – that is *I* – work".

In a study with the Guts Game, players reported that the playful experience helped them engage with the sensor as a way to learn more about their body temperature and what affects it. For example, one participant said: "I just assumed my body stayed at 37 degrees all the time, but it apparently doesn't. It's interesting to learn about what makes my body temperature change". This exploration of the bodily integration through exercise and eating facilitated an enhanced understanding of one's body: "I think [the most interesting part is] that I get more intimate knowledge of the body."

In the Arm-A-Dine study, participants did not report learning about their bodies due to the possibly short engagement time. However, participants reported how experimenting with their bodies, robotic arm and food allowed more focus on eating and feeding oneself. For example, one participant said: "If I think of a normal meal, I would not be focusing on the act of getting the food to my mouth. However, this experience pushed me to focus on that bit."

The online content surrounding the practice of using the xNT (such as user reports and FAQs, which we widely explored) suggests that potential users are interested in learning about how their body would respond to such a device. For example, users appear to be interested to know how their body would react to implanting or removing the chip and how the tissue context affects its usability [17]. Users are also curious about whether it is visible under the skin [18]. It seems the bodily integration can facilitate a sense of curiosity that might support people learning about their bodies in the future; however, we acknowledge that whether this is playful or not is debatable and more work in this area is needed. However, as electronics inside the human body get more widespread [42], we envision that new playful approaches to learning about one's body could emerge.

When it comes to exoskeletons, we can imagine bodily games that, for example, teach proper body posture. This could facilitate learning how to assume such proper posture that carries over to situations when the wearer does not wear the device. Unlike conventional approaches that focus on information transmission, such as pamphlets for posture (supporting declarative knowledge), this learning would directly engage with the human body (supporting procedural knowledge).

With the bionic hand, the designers could aim to facilitate not only learning how to operate the "new" hand (as it takes some training [67]) but also facilitate users playfully learning about the limitations of the other hand. For example, a game that teaches how to rotate the bionic hand could also ask users to rotate the other hand to learn about people's existing bodily capacities (i.e. how much they can rotate their existing hand), facilitate learning about their bodies through contrasting the prosthesis limb with the non-prosthesis limb.

4.2 Highlight Opportunities for Play Resulting from the Bodily and Temporal Availability

This strategy is concerned with the extent to which the system highlights opportunities for play that are the result of the system's intrinsic characteristic that it is always available, both temporal and corporeal. Mobile devices or wearables, can often be left behind, lost, or buried at the bottom of a bag. On the other hand, bodily integration play systems are typically always ready to play as they are integrated with the body. Designers can draw on this and highlight that there is always an opportunity for play (we acknowledge that some bodily integrated systems are not always "on", for example, Arm-A-Dine might be taken off outside eating/at night). This highlighting is important, as due to the device being integrated with the body, players can "overlook" that they have the device in the same way we can overlook we have a body [106] as our attention is often drawn away from our bodies, making us seemingly not aware of them, for example when focusing on a demanding desk-based job that makes us not realize how our body begins to hurt from sitting too long. The "always available" characteristic aligns with prior work around pervasive games that pointed to the fact that these games blur the boundary of time usually prevalent in traditional games, which is described with "blurring play's magic circle" [58]. We extend this by including bodily availability as a way to blur the magic circle between the human body and play objects, i.e. toys, where the body and the "toy" integrate, underlining the prior work that postulated that designers should go from using the body to play with objects to support users experiencing their bodies as play [62].

In the Guts Game, the player may be challenged by a task by the other player to change his/her body temperature. This reminds players that the sensor may still be inside their bodies. Players can either accept the challenge refuse without penalty if they have other important things to do. We suggest designers highlight opportunities for play while considering that play might interrupt players' daily routine. Despite using a smartphone, participants recognized how their bodies acted like the entire play system. For example, one participant said: "My body was the interface".

In the Arm-A-Dine study, participants wore the robotic arm only during mealtime. If they had worn it the entire day, opportunities for playful engagement in between meals would have been possible. For example, having the arm pick up snacks while queuing at a coffee shop or "stealing" a friend's lunch while eating together. Participants were able to exploit the advantage of having a third arm by using it as an assistant for feeding while the participants' own arms are already occupied.

With the xNT, there is no deliberate highlighting of the opportunity for play, as the current implementation focuses on productivity. However, we can envision future systems which highlight the presence of the NFC tags to entice playing at any time. For example, a system could detect if multiple people within a crowd carry an xNT, such as at a conference's social gathering. The system then highlights to participants wearing an xNT that there are others "like them" in the crowd, and the game challenge is to guess who they are. Players are told to inconspicuously stand closely next to their "guess" so to be able to secretly swipe their phone across the other person's hand to detect if a sensor is present, and if they are right, they are introduced to each other through the system. If they are wrong, they are "punished" by the social awkwardness of having stood too close to a stranger and almost touched their hand with their phone, having invaded their intimate bodily proxemics zone [64].

With a powered exoskeleton, the system could sense that the wearer is on their way home to relax later in the day (for example by checking the wearer's calendar), yet there is plenty of battery power left. The system could highlight that there is now an opportunity for (bodily) play by supporting the wearer to put a "skip" into his/her step, making him/her jump a little with every step, facilitating a more playful walk home.

With the bionic hand, opportunities for play could be highlighted by promoting playful gestures during daily activities, such as facilitating through (bodily) actuation to make a victory sign when done with the dishes or offering playful hand gestures when greeting friends such as a Vulcan salute.

4.3 Facilitate Self-Expression through Bodily Integrated Movement

This strategy is concerned with the extent to which the system facilitates self-expression through bodily integrated movement. Self-expression has previously been described as a key aspect of playful experiences [91], thus we propose that bodily integration provides opportunities for self-expression. These opportunities for self-expression through movement have previously been associated with playful user experiences [10, 11]. We highlight the specific opportunities as a result of bodily integration.

In the Guts Game, participants explored various means to change their body temperature, such as eating hot food. They also discovered that exercise like running and push-ups produced greater temperature increases while the sensor was in their intestines. Participants were free to perform any movement thus supporting self-expression. As the sensor remained inside their body, participants used this opportunity to explore different movements to manipulate their body temperature. Unlike Kinect and other stationary sensors, participants were not restricted in performing movements inside a room but could explore movements outside their homes. Furthermore, participants were able to engage with movements at any time, without having to first setup a sensor, as the pill was integrated with their body. Lastly, this did not hinder or restrict any movement as might be the case with wearables. Despite this opportunity for self-expression through movement, participants also reported the game sometimes made them feel socially awkward at work. Abele [85] highlighted that social awkwardness might arise when games encourage bodily movement in public places. With a rise of bodily integration play systems, this might become increasingly common. She related it to Goffman who argued that people have a "stage" (performing in public) and a "backstage" (performing in private) side to their social interactions. The Guts Game participants were fine with the game motivating them to perform bodily movement "backstage", but not in inappropriate "stage" places like workplaces. Designers that aim to support self-expression through bodily integration need to consider that bystanders may experience discomfort of confusion when people perform such actions in public.

With Arm-A-Dine, the fact that the robotic arm was integrated with the player's body thus afforded participants to explore their bodies in controlling the robotic arm. Movements included moving their upper torso both left and right to pick up particular food items and also bend forward and backward to move the gripper closer to their own or their partner's mouth when feeding. Because food differs in shapes and sizes, participants moved their heads to grab the food from the gripper with their mouth. Participants explored their bodily movements through the playful act of controlling their third arm that featured very limited dexterity as well as pre-programmed movement sequences. As such, the limited movements of the third arm afforded moving the "rest" of the body in expressive ways. This reminds us of the prior work on hard-to-operate musical instruments [104] and stiff ballet costumes that afford moving in unusual ways [118]. Our first-hand experience of using Arm-A-Dine also showed that the system can generate a lot of laughter: using a third arm offers an experience we would describe as strangely joyful as it makes eating "strange again", reminding us of Dewey's work that has been previously used to engage people by making familiar experiences "strange again" through the use of technology [97]. Also, prior work on animal play highlights that playful movements are characterized by "exaggeration of movements, repetition of motor acts, and fragmentation or disordering of sequences of motor acts" [114]. We believe that Arm-A-Dine is an example of how bodily integration can be utilized to facilitate such "exaggeration of movements" through actuation technology and any limited degree of freedom. Some of these bodily movements as a result of the technical limitations of the robotic arm took on some quite elaborate forms of self-expression that the participants explored in a playful and performative manner. For example, see the instance where the gripper could not rotate all the way up, so the food needed to be eaten out of the wrapper from the bottom of the gripper. One of the participants expressed: "I had to focus on the arm and the food in order to pick it up properly. Although the table was set to my height [the table was height-adjustable], I had to sway my body and coordinate it with the movement of the arm to pick up the food perfectly." Another participant said: "I enjoyed the bodily movement involved in the experience as I aimed to pick up tougher food substances like chips."

Even the xNT facilitates bodily movement, although not much: it requires the user to swipe his/her hand across an RFID reader to access its functionality, for example when using it to pass the automatic gate upon entering a subway station. This swiping of the hand might also facilitate self-expression, possibly depending on whether it occurs on "stage" or "backstage": when opening one's office door in private, not much self-expression is probably being facilitated. However, when in public, such as at a subway station, users are aware that others see them using only their hand to gain access. Depending on whether they are extrovert or introvert, they might make more extravagant hand motions to make others aware that they are "just using their hand" to gain access, turning the simple access task into a public performance. Alternatively, they might (when busy or tired of being asked about their implant) choose to quickly swipe their hand in a concealed manner as to not attract attention. Designers could support self-expression by using sensors and antennas sophisticated enough so to detect not only close and slow swipes but also more elaborate movements that might involve larger gross-motor movements (so that others are more likely to see them from a distance). However, designers also need to consider the trade-off with data security; for example, being able to read the xNT from afar might be a security issue.

An artistic example of using an exoskeleton to facilitate bodily movement [19, 123] plays music and "forces" people to dance through the use of actuators that make people move their arms in response to the music, encouraging them also to move their legs. We can envision an extension of this work in which artificial limbs such as the bionic hand could also sense music being played, and subtly begin "tapping" along to the beat through actuation technology when the user is idle, facilitating the engagement of bodily movement through including other body parts (and possibly ultimately dancing) as a way to support self-expression. How to facilitate this while supporting a user's bodily autonomy [62] is an open area for future investigation.

4.4 Initiate Playful Social Interaction Through Bodily Integration Technology

This strategy is concerned with the extent to which the system supports making others aware of the bodily integration technology to initiate social interaction. This seems counterintuitive at first, as many devices, such as the xNT, are praised for being "invisible" [28]. However, from a play perspective, it seems beneficial to consider supporting participants in the ability to use them as initiators for social interaction. Prior research already highlighted how important supporting social interactions is when aiming to facilitate playful experiences, which we draw upon [35].

In the Guts Game, the pill is not visible to anyone as it is swallowed by the user. However, participants had to carry a phone and a signal receiver in a waist bag. This bag might have been visible to bystanders, and participants reported that others have asked about it. They also reported that bystanders became aware that they were behaving differently; for example, they noticed that players drank more water than usual (as a way to reduce their body temperature) and people enquired about their "strange" behaviors. This facilitated social interactions, seemingly supporting the playful character of the experience. Although participants reported that the bag did not always match their fashion outfit, the fact that bystanders started conversations about it suggest that it also offered a benefit in the form of serving a role as a visible initiator for social interaction.

During the development process of Arm-A-Dine, the design team contemplated on changing the appearance of the brightly colored robotic-looking arm. Painting it in a darker color or decorating it in fabric was discussed. On the one hand, prior work suggests that technology distracts from the eating experience [29], which indicates that making the robotic arm less prominent would be advantageous. However, it was believed that any robotic third arm would attract attention regardless of its appearance. We believe the arm's look-and-feel not only facilitated social interaction around it in terms of what it is, but the mechanics being exposed also allowed for conversations about how the arm works and what can be achieved with it. By understanding its capabilities (and limitations), it appeared that participants quickly accepted the arm as an integration of their own body and exploit its capabilities for play.

The xNT is mostly invisible. However, personal stories (e.g. [7]) suggest that people are often curious whether the device is "really" inside the hand, and they touch it to see if they can feel it, squeezing the skin to examine if they can experience it tacitly. Users also report that they can at times feel the implant when doing specific movements or bumping into things, resulting in intriguing stories that they are happily sharing with others [4]. It seems exciting to have such a bodily integrated device that others want to touch, experience and hear about. This "showing off" is for us a form of social play that designers should consider. We argue that this social perspective has direct implications for the design of future technologies; for example, it is usually assumed that making implantable devices smaller is desirable [7]. Making these devices smaller can make implantation processes easier. However, users will lose the opportunity to have themselves and others tacitly experience their device, possibly missing out on any resulting social interactions. The same applies to exoskeletons; they are getting smaller and could eventually be hidden underneath clothing. However, for us, it seems important that designers might want to consider making them not always completely disappear, to not miss out on associated social interactions. Prior research that suggests that users appreciate social interactions as a result of the newness of the technology [27] seems to confirm this. This might change if such technology becomes more prevalent.

When it comes to the bionic hand, we point to prior work around prostheses that found that making others aware of the device can have benefits in terms of social interaction [73]. This contrasts the previously held belief that a prosthesis should look as close as possible to the limb that it replaces not to attract attention. Recent examples, however, highlight the potential to design prostheses that are deliberately different from the original limb [5], drawing attention. We subscribe to this view and highlight that making others aware of these bodily integrations could be a valuable resource for designers. The kangaroo shoes [77] are an example of a simple exoskeleton designed for play: they allow larger jumps while walking thanks to integrated springs and levers. By making this functionality visible to others (they are not encased in some protective shell), the designers seemed to have chosen to make others aware of the shoes' inner workings as a way to initiate social interaction.

4.5 Facilitate Reflection On Both Having and Being an Integrated Body

This strategy is concerned with the extent to which the system facilitates reflection on both *having* and *being* an integrated body. Prior work [62] has highlighted the importance of realizing that humans both *have* a body and *are* a body. This was underlined by using the German words "Körper" and "Leib" that allow seeing the body from two perspectives: from a material perspective ("Körper", *having* a body) and a lived perspective ("Leib", *being* a body). The authors argue that bodily play designers can benefit from taking on both perspectives. We believe integrated systems lend themselves to be powerful facilitators for this due to their ability to extend physical capacities of the users' bodies. For example, a user usually begins to examine the technology taking on a "Körper" perspective by asking material questions such as: "Will the size fit me?", or "Does this allow me to increase my performance?". This "Körper" perspective similarly considers the body as one would consider the "body" of a car when buying an accessory for it (asking questions such as: "Is this accessory compatible with my car model?"). The user might then try on the technology, and through this first-person "Leib" perspective [80] of experiencing the device might ask: "How does the extended physical capacity make me feel?" Due to the technology being first a material "thing" that then becomes integrated with the human body through use, we believe the resulting extended physical capacity supports reflection on what it means to both have an integrated body and be an integrated body. This is important, as prior work [62] highlighted that engaging with these two perspectives through play can increase one's bodily understanding and appreciation of one's body, and possibly even advance kinesthetic literacy [76].

In the Guts Game study, interview participants were asked about their extended physical capacity. This seemed to facilitate a reflection on what it means to both have an integrated body and be an integrated body. For example, participants said: "The game wasn't on the phone. It was in here [in the body]. The sensor was just a device but you were playing with your body more or less." Designers could promote such reflection via a diary that documents the user's engagement with the system.

In Arm-A-Dine, a similar study approach was followed. Participants commented that although the system made eating more difficult (Körper), they felt positive about it (Leib) as it enriched the embodied and social character of the eating experience. By reflecting on it, it appeared that the participants became more aware that they both have an integrated body and are an integrated body: "It [eating with a robotic arm] pushed me [to put] extra effort and attention into eating. When I got the food, it felt really rewarding and satisfactory." It not only helped participants to focus on the food and the eating process, but also supported them reflecting on facial expressions during eating: "I felt like my arm was more in control than my opponent's and I felt as if I was being fed by both, my arm and my opponent's arm as well. I think this might be because I figured out the connection between emotions and how the arms picked up the food [giggles]. Eventually, I tried to focus on my emotions and shape my facial expressions in a way that would make the arm pick food for me all the time [laughs]."

When it comes to the xNT, we find that user reports, as often posted online, are seemingly used to reflect on both having an integrated body and being an integrated body. For example, famous proponent Shanti Korporaal talks about using the system to open the gate to her gym [3]. However, she also talks about how she feels about the system, which enabled her to get engaged in activities she would not have had without the system, for example, she was invited to star at the launch of the Deus Ex game [69]. The artwork that uses exoskeletons to "make" people dance [19, 123] might also support reflection on what it means to both have an integrated body and be an integrated body, as it asks whether people whose bodies are made to dance are actually dancing: their bodies might be regarded as dancing, but the experience of dancing and how people feel about it might be very different to a "voluntary" dance. Similar questions were raised in work around electronic muscle stimulation [54]: we believe games that move people's bodies could equally be used to support reflection on what it means to both have and be an integrated body.

Devices like the bionic hand seemingly support reflection on what it means to both have an integrated body and be an integrated body, with testimonials suggesting that prostheses in use are not only about functionality but also how people feel about them [6]. We believe supporting these two perspectives through play is an intriguing area deserving further investigation.

4.6 Challenge Cultural Norms Around the Body Through Bodily Integration

This strategy is concerned with the extent to which the system challenges cultural norms around the body through bodily integration. Challenging cultural norms can be engaging, as previously pointed out by work on uncomfortable, yet playful interactions [9]. Work on playful design has similarly highlighted the potential of "breaking social rules and norms" [64] as a way to facilitate play. We find that bodily integration affords the challenging of cultural norms as many of them center around the human body.

In the Guts Game, the cultural norm of not ingesting non-edible items (like wireless pills) is challenged by the game. Several players admitted participating in the study because they were intrigued by the idea of swallowing a wireless pill: "I think it's a pretty new idea. I haven't seen any other game with ingestible devices. This might lead a new trend in the future." The challenge was supported by providing players with a narrative at the beginning of the study: the researchers dressed up as medical doctors and told a fictitious story about a parasite entering participants' bodies as a result of the snack (provided by the research team) participants had just eaten. They now needed to play the game to "kill" the parasite by changing their body temperature. The interviews suggested that this approach worked: "I think [the story] motivated me to play this game and made me relaxed a little bit before I took the sensor."

In Arm-A-Dine, participants reported that having a third arm picking up food challenged the cultural norm of not eating with your hands predominant in Western cultures. The robotic arm was clearly not a human hand, yet it was picking up food "like" a human. This stimulated to talk about the practice of eating with hands: "It is not common in our culture that we eat with our hands, but this experience reminded me of travels to Sri Lanka where I saw people eating food with their hands and it was very interesting to see people eating this way." This was further facilitated when the third arm presented food to the other person. Participants were often unsure whether to use their mouth to grab the food from the robotic arm or use their hands. The embodied arm facilitated cultural discussions about eating with hands, whether they are human hands or robotic hands. Some participants were even so involved in the game that they chose to forgo the notion of being hesitant to eat with their hands.

The use of an implanter that involves a visit to a piercing studio challenges the cultural norm of what is required before one can use an xNT: implanting such a tag, i.e. surgically opening the human body, challenges cultural norms. For example, when a company offered free RFID implants to all employees, it triggered worldwide news coverage [82]. Furthermore, entering a piercing studio also has cultural connotations, such as that in most countries entering them is restricted to over 18-year-olds. Game design has a long history with age restrictions (see the debate about R18+ classifications [44]), which might be further fueled by such cultural norms when this technology becomes more commonplace.

Similar to proxemics zones [64] that highlight cultural differences between how people interpret their interpersonal distance (i.e. for a Spanish person standing "too close" is different to a Finnish person), we note cultural differences in regard to bodily integrated play. As an example of this, in 2018, Australian authorities deactivated a transit pass that a person had implanted into his hand [59]. Some websites also provide instructions on how to perform the implantable procedure on your own [7, 21], which challenges the cultural norm of slicing or piercing one's skin. We note that this could also be part of the appeal of these devices, contributing to the playful fear aspect of engaging with them, similar to a horror game. Designers could facilitate this further by embedding the challenging of cultural norms into a narrative, similarly as with the Guts Game's narrative.

Scenarios around exoskeletons that help older adults to keep their motor strength [57] suggest that they could be used to challenge the cultural norm that with increased age comes limited bodily strength. Game designers could create experiences that further challenge this, drawing on character design: for example, designers could encode gait data from females into exoskeletons worn by males to facilitate playful experiences about what it means to "walk in her shoes".

User stories such as arm-wrestling with bionic hands use play to challenge the cultural norm that people with disabilities have limited capabilities: the arm-wrestling story demonstrates that having a particular technology can make a "disabled" person superior [26]. Designers can draw on this by supporting users to play in more "powerful" ways than people without disabilities. We encourage designers who think about aiming for the bionic hand to be as powerful (or as agile, etc.) as a human hand to go beyond and consider allowing for "superhuman" actions using the fantasy element of being a superhuman. The benefit of offering such superhuman extended physical capacities has already been highlighted in prior work [62] that resulted in eBike riders believing that they had superhuman cycling capacities.

5 LIMITATIONS AND FUTURE WORK

We acknowledge the limitations of our designerly approach through a portfolio [115] of works. In particular, we point out that an in-the-wild evaluation [116] of our strategies, for example, through workshops with designers, could be a fruitful avenue for future work. We also acknowledge that we have only begun to scratch the surface when it comes to discussing wearables and how they can be designed to become bodily integrated systems. For this, we point out that we believe that our understanding of fusion between technology and the human body will become more sophisticated in the future. Furthermore, we also acknowledge that bodily integrated play could be investigated through other approaches, for example, a phenomenological approach that takes on different perspectives on the human body [62] and the social environment [119] that might reveal additional insights from a theoretical perspective, complementing our practice-driven approach. Another approach could be to draw on values, leaning on prior work on values in HCI [120] and body-centric HCI values [65, 121].

We also highlight the need for critical reflection on the potential but also the dangers of bodily integrated play. We acknowledge that we have painted a somewhat utopian future that might as well turn dystopian. As with any new technology, our devices have the potential to trivialize play as well as utilize it for immoral purposes. For example, we can imagine corporations offering such devices for play, yet secretly collecting bodily data. Furthermore, using such technology might also widen the socioeconomic divide of who can access play; other similar ethical, social and political issues around these technologies (e.g. [100-102]) that will impact play should also be discussed in future work. We hope our work can contribute to such a discourse.

6 CONCLUSIONS

There is an increasing trend in utilizing interactive technology for bodily integrations, fueled by technological advancements. In particular, we note a trend in integrating the human body with interactive technology. Unlike many examples seemingly suggest, we believe this trend of extending our physical capacities can be not only useful for productivity but also experiential purposes. In response, we have argued for the potential to enable novel play experiences. To illustrate our thinking, we have articulated an initial set of design strategies based on our experiences of designing bodily integrated play and related work.

We believe that, with the advancement of miniaturization, the reduction in the cost of sensors [45], and the progress in terms of biodegradable electronics [39, 49], we will see a proliferation of technologies that will drive this field forward. We can envision that if such devices become even smaller, they can be so small that we might consume them every time we eat [43], making such systems accessible to a large part of the population.

Ultimately, we hope we are aiding the facilitation of the many benefits of engaging the human body through games and play, so that people will profit from bodily play even in a future where machine and human converge.

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