# InsideOut: Towards an Understanding of Designing Playful Experiences with Imaging Capsules

**Zhuying Li**[1], **Yan Wang**[1], **Jacob Sheahan**[2], **Beisi Jiang**[3], **Stefan Greuter**[4], **Florian 'Floyd' Mueller**[1]
[1]Exertion Games Lab, Monash University, Australia, {zhuying, yan, floyd}@exertiongamelab.org
[2]School of Design, RMIT University, Australia, jacob.sheahan@rmit.edu.au
[3]School of Clinical Sciences, Monash University, Australia, beisi.jiang@monash.edu
[4]School of Communication and Creative Arts, Deakin University, Australia, stefan.greuter@deakin.edu.au

## ABSTRACT
Imaging capsules are ingestible sensors that capture the video of one's gastrointestinal tract for medical diagnosis. We believe that the capsule's experiential perspective is often overlooked by associated medical applications. This work explores the design of this experiential perspective through combining imaging capsules with digital play. We designed a playful wearable system called "InsideOut", where users play with the real-time video of their gastrointestinal tract captured by an imaging capsule. Based on an in-the-wild study, we derived four themes articulating the play experiences and discussed key design implications to guide future playful designs using imaging capsules. Our research highlights the opportunity of using medical imaging technologies to enable intriguing bodily play experiences. Furthermore, such experiences can deepen the players' engagement with and understanding of their bodies, ultimately contributing to a more playful and humanized health care agenda.

### Author Keywords
Ingestible sensors; imaging capsules; play; bodily play; ingestible play; medical imaging technology; well-being.

### CCS Concepts
•**Human-centered computing** → **Human computer interaction (HCI); Interaction design;** *Interaction paradigms;*

## INTRODUCTION
Imaging capsules are similar in shape to standard pharmaceutical capsules, and contain a small video camera, LED light and video transmitter powered by a battery. Once swallowed, the capsule moves naturally along the user's gastrointestinal tract (GIT), taking continuous pictures to form a video for further medical analysis [70]. Recent research suggests that in addition to their medical utility, imaging capsules have the potential to facilitate intriguing bodily experiences [68] which may bring about exciting opportunities for the field of bodily play [47, 48]. However, current research related to imaging capsules mainly focuses on their technical development and usability in medical diagnosis [13, 15, 34, 37, 43, 45], while the technology's potential to support experiential qualities is mostly overlooked.

We believe there is a novel design space of combining imaging capsules with digital play. First, such a combination could be entertaining and fun, therefore improving the patients' lived experience during potentially stressful medical procedures [50, 64]. Second, playing with imaging capsules could promote healthcare by engaging people with their personal data, i.e., their interior body images. Such an engagement could let players experience a higher sense of control over their bodies and health, facilitate doctor-patient communications, and support data sharing with others [29, 50, 75]. Third, seeing one's interior body could increase the individual's bodily knowledge [1], leading to better self-understanding and self-care practices [59]. Fourth, combining imaging capsules and play might result in the benefits known from bodily play since imaging capsules can be seen as part of body-centric computing [52]. Such play might not only benefit physical health [28, 38] and mental well-being [54, 55] but also engage people with their bodies in a playful manner, ultimately leading to a more humanized future of medical technology [53]. In summary, the combination of imaging capsules and play might bring about intriguing playful experiences and engage players with their bodies, hence offering potential to deepen the players' understanding of their bodies and ultimately benefit their health and well-being. Considering these potential benefits, we believe the opportunity to combine imaging capsules and digital play is worth exploring.

To explore this opportunity, we present *InsideOut*, a playful wearable system around imaging capsules. With *InsideOut*, the player swallows an imaging capsule and wears a garment containing a display showing the real-time video captured by the capsule. The system supports players to freely explore how they can influence their GIT; motivated by our software that maps the player's body movements to various video image manipulations such as scaling and rotation. Moreover, to prolong and enrich the player's engagement with the system, we designed six additional play modes. We invited seven participants to experience *InsideOut* in-the-wild (i.e., using the system in their homes and workplaces) and conducted semi-structured interviews afterwards. This qualitative study aimed to understand the player experience with *InsideOut*, especially about the player's bodily experiences when playing with their interior body video. Through a thematic analysis [7], we articulated four themes explaining the player experience, i.e.,



*DIS'20,* July 06–10, 2020, Eindhoven, Netherlands



ISBN 978-1-4503-6974-9/20/07…$15.00
DOI: http://doi.org/10.1145/3357236.3395484

*Experiencing the Enchanted Body as Subversive Play, Experiencing the Lived Body as Exploratory Play, Experiencing the Absent Body as Relaxed Play, Experiencing the Cultivated Body as Serious Play*. Finally, by combining the themes with our design craft knowledge, we proposed design implications for digital play around imaging capsules which are useful for designers who are interested in facilitating intriguing bodily experiences with imaging capsules.

## RELATED WORK

Our work derived inspiration from prior works involving ingestible sensors in art and digital play, interaction design related to medical images and the effect of interior body imaging on bodily experiences.

### Ingestible Sensors, Artworks, and Digital Play

Beyond medical applications, ingestible sensors have been used by body artists to express their understanding of the human body and medical technologies. For example, for an art performance, Stelarc ingested a self-developed sensor that contained a beeper and a flashing light. This performance aimed to challenge the traditional role of the human body by turning it into an "exhibition" space [69], which inspired us to make the interior body public in our work. Artist Jan Poope designed *Audiopill* that lets users experience music "from the inside" after swallowing an ingestible sensor. This sensor functions like a "speaker" that can be controlled by placing a probe on the user's skin [61]. *Audiopill* inspired us to consider touch interactions on the user's body. Body artist Phillip Warnell underwent a live capsule endoscopy procedure [76] to raise the awareness of the interior body beyond medical uses [57]. Similarly, Mona Hatoum presented her work *Corps étranger* which uses an endoscopy to shoot a video of the artist's interior body. To engage with the art installation, audiences are "trapped" in a cylindrical structure with the endoscopic video projected on the floor [5]. *Corps étranger* aimed to show viewers the unknown parts of the human body and motivate reflections on the "violent" appropriation of contemporary imaging technologies [66]. This work inspired us to consider pervasive interactions when engaging with the capsule's video. Overall, although these artworks do not tell us how to design playful experiences around ingestible sensors, they highlight the opportunity of engaging with the experiential perspective of ingestible sensors through digital means.

Inspired by experiential perspectives of ingestible sensors, HCI researchers have introduced ingestible sensors to digital play and called for works investigating the design of playful experiences around ingestible sensors [47, 48]. For example, Li et al. [44, 46, 47, 48] developed the *Guts Game* and *HeatCraft*, which are playful systems around an ingestible body temperature sensor. The authors investigated the associated user experiences and presented design strategies to guide the future design of playful experiences around ingestible sensors. These works demonstrate that play experiences around ingestible sensors can be influenced by the extent of integration of the digital sensor and the human body, the player's agency on the ingestible sensor, and the player's physical and social environment. Furthermore, playing with ingestible sensors might increase the player's bodily awareness and body knowledge. Also, ingestible sensors as a bodily-integrated technology have the potential to bring about novel ubiquitous play experiences by integrating the play into the player's daily life [47, 48]. We consider these strategies individually later under the section Design Rationale. However, there is still a lack of understanding regarding the design of playful experiences with imaging capsules.

### Interaction Design around Medical Images

Designers have a rich history of seeking novel materials for facilitating intriguing experiences. One example is the use of medical images for interaction design outside a clinical context. For example, as early as 1896, Natale [58] has analyzed the visual power of X-rays for public entertainment and called it "making the invisible visible", even before the technology became popular in medical practice. This inspired our work to make the capsule's video visible to the user and others. In recent years, more and more HCI researchers and designers have been using medical images as a design material. For example, Hoang et al. [31] developed an augmented reality system which projects anatomical structures and annotations over the user's body for educational purposes. This inspired us to display the capsule's video directly on the player's body. Ruth et al. [32] let hospitalized children use their X-ray sheets to create play characters in order to make young patients more active participants in their hospital experience. This led us to consider the capsule's video as an interaction element for players to play with in some play modes of *InsideOut*. Giraud et al. [27] proposed an installation which explores how medical images and self-images interfere with each other. This inspired us to ask players whether the play with imaging capsules influenced their understanding of their bodies. We note that these prior design works usually see the medical images only from a functional perspective (e.g., for education or diagnosis) and neglect the lived experience of seeing one's medical images, which might restrain our understanding of medical images' experiential affordances in interaction design. Hence, we believe there is a need to investigate the design of playful experiences around imaging capsules from an experiential perspective.

### Interior Body Images and Bodily Experiences

Seeing the images of one's interior body might facilitate intriguing bodily experiences and engage the individual with their own bodies [62, 66, 67, 68, 73]. Helman [29] suggests that despite being confronting at first, interior body images can bring about a strange pleasure to the viewer [17, 62] due to the images' novelty and the low level of bloodiness and messiness [72]. From this we learned that imaging capsule video could facilitate uncomfortable interactions [6] which have been used to inform bodily play design [11, 33, 56], and hence we also made use of this by aiming to design for the fine line between intrigue and discomfort. Moreover, the experience with one's medical images is influenced by the social context. For example, a patient might feel embarrassed when his/her "unclean" intestines are seen by others [62]. This inspired us to provide players with opportunities of showing the video to close social circles but also hiding the video to the public.

Prior work also suggests that besides facilitating engaging bodily experiences, interior body images have the potential

to shape the viewers' understanding of their own bodies and health. For example, Di Stefano argued that seeing interior body images makes viewers become more aware of their bodies and help reach a deeper body consciousness [20]. Slatman also argued that images of the interior body change the viewer's imagination of their interior body and bodily perceptions, which may further influence their self-identity [66]. Van Dijck [73] proposed that endoscopic video makes us experience more power over our bodies and influence our understanding of health. For example, interior body images usually look novel and even pleasant when exhibited in art performances or on TV, possibly making viewers be more accepting towards surgical procedures [72]. Similarly, Giraud et al. [27] suggested that the interior body images can benefit the planning of therapies, support predictive simulations; and enhance diagnosis, education, and patient-doctor communication. Therefore, we designed most game experiences depicting the display of "realistic" video of their GIT to engage players with their own bodies. Such a design might even provide benefits to the health domain. Overall, the related work suggests that there is an opportunity of using interior body images as design material to enrich people's engagement with their bodies and understanding of their health. As this is the first investigation into this nascent area, we focus on the potential for engagement and hence the user experience, and leave implications for health for future work.

In light of the above, we identify a gap of investigating the design of playful experiences with imaging capsules. Filling this gap would offer great potential in facilitating playful bodily experiences and deepening the players' understanding of their bodies, hence benefiting their well-being. To explore this opportunity, we ask the question: *How can we design playful experiences around imaging capsules?*

## INSIDEOUT

To explore the design around imaging capsules, we designed *InsideOut* (Fig 1c). *InsideOut* is based on the OMOM® SmartCapsule Endoscopy System [36] which is TGA and CE-approved [45]. The system consists of an imaging capsule, a waist belt containing an antenna array for receiving signals from the capsule wirelessly, and a data recorder receiving data from the antenna array. The recorder is put in a pouch and worn by the user over the shoulder during the medical procedure. A software called ImageStation supports seeing the video captured by the imaging capsule in real-time if connecting the data recorder to a PC.

*InsideOut* comprises the OMOM® SmartCapsule Endoscopy System, a display (iPad), a laptop (MacBook), and a powerbank for providing additional power for the laptop as the play can last about eight hours (see Fig 1b). The laptop uses Open Broadcaster Software (OBS) [16] to collect the video shown on the ImageStation software and stream it into the Touch Designer software [19] for composing and interactivity. The transformation of the capsule's video is based on the player's body movements and surrounding environment which are sensed by the iPad and sent to the Touch Designer via GyrOSC [65]. The output video of the Touch Designer is shown on the display (iPad) via Duet Display [22].


Figure 1: (a) An early prototype of *InsideOut*; (b) The system diagram of *InsideOut*; (c) A player is engaging with *InsideOut*.

.

## DESIGN RATIONALE

In the following subsections, we elaborate on the design rationale of *InsideOut*.

### Design Guidelines

We first identified design guidelines from prior works [47, 48] that explored the design of playful experiences around ingestible sensors. We combined the design strategies proposed in prior work into the following ten design guidelines that guided the design of *InsideOut*.

1. Design always-available interactive systems to facilitate symbiotic relationships.
2. Consider body boundaries to facilitate playful experiences.
3. Consider uncomfortable interactions in ingestible play.
4. Design for emotions to help players accept the ingestible sensor psychologically.
5. Consider designing various playful interactions across the play duration.
6. Consider the human body from both the first and third perspective to facilitate lived body experiences.
7. Design appropriate feedback to regulate the player's bodily awareness.
8. Consider ambiguity as a way to communicate the low agency to players.
9. Consider the environment perspective in ingestible systems.
10. Design social play for ingestible systems.

### Design Wearability to Facilitate Always-Available Play

Based on design guideline 1, we designed *InsideOut* to provide always-available interactions. The maximum play duration of *InsideOut* is about eight hours due to the imaging capsule's battery life. Currently available AR head-mounted displays are usually not suitable to use continuously for eight hours due to the weight and battery limits. Hence, we decided to design *InsideOut* as a system that is worn like fashion clothing, where the display is worn on the user's body (see Fig 1a illustrating an early prototype). Our vision is that, in the future, all parts of clothing offer the functionality like interactive displays: for now, we implemented a display within a T-shirt (Fig 1c).

During the design process, we considered using a smartwatch as the display; however, smartwatches are too unobtrusive, making it hard to facilitate social interactions and pull the player's attention back to any play without explicit notifications. Inspired by design guideline 2, we chose to place the display in front of the user's stomach. An imaging capsule already challenges one's body boundary by literally entering the body. We hoped that placing a display in front of the user's body further highlights the "crossing of body boundaries" by creating a feeling that the skin becomes transparent and the body boundary is blurred. Moreover, wearing the display in front of the body was not viewed as hindering the player's movements by the design team. The player can lower the head to view the screen at any time, stepping towards always-available play. Also, this position allows other people to see and interact with the capsule's video, which might facilitate engaging social play experiences (design guideline 10) or bring about uncomfortable interaction experiences (design guideline 3) which could promote critical reflections on the bodily data and associated technologies [4, 6, 40]. To balance the uncomfortable interaction, we also designed a button that looks like an eye for to hide the video for privacy.

### Design Playful Interactions to Support Experiencing the Interior Body as Play

The design goal of *InsideOut* is to let players experience their interior bodies as play rather than their bodies as controllers [53]. Therefore, players could be more engaged with their bodies, experiencing that they not only *have* a body but *are* bodies. To achieve this, we followed design guideline 6, i.e., we took two perspectives: *Körper* (3$^{rd}$ person perspective) and *Leib* (1$^{st}$ person perspective) on the human body. Mueller et al. [53] suggested that supporting players in exploring the interplay between *Körper* and *Leib* could increase the players' understanding of the human body, e.g., by supporting players to use their *Körper* to influence their *Leib* experiences. With *InsideOut*, players' *Leib* experiences can be evoked by seeing the interior body images [68]. Therefore, we designed the principal interactions of *InsideOut* as letting player activate their bodies (*Körper*) to experience their interior body changes (*Leib*). To be more specific, we designed *InsideOut* to be open-ended, encouraging players to freely explore how they can interact with their interior bodies.

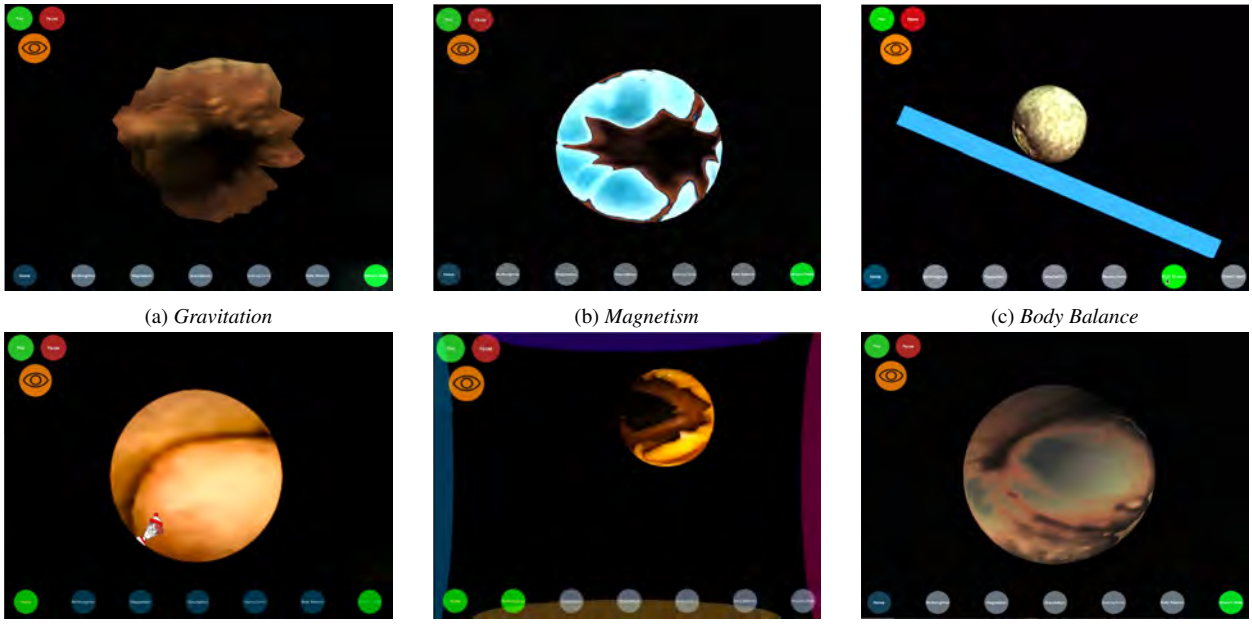
### Enhancing and Enriching Playful Experiences

We adopted the *Experience Prototyping* design method which enables designers and users to gain first-hand experience by engaging with prototypes [10]. Three researchers of this project wore an iPad playing a video of human GIT captured by an imaging capsule for one day. During the experience, the authors also used this prototype to communicate the idea with their friends to collect informal feedback on the *InsideOut* design. Most people who interacted with the researchers loved the idea of *InsideOut*. Based on the research team's initial experiences with the prototype, we explicated the following design challenges:

1. Users may experience fascination about the interior body video at first while feeling uncomfortable after looking at the video for a long time, which might lead to disengagement with the video.
2. Users may feel uncomfortable to show the video within certain social contexts, e.g., in public spaces.
3. Many people liked to see how food is digested while few people thought of how moving can influence their interior bodies. This might prevent players from exploring how they can influence their interior bodies through movements.
4. Most people expected a high agency towards their interior body; hence they might feel frustrated if they experience a low-level of control over the video.

Considering the above design challenges, we decided to use body movements to influence the video images' scaling and rotation to further enrich the play experience and encourage player actions. By doing so, players can still freely explore their interior body since the video feed is still provided; however, we hope they experience a higher agency towards the video, tackling the fourth challenge. As a result, players may not only enjoy better play experiences [71] but also experience more control over their bodies which increases their well-being in general [50]. Moreover, mapping the players' movements to influence the video transformation can tackle the third challenge by encouraging players to perform more bodily movements, which might further influence the shape of their GIT and thus the video. As such, players might be inspired to try more bodily movements to interact with their interior bodies.

Based on the design guideline 5 and 7, and first design challenge, we decided to add six additional play modes to enrich the play experiences (Fig 2). The six play modes were designed based on the *Four Keys* for creating emotions in play [41]. *Gravitation* (Fig 2a) and *Magnetism* (Fig 2b) were designed to facilitate the key *Easy Fun* by embracing ambiguity and environmental data to evoke players' curiosity and facilitate interaction, exploration, and imagination [41], which corresponds to the design guideline 8 and 9, and the second design challenge. We designed *Body Balance* (Fig 2c) and *Finding Wally* (Fig 2d) to facilitate the key *Hard Fun* by proposing game challenges and directing players' attention to the associated goals. *Finding Wally* also facilitates the key *People Fun* because it supports other people interacting with the video on the display. *Borborygmus* (Fig 2e) and *Bloating Moves* (Fig 2f) were designed to facilitate the key *Serious Fun* since they might motivate players to reflect on how imaging capsules might change their interior bodies by simulating the intestine' rumbling sound and shape changing in an exaggerated way.



(a) *Gravitation* (b) *Magnetism* (c) *Body Balance*

(d) *Finding Wally* (e) *Borborygmus* (f) *Bloating Moves*

Figure 2: (a) *Gravitation* and (b) *Magnetism* transform the video based on the surrounding magnetic field's strength and gravitational acceleration respectively. (c) *Body Balance* turns the video into a rolling ball and requires the player to move the body to balance the ball on a seesaw. (d) *Finding Wally* requires the player to search for hidden gems, identifying them results in a visual effect and a rumbling sound. (e) *Borborygmus* moves the video on the display based on the player's body movements. When the image touches any of the four arcs, a rumbling sound is generated. (f) *Bloating Moves* maps the video onto the surface of a flexible 3D ball with its shape changed through the player's body movements.

## STUDY

We conducted an in-the-wild study [63] in Melbourne, Australia with seven participants (4 males and 3 females, age 29 $\pm$ 3.7 (mean $\pm$ S.D.) years) to investigate the user experience of *InsideOut*. No compensation was provided.

To participate in the study, each player came to our lab in the morning, swallowed an imaging capsule and put on the wearable system. The participant then left the lab and experienced *InsideOut* in everyday life. As each capsule's battery only lasts for approximately eight hours, the participant came back to the lab after that time for a semi-structured interview. Each interview lasted about 45 min and was audio recorded.

### Ethics

Engaging with ingestible technology raises several ethical questions which were intensively discussed with our ethics board over the course of seven months. The following two paragraphs present our ethics considerations and associated discussion based on the fact that our work offers an initial investigation into this topic to further expand the thinking around methods for HCI research working with medical technologies.

We designed a study protocol to guide the user study and gained consent from the imaging capsule's manufacturer that they would support the use of the device for our non-medical purposes. In the protocol, we designed a screening procedure where only people who have previously swallowed ingestible sensors of similar size were recruited in this study, aiming to minimize the risk of participants having any obstructive disease of the GIT. Therefore, we contacted the participants of our prior studies [47, 48] in which they swallowed an ingestible temperature sensor of similar size. In addition, we collected the information on the participants' health status and medical history via a risk assessment questionnaire. A health professional interviewed the participants to further determine their suitability to participate in the study. Once a participant was eligible to take part in the study, we gave out instructions on how to prepare for swallowing the capsule. For example, we informed the players that if they wanted to see a clear view of their GIT, they should not eat and only drink clear fluids such as herbal tea and apple juice after lunch on the day before swallowing the capsule.

On the day of the study, we gave the participant a printed document listing the contact number of all the researchers, guidance for first aid in case of need, and the instructions on what they should do and should not do during the study, for example, the participants should not do strenuous physical exercise as recommended by health professionals. A health professional was accessible at any time via mobile phone for related medical queries. We also acknowledged the risk that public display of the video may cause offense in bystanders and in turn potentially create risks for the participants. To manage this risk, we suggested the participant only show the video at home and the workplace. Moreover, the participant was required to inform the people with whom they lived or worked with concerning the aspects of the study. Only if the

potential bystanders felt comfortable, the participant should continue with the study. The participant was also informed that if the bystanders proposed that they felt uncomfortable with the video during the study, the participant should turn off the screen. After the study, participants were notified that they could keep their GIT's video if they wanted. However, we highlighted that the video cannot be used for medical diagnosis as the procedure was not the same as the procedure in hospitals. There was only one participant who kept the video. The entire ethical considerations also correspond to the design guideline 4 since they could help ease any player anxiety regarding swallowing the sensor [48].

## RESULTS

The interview data was analyzed via the thematic analysis approach [7]. Two researchers read the transcripts three times to get familiar with the data and then coded the data independently. Later the two researchers discussed and extracted the codes until an agreement was reached. The codes were then iteratively clustered into higher-level themes, which we describe in the following sections. Under each theme, we use "Fx" as the shorthand for "Finding Number x".

### Theme 1: Experiencing the Enchanted Body as Subversive Play

Subversive play refers to playful experiences facilitated by breaking social norms [49]. This theme highlights that *InsideOut* can facilitate subversive play experiences since watching and showing one's own interior body can break social norms, at least to some extent. Following McCarthy et al.'s definition [51], we use "enchanted" to describe the interior body since players experienced the video as attracting, novel, unexpected during the entire play.

#### *F1. Seeing the interior body was a strange pleasure*

All of the players reported that they enjoyed seeing their own interior body. They described the video as "*fascinating*", "*novel*", "*intriguing*", "*pleasant*" and "*playful*". P1 said: "*It was quite confronting at first, but later I found it very interesting. I have never seen my intestines before*". Similarly, P2 said: "*Actually I was hesitant before the study because I was a bit afraid to see something wrong with my body. I thought it was weird to see my interior body but it was actually a pleasant experience, much more fun than I thought!*". P4 also said: "*At first the video was a bit shocking. But later I was absorbed in the images and felt like traveling inside my body. After the capsule left my stomach, it entered my intestine, the pictures were messy and a bit disgusting. But it was still fun. I kept checking the video during the whole procedure*". All the players reported that they engaged with the video although they did not have the professional medical knowledge to interpret the video. P3 said: "*I knew it was not a medical imaging examination and I could not tell whether I am healthy based on the video. But I still felt the experience was immersive. Just seeing the video was already very interesting*".

#### *F2. Watching the changing body facilitated ongoing playful engagement*

The displayed video was captured by the moving imaging capsule and hence showed the different parts of the player's GIT. The fact that the video was changing evoked players' curiosity and facilitated ongoing engagement. For example, P4 said: "*It was amazing to see how the different parts of my digestive system look. At first I saw my stomach wall which is quite smooth. After several hours, I saw my fluffy intestines wall*". Moreover, players reported that they were curious about how food would change after being ingested. For example, P5 said: "*I tried some bubble tea and then I clearly saw the black bubble inside my stomach. After some time, I could still see the bubble's shape, and this made me feel a bit disgusted. But I should say that it was fascinating to see how the food changed inside my body*".

### Theme 2: Experiencing the Lived Body as Exploratory Play

People can experience exploratory play when investigating an object or situation [49]. This theme articulates how *InsideOut* motivated the players to explore their bodily capacities in influencing their interior bodies, resulting in exploratory play. Here we use the definition of "lived body" from Gadow [25] as one being capable of affecting the world.

#### *F3. Building a connection between the video and the player's body was the basis for exploratory play*

The interviews suggested that once the players were able to establish a connection between the displayed video and their bodies, they performed more activities to explore how they could influence their interior body. This finding confirmed the prior theory that suggests a strong correlation between self-identification with the personal data and the will to influence it [60]. Our study suggested several ways that allowed players to experience the video as their own body. First, the extensive screening procedure strengthened the connection between the video and the player's body. For example, P1 said: "*The screening procedure made me feel better, because I believed it could minimize the risks. At the same time, it made me realize that it was my body to be examined*". Second, the video showing the process of swallowing the capsule helped facilitate the connection. For example, P2 said: "*After picking the capsule out of the [packing] box, I saw the video showing the room view. When I swallowed it, I saw my teeth, my tongue and I saw it entering my stomach. This was very different from seeing some internal body images online. It made me realize: 'Ah, it was my body!'*". Third, the experience of swallowing a digital capsule helped connect the video to the players' bodies. For example, P4 said: "*Swallowing the capsule was exciting but a bit scary. This motivated me to keep checking the video since I wanted to confirm my body condition*". Forth, the players connected the video to their bodies if their body condition corresponded to their actions before swallowing the capsule. For example, P3 said: "*Before I came here, I had some protein shake for breakfast. Thus, after I swallowed the capsule, I could hardly see how my stomach looks like*". Similarly, P6 said: "*I did not have any food after yesterday's lunch. Then I saw a very clear view of my stomach. I was thinking 'Yeah, it works'*". Fifth, the players experienced the video as their body when they saw they could influence the video. For example, P2 said: "*After I swallowed the capsule, I had some beef for lunch and I saw it*

*through the video. I think it motivated me to try more activities afterwards because it let me know this is my body and I can influence it*".

*F4. Players explored their lived body via eating and moving*

All the players reported that they were curious about their capacity for influencing their interior body and therefore they tried different activities to achive this. Players mentioned that the most intuitive strategies were eating and drinking. For example, P6 said: "*After I ate something, I always fixed my eyes on the video trying to find the food. It was interesting to find the food I had in my stomach*". P3 also said "*I saw the lettuce I had for lunch! It was fascinating and encouraged me to try more things to see how it would look like*". Some players also spontaneously tried to perform bodily movements in order to influence their interior bodies. For example, P1 said: "*I twitched my abdominal muscles and it was amazing to see the fluid in my intestines sloshing immediately!*" P4 also said: "*When I sat down, my intestines looked folded but when I stood up, it looked smooth. I was surprised that I can easily influence my body interior*". Four participants mentioned that the play modes motivated them to move their bodies. When they found to their surprise that movement influenced the interior body, they were motivated to explore further the relationships between different activities and the interior body. For example, P3 reported: "*I knew little about my interior body before the study and I had no idea how to influence the video. At first, I just moved my body because I was playing with some play modes like Body Balance and Borborygmus. Then I was surprised to see my intestines' shape changed! So I began to try different activities, not because of the play modes' rules, but just for exploring my own body*". P5 also said: "*The other play modes made me realize the relationship between my moves and the shape of my intestines. When I was at home, I tried to bend my body to squeeze the capsule [laugh]*". We asked the participants what they did to influence their interior body. The activities they tried included eating, drinking, changing their standing, sitting, and lying-down postures, moving and shaking their bodies, and performing abdominal twitches.

**Theme 3: Experiencing the Absent Body as Relaxed Play**

The playful experience of relaxation refers to the relief from bodily or mental work [49]. We borrowed the term *absent body* from Drew Leder who expressed that our body is sometimes phenomenologically absent from our awareness [42]. This theme suggests that after being intensely conscious about their interior bodies by watching the video, players played with certain play modes which did not show a very "realistic" interior body and as a result experienced relaxed play.

*F5. Play modes let players relax after prolonged watching*

Four players reported that although seeing and interacting with their "realistic" interior body was playful, they felt a bit uncomfortable after watching the unmodified video at times. These players mentioned that the other play modes of *InsideOut* let them "take a breath" and engage in bodily play. For example, P3 said: "*The images of my large bowl were messy and I felt a bit disgusted to see them for a long time. Then I tried other modes where I could hardly see the images, like the magnetic one, and the balancing game*". Similarly, P7 said: "*When the images were transformed, it was hard to know how my real intestines looked like* [...] *I like the idea of using the invisible environmental factors to visualize the images in an artistic way after watching the realistic video for a long time*". Players also enjoyed the play modes when they felt they had less influence over their interior body. For example, P2 said: "*After several hours, it was hard to see the food I ingested. The food could not catch up with the capsule. So I turned to other play modes which made me feel more in control*".

*F6. Play let players experience their bodies from different perspectives*

Players reported that different play modes of *InsideOut* let them experience their bodies from different perspectives, which facilitated ongoing engagement. For example, P3 said: "*The original video was quite 'realistic', letting me experience my interior body directly. The video in the Gravity and Magnetism mode was very artistic and ambiguous. It made me feel very relaxed after seeing the original video. With other modes such as the Wally and Balancing mode, I can still see the original video while my attention was more directed to my movements such as the touch and the body swing. I can say that these modes also engaged me with my body, but very different from the engagement with my interior body in the default mode*". Players expressed that they appreciated that *InsideOut* supports different play modes. For example, P2 said: "*I played with the visualization a lot, but I still wanted to see the real images, especially at the beginning, when I swallowed the capsule*".

*F7. Players chose when to experience relaxed play depending on social contexts*

All participants reported that they regarded the video of their interior body as "intimate" data, hence they would not display the video in public even if the study allowed them to do so. For example, P5 said: "*I would not share the video with people I am not familiar with. I am a 'private person'*". Similarly, P6 said: "*I don't want to share the data in public. I know it is not a clinical examination, but I still feel the data is my medical data which is private. I should own the data rather than sharing it with strangers*". Hence, players mentioned that they changed to the play modes *Magnetism* and *Gravitation* when they were with unfamiliar others. For example, P5 said: "*These two modes looked artistic. I think it was good to show such visualizations to people I am not that familiar with. By doing so, I can share my story without showing my realistic private images*". Players said that they decided whether to show the video to their friends depended on the video's "appearance" since the video formed part of their self-identity. For example, P2 said: "*I enjoyed showing my friends the video during the first several hours because then my intestines looked clean. But later the video became messy when the capsule was in the large bowel and I did not want to show it to others* [...] *It is very like sharing your photos on social media. You only want to share others your good pictures*". When it comes to intimate relationships, all the players reported that they enjoyed sharing the video and play experiences with partners, close friends, or parents, but this was dependent on the other per-

son's personality. For example, P4 said: "*When my boyfriend returned home, I was very excited and asked him to see my intestines. I think this was fun and was part of my body. I wanted to share this with him*". P3 also said: "*I shared the video with my colleagues because I know they would love to see this. But I did not show it to my mom. I think she would not feel comfortable*".

### Theme 4: Experiencing the Cultivated Body as Serious Play

According to Gadow's theory [25], the cultivated body is experienced when a harmony of the lived body and object body is reached. We found that *InsideOut* has the potential to deepen players' understandings of their body and ultimately step towards a cultivated body, which corresponds to an understanding of serious play, i.e., digital play that can motivate real-world benefits to help players change how they think, feel, and behave or to accomplish serious work [41].

#### *F8. Players became more aware of their bodies*

All players mentioned that *InsideOut* made them more aware of their bodies, especially the interior parts. Players reported that before doing the study, they were not aware of their interior bodies. For example, P1 said: "*I rarely thought about my interior body, maybe because the interior parts are invisible and I nearly have no sensory experiences with these parts. But when playing InsideOut, I was fully aware of the existence of my interior body because it was constantly showing me how my intestines looked like!*" Similarly, P7 said: "*It definitely increased my body awareness. One reason is that I swallowed a digital sensor, and this made me more conscious of my body. Also, seeing the video of my internal body made me more aware of my body than usual, especially of my digestive system. I consciously linked my feelings like hungry and full to the images I saw*.

#### *F9. InsideOut increased the players' bodily knowledge*

All players said that *InsideOut* increased their bodily knowledge. For example, P2 reported: "*It helped me know more about the digestive system, like the digestion speed. It was amazing that the food I had two hours later caught up with the capsule!*". P6 also said: "*I knew little about my interior body before the study and I had no idea how to influence the interior parts. But after the procedure, I think I recognized the digestive system as part of my own body*". The play with *InsideOut* also motivated self-learning of the human body. P4 reported that: "*It taught me a lot about my body. After several hours, I say my intestines' wall being fluffy and then I searched online. Now I know that it was my small bowel. The texture of different parts of the digestive system is different.*". P1 said: "*This experience motivated me to learn more about my body. I searched the related body knowledge online and I was particularly interested in the digestion rate*". Some players reported that they knew more about how the food is digested through the play. For example, P5 said: "*The food's digestion process is amazing. When [the food was] in the stomach, I could still recognize the food. But later, it was smashed*".

#### *F10. InsideOut let players feel more intimate with their bodies*

*InsideOut* deepened the players' understanding of the body and increased the intimacy with their bodies. By doing so, the body and self became more harmonized. For example, P4 said: "*It made me [think] about my body. I can feel the pain, touch, and lots of sensations on the skin but I usually could not feel them with my digestive system. The body is weird. Isn't it?*". Similarly, P7 reported that: "*It was interesting to know that I actually have some control over my digestion. But I could not fully control it. I remembered once I saw something big on the screen, but it passed very quickly. I really wanted to control the capsule to catch up with it, but I couldn't. I knew this is my own body, but it can never be fully controlled*".

#### *F11. InsideOut facilitated self-reflections*

*InsideOut* motivated players to reflect on their behaviors, especially about their movements and diet. For example, P3 said: "*It made me think about my diet. When I saw something, which is hard to recognize, I thought about what I had in my last meal*". P7 also said: "*After I found that different posture might influence my intestines' shapes, I began to think about what postures might be good for my digestion*". The reflections modified the players' behavior, even outside the game. For example, P3 said: "*My digestion rate is slower than I thought. I could see the food I had several hours ago in my stomach. This made me eat slower and more mindful*". Interestingly, *InsideOut* might be able to influence the player's long-term behavior as well. P3 contacted us a week after the study, telling us she still consciously ate slower and chewed more often (as recommended by mindful eating [21]). Moreover, the *Gravitation* and *Magnetism* play modes encouraged players to reflect on the relationship between their bodies and the environment. For example, P6 said: "*I like the modes combining the environment data and the video. It made me think of how my environment might influence my body. The gravity and the magnetic field are invisible for me, however, they act on my body*".

## DISCUSSION

Based on our craft knowledge and the study results, in this section, we discuss design implications to improve the design of future playful experiences with imaging capsules.

### Design Always-Available Changing Video to Support the Enchanted Body

Theme 1 suggests that the players enjoyed seeing their interior body video and the changing content showing a "dynamic" body facilitated ongoing engagement. *InsideOut* stepped towards a lasting engagement with the imaging capsule's video by engaging with the following strategies. First, *InsideOut* did not decrease the frame rate of the video captured by the imaging capsule (2fps), hence providing real-time images of the player's interior body. That is, players could get immediate feedback of certain activities they take to influence their GIT. Second, *InsideOut* was designed to be wearable and hence supported ubiquitous play experiences, facilitating ongoing always-available play. Third, since the parts of one's GIT might look different, *InsideOut* provoked players' curiosity by presenting the eight-hour video captured by the traveling

capsule to show the differences, promoting players' ongoing engagement.

The findings with *InsideOut* align with prior play theories. For example, the element *Concentration* and *Feedback* in the *Pervasive Gameflow Model* [35] suggests that pervasive play should let players concentrate on the play, support switching concentration between the play and physical surroundings, and provide immediate feedback for the players. *InsideOut* showed the entire "body voyage" to facilitate play concentration; used always-available interaction to support switching concentration; and used high frame rate video to support immediate feedback. Therefore, we suggest designers support player concentration and design immediate feedback, which can be facilitated by the always-available high-frame rate video showing the entire GIT. Such design implications can also be found in related design practices. For example, the VR system *A Body Odyssey* simulates the journey of food digestion [24]. Viewers wear a head-mounted display to see the food traveling through digestive organs while getting digested from a first-person view. This system facilitates concentration by providing continuous VR experiences and provides immediate feedback by letting players moving forward in the VR environment through crawling.

#### Guide Players to Play with Interior Body to Support the Lived Body

Theme 2 suggests that with *InsideOut*, players play with their lived body by exploring their capacity to influence their interior body. Based on the players' strategies before swallowing the capsule, we divided them into two groups. We called them the "dieters" and the "eaters". Dieters restricted their diet one day before the play and hence could see a clear view of their GIT. During the play, dieters tended not to eat anything several hours after swallowing the capsule in order to keep the clear view. Eaters did not diet before the play and hence they usually could see the residue in their GIT. During the play, eaters usually enjoyed trying different food to see the digestion and identifying the residue based on the food they had before and during the play. Therefore, dieters might gain more bodily knowledge while eaters might know more about the body-food relationship. Moreover, dieters spent more time seeing the unmodified "realistic" video while eaters usually switched between the unmodified video and other play modes. Dieters and eaters also had different social play experiences. Dieters were usually willing to share the video with their family and friends while eaters might only want to show the "messy" GIT to people with whom they had close relationships.

Cognizant of the differences between dieters and eaters, we suggest designers guide the players to be a "dieter" or an "eater" based on the design goals. Designers might encourage players to be dieters if aiming at increasing the players' body knowledge while they should guide players to be eaters to promote human-food interactions [2, 39] as a way to facilitate increased body-food relationship knowledge. To guide the players, we propose two strategies. First, we suggest designers engage with body preparations (i.e., one day before swallowing the imaging capsule). Designers could design a strict diet during the preparation phase to guide players to be dieters or allow players to freely decide what to eat during the preparation to guide them to be eaters. Designers can even encourage players to ingest certain kinds of food to facilitate specific food-related experiences. This strategy is similar to the prior theory that suggests the preparation for medical imaging procedures translates a patient's body into an object of medical visualization, which influences the patient's sensory perceptions, emotions, reflections, agency, and experiences [62]. Second, we suggest designers consider the input of play. To guide players to be dieters, the playful design might encourage body movements to influence the players' interior body. Designers should note that the GIT is lined with smooth muscles that cannot be directly controlled by the player [9], however, the shape of GIT might be influenced by skeletal muscles which are muscles that produce the movements of body parts in relation to each other [8]. Therefore, we suggest designers consider designing skeletal muscle movements which can influence the player's GIT shape if aiming to guide the players to be dieters. Meanwhile, for designers who are interested in facilitating playful imaging capsule experiences with food digestion, eating can be designed as an interactive way to manipulate the video images to encourage various eating actions. Examples of using eating as play input can be seen in Arnold et al.'s work [3] where using eating to influence the player's vision in a VR game. Therefore, future designs with imaging capsules may use eating as input, for example, to influence the scale of the capsule's video in order to motivate food-related experiences.

#### Manipulate the Interior Body Video to Support the Absent Body

Theme 3 suggests that *InsideOut* supports the absent body experiences by providing play modes without a very "realistic" interior body video. We divide the manipulations we designed into two types: *video as a playful expression* and *video as a play resource*. These two types of manipulations led players' attention differently.

##### *Video as a playful expression*

*Magnetism* and *Gravitation*'s artistic and ambiguous visualizations aroused the player's curiosity, facilitated playful expressions, and also encouraged social sharing by dampening the "messiness" of the GIT. With this type of manipulation, the player's attention was directed to the body as well as the video, going back and forth. This finding corresponds with prior works suggesting that ambiguity as a design resource can evoke non-goal-oriented interactions [18, 74], and facilitate exploratory play [12, 14, 23, 26, 30, 49]. Therefore, we suggest designers consider manipulating the video to be ambiguous and even artistic to support self-expression and facilitate social sharing. In *InsideOut*, we designed an ambiguous transformation related to the environmental data, which facilitated players' reflections on their bodies and surroundings. Hence, designers could consider designing the transformation based on specific data on which they hope the players will reflect.

##### *Video as a play resource*

*Borborygmus*, *Bloating Moves*, *Body Balance* and *Finding Wally* manipulated the interior body video to be a play resource which players can interact with through movements

or gestures. With this type of manipulation, the players' attention can be directed outwards to the play (device), rather than the body. We found that players particularly engaged with this type of play mode when they wanted to escape from the "messy" interior body video or when they felt frustrated because of experiencing the low agency of their interior bodies. Therefore, when designing playful experiences with imaging capsules, we suggest designers consider transforming the capsule's video into a play resource and let players play with it in order to help players relax from the "intense" experiences with the "realistic" interior body video and the frustration caused by the player's low agency towards their interior body parts. Moreover, *Borborygmus* and *Bloating Moves* facilitated engaging bodily play experiences by amplifying the influences of one's body movements on the interior body, facilitating playful experiences and increasing bodily knowledge. Therefore, we suggest designers consider letting players interact with the play resource, i.e., the interior body video, and playfully amplify how such an interactive way might influence one's interior body.

## LIMITATIONS AND FUTURE WORK

This work has several limitations. First, we did not propose design strategies to support the fourth design theme, i.e., the cultivated body. The reason is that *InsideOut* does not lead to the cultivated body through our design, but by facilitating the other three themes. Future design research can be done to investigate how to explicitly further the cultivated body experiences through design. For example, designers might use machine learning algorithms to identify the interior body parts based on the video and therefore increase the player's body knowledge, stepping towards a cultivated body. Second, this work only presents *InsideOut* as a case study to investigate the design of playful experiences with imaging capsules. In future works, more design practices around imaging capsules could make our understanding of designing the imaging capsules' experiential perspective more complete. Third, our study had seven participants due to the high cost of imaging capsules system: a kit including the data recorder, belt, recorder holders and the software was approximately $8000 and each capsule was about $500. Future studies can be done with a larger number of users when the cost of capsules decreases. Fourth, we recruited participants from the participants of our prior studies related to ingestible sensors. These people were recruited via a mix of convenience sampling and snowball sampling method. Therefore, these volunteers were probably adventurous types that actively engaged in the subversive experiment, which might have led to more positive results. In the future, we might recruit a more conservative participant cohort. Fifth, as an initial exploration, we investigated the user experience with healthy people. Future work could explore the design with specific user groups, e.g., patients with GIT diseases. Sixth, we acknowledge that there might have been a novelty effect when using such intriguing technology, which might have skewed the results towards more positive responses. Future long-term studies might strengthen the results. Seventh, although prior works and our study indicate the potential benefit of combining imaging capsules and play for health and well-being, this work did not investigate the project's impact on health. Rather, we situate our work in play research in order to fully understand the experiential perspective of imaging capsules. We believe such an understanding can benefit and inspire future investigations on how digital play with imaging capsules could benefit players across a range of domains, including health and well-being. Eighth, our study indicates that playing with imaging capsules might result in self-reflection. However, we acknowledge that such reflections might not always lead to a proper understanding of the human body and health. For example, Van Dijck [73] proposed that medical images might lead people to believe that "seeing is curing", which is not accurate. We hope with our work, we can fuel such discussions by providing first-hand accounts from a design perspective in order to advance critical thinking in this field.

## CONCLUSION

This study explored the design of the experiential perspective of imaging capsules through investigating the design of playful experiences with imaging capsules. We designed and developed the prototype *InsideOut*, a playful wearable system that motivated seven participants to engage with their interior bodies as part of an in-the-wild study. Our work makes the following contributions. First, we contribute to practice by presenting a novel design prototype around imaging capsules. Second, we present the results of an in-the-wild study that shows how a design around the use of imaging capsules can facilitate playful bodily experiences and shape a player's understanding of their bodies. Third, we present four design themes (*Experiencing the Enchanted Body as Subversive Play, Experiencing the Lived Body as Exploratory Play, Experiencing the Absent Body as Relaxed Play, Experiencing the Cultivated Body as Serious Play*) that can help researchers understand play experiences with imaging capsules. Fourth, we present design implications to guide designers when aiming to create playful interactive experiences with imaging capsules. More broadly speaking, our work might inspire designers to explore the role that imaging capsules can play in facilitating intriguing interactions and playful experiences; motivate designers to seek medical technologies to facilitate future interactive experiences; and encourage medical technology developers and health professionals to think about novel ways of how they can engage their patients with their health data and medical procedures using game design thinking. Ultimately, with our work, we aim to advance our understanding of designing playful medical imaging experiences in order to further a more playful and humanized health care agenda.

## ACKNOWLEDGEMENT

We thank Professor Finlay Macrae and Ms Stephanie Quah from the Royal Melbourne Hospital for their insights. Thanks also to Cellmed Pty Ltd (Australia) and Jinshan Science & Technology (Group) Co., Ltd (China) for their support. We also acknowledge the support from the School of Design at RMIT University, Australia.

## REFERENCES

[1] Teresa Almeida, Rob Comber, Gavin Wood, Dean Saraf, and Madeline Balaam. 2016. On Looking at the Vagina through Labella. In *Proceedings of the 2016 CHI*

*Conference on Human Factors in Computing Systems (CHI '16)*. Association for Computing Machinery, New York, NY, USA, 1810–1821.

[2] Ferran Altarriba Bertran, Samvid Jhaveri, Rosa Lutz, Katherine Isbister, and Danielle Wilde. 2019. Making Sense of Human-Food Interaction. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19)*. Association for Computing Machinery, New York, NY, USA, Article Paper 678, 13 pages.

[3] Peter Arnold, Rohit Ashok Khot, and Florian'Floyd' Mueller. 2018. "You Better Eat to Survive" Exploring Cooperative Eating in Virtual Reality Games. In *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction*. 398–408.

[4] Shaowen Bardzell, Jeffrey Bardzell, Jodi Forlizzi, John Zimmerman, and John Antanitis. 2012. Critical Design and Critical Theory: The Challenge of Designing for Provocation. In *Proceedings of the Designing Interactive Systems Conference (DIS '12)*. ACM, New York, NY, USA, 288–297.

[5] Frédérique Baumgartner. 2019. Corps étranger. `http://www.newmedia-art.org/cgi-bin/show-oeu.asp?ID=150000000007761&lg=GBR`. (2019). Accessed Jul 5, 2019.

[6] Steve Benford, Chris Greenhalgh, Gabriella Giannachi, Brendan Walker, Joe Marshall, and Tom Rodden. 2012. Uncomfortable Interactions. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. ACM, New York, NY, USA, 2005–2014.

[7] Virginia Braun and Victoria Clarke. 2006. Using Thematic Analysis in Psychology. *Qualitative Research in Psychology* 3, 2 (2006), 77–101.

[8] Encyclopaedia Britannica. 2020a. Skeletal muscle. `https://www.britannica.com/science/skeletal-muscle`. (2020). Accessed Sep 28, 2020.

[9] Encyclopaedia Britannica. 2020b. Smooth muscle. `https://www.britannica.com/science/intercostalis-muscle`. (2020). Accessed Sep 28, 2020.

[10] Marion Buchenau and Jane Fulton Suri. 2000. Experience Prototyping. In *Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques (DIS '00)*. Association for Computing Machinery, New York, NY, USA, 424–433.

[11] Richard Byrne, Joe Marshall, and Florian Floyd Mueller. 2018. AR Fighter: Using HMDs to Create Vertigo Play Experiences. In *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '18)*. Association for Computing Machinery, New York, NY, USA, 45–57.

[12] Roger Caillois. 2001. *Man, play, and games*. University of Illinois Press.

[13] Elizabeth J. Carey, Jonathan A Leighton, Russell I. Heigh, Arthur D. Shiff, Virender K. Sharma, Janice K. Post, and David E. Fleischer. 2007. A single-center experience of 260 consecutive patients undergoing capsule endoscopy for obscure gastrointestinal bleeding. *American Journal of Gastroenterology* 102, 1 (1 2007), 89–95.

[14] Rodney P Carlisle. 2009. *Encyclopedia of play in today's society*. Vol. 1. Sage.

[15] André K H Chong, Andrew C F Taylor, Ashley M Miller, and Paul V Desmond. 2003. Initial experience with capsule endoscopy at a major referral hospital. *Medical Journal of Australia* 178, 11 (2003), 537–540.

[16] OBS Studio Contributors. 2020. Open Broadcaster Software. `https://obsproject.com/`. (2020). Accessed Jan 21, 2020.

[17] Stephanie de Smale. 2015. *Level Up: A Media-Archaeological Study on the Rhetoric of Progress about Serious Health Games*. Master's thesis. Utrecht University.

[18] Linda de Valk, Tilde Bekker, and Berry Eggen. 2013. Leaving Room for Improvisation: Towards a Design Approach for Open-ended Play. In *Proceedings of the 12th International Conference on Interaction Design and Children (IDC '13)*. ACM, New York, NY, USA, 92–101.

[19] Derivative. 2019. Derivative TouchDesigner. `https://www.derivative.ca/`. (2019). Accessed Sep 19, 2019.

[20] Elisabetta Di Stefano. 2018. Cosmetic Practices: The Intersection with Aesthetics and Medicine. In *Aesthetic Experience and Somaesthetics*. Brill, 162–179.

[21] Michelle M Donovan. 2018. Mindful Eating: A Guide to Rediscovering a Healthy and Joyful Relationship With Food. *Journal of Nutrition Education and Behavior* 50, 7 (2018), 752.

[22] Duet. 2020. Duet Display. `https://www.duetdisplay.com/`. (2020). Accessed Apr 14, 2020.

[23] Scott G Eberle. 2014. The elements of play: Toward a philosophy and a definition of play. *American Journal of Play* 6, 2 (2014), 214–233.

[24] Satoshi Fujisawa, Takeo Hamada, Ryota Kondo, Ryohei Okamoto, and Michiteru Kitazaki. 2017. A body odyssey: exploring the human body as digested food. In *Proceedings of the 8th Augmented Human International Conference*. 1–2.

[25] Sally Gadow. 1980. Body and self: A dialectic. *The journal of medicine and philosophy* 5, 3 (1980), 172–185.

[26] William W. Gaver, Jacob Beaver, and Steve Benford. 2003. Ambiguity As a Resource for Design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '03)*. ACM, New York, NY, USA, 233–240.

[27] Tom Giraud, Matthieu Courgeon, Marion Tardieu, Alexandra Roatis, and Xavier Maitre. 2014. A Three-dimensional Mirror Augmented by Medical Imaging: Questioning Self-portraying at the Limit of Iintimacy. In *CHI '14 Extended Abstracts on Human Factors in Computing Systems (CHI EA '14)*. ACM, New York, NY, USA, 845–854.

[28] Eberhard Graether and Florian Mueller. 2012. Joggobot: A Flying Robot As Jogging Companion. In *CHI '12 Extended Abstracts on Human Factors in Computing Systems (CHI EA '12)*. ACM, New York, NY, USA, 1063–1066.

[29] Cecil Helman. 2007. *Culture, health and illness*. CRC press.

[30] Thomas S Henricks. 2015. *Play and the human condition*. University of Illinois Press.

[31] Thuong Hoang, Martin Reinoso, Zaher Joukhadar, Frank Vetere, and David Kelly. 2017. Augmented Studio: Projection Mapping on Moving Body for Physiotherapy Education. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17)*. ACM, New York, NY, USA, 1419–1430.

[32] Ruth Sancho Huerga, Jennifer Lade, and Florian Mueller. 2016. Designing Play to Support Hospitalized Children. In *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '16)*. ACM, New York, NY, USA, 401–412.

[33] Amy Huggard, Anushka De Mel, Jayden Garner, Cagdas "Chad" Toprak, Alan D. Chatham, and Florian Mueller. 2013. Musical Embrace: Facilitating Engaging Play Experiences through Social Awkwardness. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems (CHI EA '13)*. Association for Computing Machinery, New York, NY, USA, 3067–3070.

[34] Gavriel Iddan, Gavriel Meron, Arkady Glukhovsky, and Paul Swain. 2000. Wireless capsule endoscopy. *Nature* 405, 6785 (2000), 417.

[35] Kalle Jegers. 2007. Pervasive game flow: understanding player enjoyment in pervasive gaming. *Computers in Entertainment (CIE)* 5, 1 (2007), 9–es.

[36] JinShan. 2019. OMOM Capsule Endoscopy. `http://english.jinshangroup.com/capsuleendoscopy.html`. (2019). Accessed Sep 19, 2019.

[37] Kourosh Kalantar-zadeh, Nam Ha, Jian Zhen Ou, and Kyle J. Berean. 2017. Ingestible Sensors. *ACS Sensors* 2, 4 (2017), 468–483.

[38] Pamela M. Kato. 2010. Video Games in Health Care: Closing the Gap. *Review of General Psychology* 14, 2 (2010), 113–121.

[39] Rohit Ashok Khot and Florian Mueller. 2019. Human-Food Interaction. *Foundations and Trends® Human–Computer Interaction* 12, 4 (2019), 238–415.

[40] Martijn J.L. Kors, Gabriele Ferri, Erik D. van der Spek, Cas Ketel, and Ben A.M. Schouten. 2016. A Breathtaking Journey. On the Design of an Empathy-Arousing Mixed-Reality Game. In *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '16)*. ACM, New York, NY, USA, 91–104.

[41] Nicole Lazzaro. 2009. Why we play: affect and the fun of games. *Human-computer interaction: Designing for diverse users and domains* 155 (2009), 679–700.

[42] Drew Leder. 1990. *The absent body*. University of Chicago Press.

[43] BS Lewis, GM Eisen, and S Friedman. 2005. A pooled analysis to evaluate results of capsule endoscopy trials. *Endoscopy* 37, 10 (2005), 960–965.

[44] Zhuying Li, Felix Brandmueller, Florian Mueller, and Stefan Greuter. 2017. Ingestible Games: Swallowing a Digital Sensor to Play a Game. In *Extended Abstracts Publication of the Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '17 Extended Abstracts)*. ACM, New York, NY, USA, 511–518.

[45] Zhaoshen Li, Dan Carter, Rami Eliakim, Wenbin Zou, Hao Wu, Zhuan Liao, Zhaotao Gong, Jinshan Wang, Joo Won Chung, Si Young Song, Guohua Xiao, Xiaodong Duan, and Xinhong Wang. 2014. *The Current Main Types of Capsule scopy*. Springer Netherlands, Dordrecht, 5–45.

[46] Zhuying Li, Weikang Chen, Yan Wang, Ti Hoang, Wei Wang, Mario Boot, Stefan Greuter, and Florian 'Floyd' Mueller. 2018a. HeatCraft: Playing with Ingestible Sensors via Localised Sensations. In *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts (CHI PLAY '18 Extended Abstracts)*. ACM, New York, NY, USA, 521–530.

[47] Zhuying Li, Rakesh Patibanda, Felix Brandmueller, Wei Wang, Kyle Berean, Stefan Greuter, and Florian Mueller. 2018b. The Guts Game: Towards Designing Ingestible Games. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '18)*. ACM, New York, NY, USA.

[48] Zhuying Li, Yan Wang, Wei Wang, Weikang Chen, Ti Hoang, Stefan Greuter, and Florian Floyd Mueller. 2019. HeatCraft: Designing Playful Experiences with Ingestible Sensors via Localized Thermal Stimuli. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (CHI '19)*. ACM, New York, NY, USA, Article 576, 12 pages.

[49] Andrés Lucero, Evangelos Karapanos, Juha Arrasvuori, and Hannu Korhonen. 2014. Playful or Gameful?: Creating Delightful User Experiences. *interactions* 21, 3 (May 2014), 34–39.

[50] Deborah Lupton. 2013. The Digitally Engaged Patient: Self-monitoring and Self-care in the Digital Health Era. *Social Theory & Health* 11, 3 (01 Aug 2013), 256–270.

[51] John McCarthy, Peter Wright, Jayne Wallace, and Andy Dearden. 2006. The experience of enchantment in human–computer interaction. *Personal and ubiquitous computing* 10, 6 (2006), 369–378.

[52] Florian Mueller, Josh Andres, Joe Marshall, Dag Svanæs, MC Schraefel, Kathrin Gerling, Jakob Tholander, Anna Lisa Martin-Niedecken, Elena Márquez Segura, Elise van den Hoven, and others. 2018a. Body-centric computing: results from a weeklong Dagstuhl seminar in a German castle. *interactions* 25, 4 (2018), 34–39.

[53] Florian Mueller, Richard Byrne, Josh Andres, and Rakesh Patibanda. 2018b. Experiencing the Body As Play. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems (CHI '18)*. ACM, New York, NY, USA, Article 210, 13 pages.

[54] Florian Mueller and Katherine Isbister. 2014. Movement-based Game Guidelines. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 2191–2200.

[55] Florian Mueller, Rohit Ashok Khot, Kathrin Gerling, and Regan Mandryk. 2016. Exertion Games. *Foundations and Trends® in Human–Computer Interaction* 10, 1 (2016), 1–86.

[56] Florian Mueller, Sophie Stellmach, Saul Greenberg, Andreas Dippon, Susanne Boll, Jayden Garner, Rohit Khot, Amani Naseem, and David Altimira. 2014. Proxemics Play: Understanding Proxemics for Designing Digital Play Experiences. In *Proceedings of the 2014 Conference on Designing Interactive Systems (DIS '14)*. Association for Computing Machinery, New York, NY, USA, 533–542.

[57] Andi Nahmias. 2010-2011. Phillip Warnell. `http://istanbulmuseum.org/artists/phillip%20warnell.html`. (2010-2011). Accessed Jul 5, 2019.

[58] Simone Natale. 2011. The Invisible Made Visible: X-rays as attraction and visual medium at the end of the nineteenth century. *Media History* 17, 4 (2011), 345–358.

[59] Leyla Norooz, Matthew Louis Mauriello, Anita Jorgensen, Brenna McNally, and Jon E. Froehlich. 2015. BodyVis: A New Approach to Body Learning Through Wearable Sensing and Visualization. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. Association for Computing Machinery, New York, NY, USA, 1025–1034.

[60] Claudia Nunez-Pacheco and Lian Loke. 2014. Crafting the Body-tool: A Body-centred Perspective on Wearable Technology. In *Proceedings of the 2014 Conference on Designing Interactive Systems (DIS '14)*. ACM, New York, NY, USA, 553–566.

[61] Jan Poope. 2015. Audiopill. `http://www.audiopill.net/en/`. (2015). Accessed Dec 12, 2019.

[62] Maud Radstake. 2007. *Visions of Illness: an Endography of Real-time Medical Imaging*.

[63] Yvonne Rogers. 2011. Interaction Design Gone Wild: Striving for Wild Theory. *interactions* 18, 4 (July 2011), 58–62.

[64] Karen Schultheis, Lizette Peterson, and Vanessa Selby. 1987. Preparation for stressful medical procedures and person × treatment interactions. *Clinical Psychology Review* 7, 3 (1987), 329 – 352.

[65] Bit Shape. 2010. GyrOSC. `http://www.bitshapesoftware.com/instruments/gyrosc/`. (2010). Accessed Apr 14, 2020.

[66] Jenny Slatman. 2007. *Recognition beyond Narcissism: Imaging the Body's Ownness and Strangeness*. Palgrave Macmillan UK, London, 186–204.

[67] Jenny Slatman. 2009. Transparent bodies: Revealing the myth of interiority. *The body within: Art, medicine and visualization* 3 (2009), 107–122.

[68] Jenny Slatman. 2016. *Our Strange Body: Philosophical Reflections on Identity and Medical Interventions*. Amsterdam University Press.

[69] Stelarc. 2019. Stomach Sculpture. `https://stelarc.org/?catID=20349`. (2019). Accessed Sep 19, 2019.

[70] Paul Swain. 2003. Wireless capsule endoscopy. *Gut* 52, suppl 4 (2003), iv48–iv50.

[71] Penelope Sweetser and Peta Wyeth. 2005. GameFlow: A Model for Evaluating Player Enjoyment in Games. *Comput. Entertain.* 3, 3 (July 2005), 3–3.

[72] José van Dijck. 2001. Bodies without borders: The endoscopic gaze. *International Journal of Cultural Studies* 4, 2 (2001), 219–237.

[73] José Van Dijck. 2011. *The transparent body: A cultural analysis of medical imaging*. University of Washington Press.

[74] Lieselotte Van Leeuwen and Diane Westwood. 2008. Adult play, psychology and design. *Digital Creativity* 19, 3 (2008), 153–161.

[75] Catherine Waldby. 1997. The body and the digital archive: the Visible Human Project and the computerization of medicine. *Health* 1, 2 (1997), 227–243.

[76] Phillip Warnell. 2006. Endo Ecto. `http://www.phillipwarnell.com/Performance`. (2006). Accessed Jul 5, 2019.