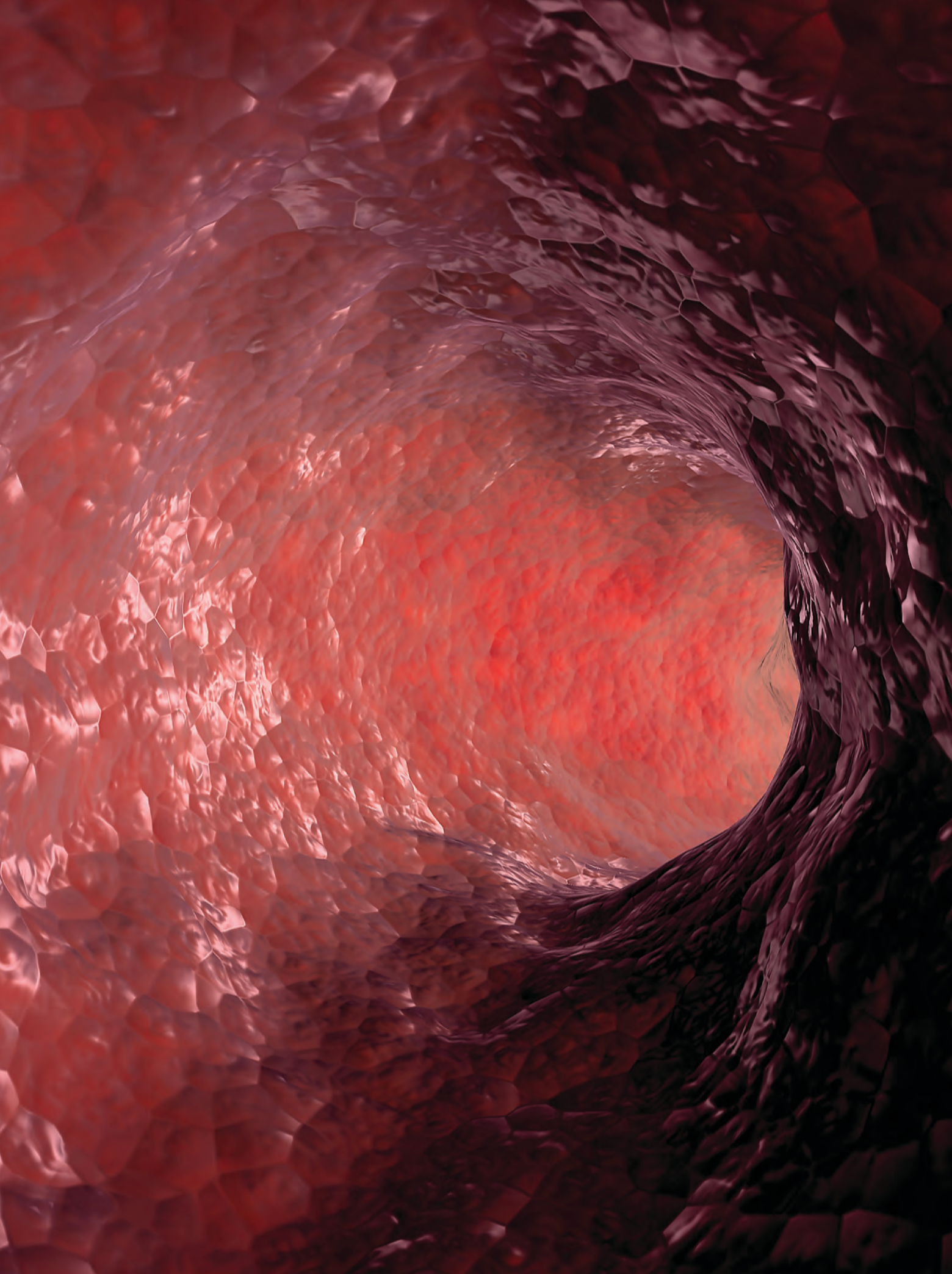

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Playing with the Interior Body

Insights

- Ingestible devices provide an opportunity to transform the user's interior body into a design element for digital play.
- InsideOut is a novel wearable system with imaging capsules that allows users to play with their gastrointestinal tract.
- Playing with the interior body can lead to intriguing bodily experiences and a deeper understanding of the human body.

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Fantastic Voyage is a 1966 science-fiction movie in which a crew enters a submarine that is then shrunk and injected into a physicist's bloodstream to facilitate the removal of a life-threatening blood clot. The film exemplifies the ever-present human desire to know more about the interior body. Among contemporary modern medical technologies, ingestible sensors—capsule-shaped digital devices that perform sensing and actuating functions [1]—are analogous to the movie's submarine. One common type of ingestible sensor in clinical uses is an imaging capsule, which contains a small video camera, an LED, a video transmitter, and a battery. After being swallowed, the capsule streams a video of the user's interior body as it moves naturally through their gastrointestinal tract (GIT).

Artists have employed imaging capsules beyond their medical use, transforming the interior body into a design element. For example, Phillip Warnell underwent a capsule endoscopy medical procedure, producing more than 70,000 pictures of his GIT as material for an art project. Similarly, artist Mona Hatoum presented *Corps Étranger*, an art installation using endoscopic footage of her interior body.

These creative works have inspired us to consider how we might use ingestible devices beyond their medical purposes, in particular how they might transform our interior body as a design element for digital play. Our explorations have also been inspired by the ways in which the human body has begun to occupy a more central role in contemporary interaction design [2]. Work in areas such as somatic design, the quantified self, and inbodied design [3] aims at expanding and enriching our bodily awareness and understanding. Although many of these works engage people with their own bodies by measuring bodily data through on-body physiological sensors, they do not engage with the interior body.

In our work, we highlight the opportunity for combining ingestible devices with creative thinking—in particular, game-design thinking—to support people in the exploration of their interior bodies in playful ways. In this respect, we have developed InsideOut [4], a wearable device that interacts with an imaging capsule system. With InsideOut, the player swallows an imaging capsule and wears clothing with a screen embedded on the front. The screen displays the video captured by the capsule in real time, allowing us to "see inside." The system allows players to freely explore how they can influence their GIT (through eating a meal, for example, or engaging in physical activity) while the software maps their body movements to manipulations such as scaling and rotating the video image. The system provides six additional play modes to enable engaging interactions with the content. For example, one play mode challenges users to tap an animated character flashing in their GIT video. In another mode, users try to balance the imaging capsule's video stream on a virtual seesaw that is sensitive to their movements.

To understand the user experience of InsideOut, we conducted a study. Each player visited the Exertion Games Lab, swallowed a nonreusable imaging capsule, and put on the wearable system. The player then left the lab and experienced InsideOut in everyday life. Each capsule's battery lasted for approximately eight hours, after which the players returned to the lab for a semi-structured interview. After approximately 12 to 36 hours, the capsule was excreted.

ETHICS CONSIDERATIONS

Engaging with ingestible technology raised a number of ethical questions that we intensively discussed with our ethics board, including the risks associated with the act of swallowing ingestible sensors, displaying real-time footage of the players' intestinal tracts, and privacy more generally. We believe the insights we gained can expand our knowledge around methods for interaction designers working with medical technologies beyond their medical uses.

Risks associated with swallowing ingestible sensors. To minimize the risk of players having a GIT obstruction, we established a screening procedure. We invited only people who had previously swallowed ingestible sensors. In addition, we required participants to complete a health questionnaire—the data collected from it was destroyed after the study was complete—and had a health professional evaluate each player's suitability for the study. Once a person was deemed eligible to take part, they were given preparatory instructions, including what they should and should not do prior to the study. For example, players were not allowed to take vitamins containing iron for seven days before the study.

On the day of the study, we provided each participant with a list of contact numbers for all the researchers, guidance for first aid in case of emergencies, and a copy of the study do's and don'ts (e.g., players were warned to not go near MRI machines while the imaging capsule was inside their body, because of the possibility of serious injury being caused by the machine's magnetic field). During the study, a health professional was available to answer any questions.

Risks associated with the public display of intestinal tract video. To manage the risk of bystanders being offended by public display of the GIT videos, we suggested that players use the video-only version at home and in the workplace. The system also features a button to hide the video display when in public. Moreover, the player was required to inform potential spectators, such as roommates and colleagues, about the study. Players were instructed to continue with the study only where potential spectators felt comfortable. We informed players that they could share any aspect of the study with potential spectators, including the motivation, technology, design, and their experience. If players found potential spectators' questions too hard to answer, they could provide them with the researchers' phone numbers.

Risks associated with data privacy. Players were given the option of keeping their GIT's video after the study (only one player took us up on this offer). We requested formal permission from players before using anonymous GIT video in our dissemination of results; if we did not receive permission, the data would be deleted after the study ended. All of the players provided us with permission.

Open discussions. The above describes the practical ethical considerations. We acknowledge that InsideOut can also be leveraged as a design exemplar to facilitate critical thinking among both the public and designers regarding the interactions with ingestible devices in particular and intracorporeal technologies—such as implants, ingestibles, and injectables—more generally.

Intracorporeal technologies can mediate our perceptions of bodies on both a micro and macro level. On a micro level, intracorporeal technologies might influence the user's awareness and consciousness of the interior body. Without technology interventions, one's interior body is usually out of consciousness. We believe that by observing and interacting with interior-

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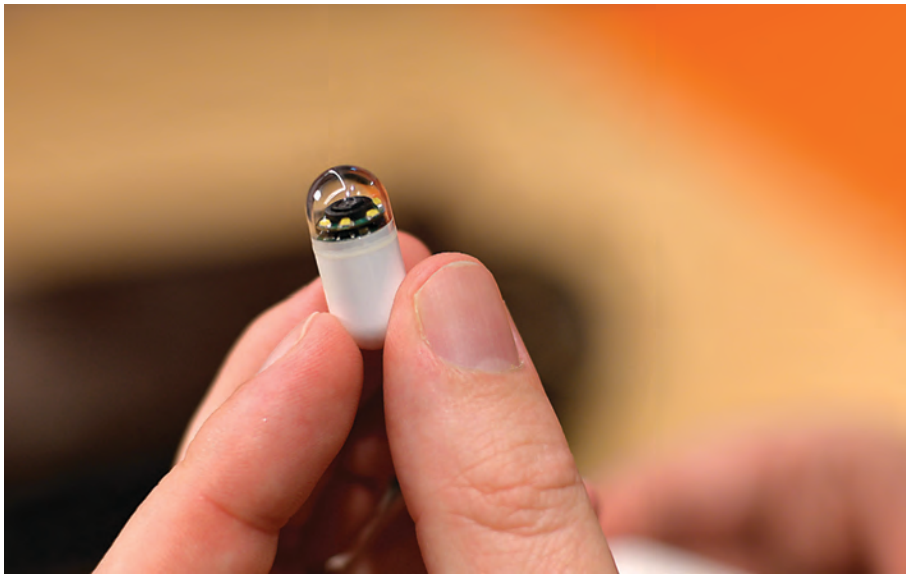
Moreover, intracorporeal technologies might let people perceive their bodies as more "transparent" as they learn more about their invisible interior bodies. The influence of intracorporeal technologies on someone's bodily experience and perceptions can thus bring about macro-level influences that shape society's view on the human body. Such a collective view has the potential to influence people's perceptions of disease and treatment and even affect healthcare policies [5]. We should note, however, that the influence is not always positive. For example, the ubiquitous presence of the interior body on public media might lead people to see invasive surgeries as harmless. In addition, the increased level of body transparency might lead people to believe that "seeing is curing," which is not accurate.

We believe critical discussions of interacting with the interior body are timely for a "third-wave HCI." Third-wave HCI focuses on the cultural, emotional, and experiential aspects of interactions as technologies become increasingly common in our everyday lives. Inspired by the vision of ubiquitous computing that technologies will be seamlessly integrated into everyday life, we believe that intracorporeal devices such as imaging capsules will become increasingly common, as these technologies are always inside the human body, sensing or actuating on the body and continuously connecting to the network. With the advancement of nanotechnology, intracorporeal devices might even become part of our food, entering our tissue and cells after being ingested. Therefore, we hope our work offers a good starting point for designers and HCI researchers to consider the broad cultural effect of interacting with the interior body.

INSIGHTS FROM INSIDEOUT

Through the study of InsideOut, we gained the following insights into the experiences of playing with the interior body.

Knowing the interior body status can result in a fearful joy. People rarely see, show, or interact with their interior body; unsurprisingly, all participants



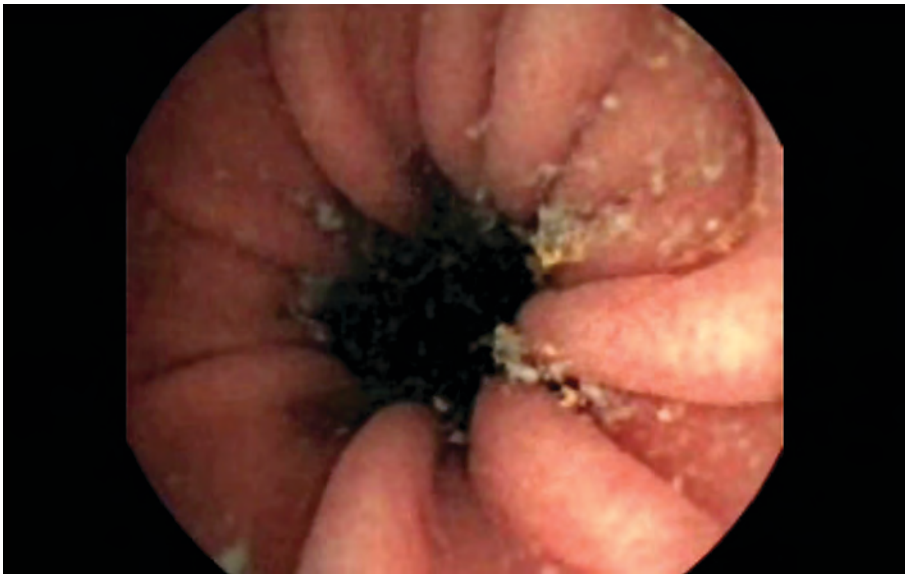
An imaging capsule.

A participant has put on the system and just swallowed the imaging capsule.

A participant using a play mode that turns the player's gastrointestinal video into a ball and requires them to move their body to balance the ball on a seesaw.

A participant trying to see the food they have consumed moving through their gastrointestinal tract.

A participant using the Finding Wally mode with a friend. Finding Wally requires the player to search for hidden gems and identifies their results with visual and sound effects.



A screenshot of a participant's gastrointestinal video filmed by the imaging capsule.

initially found the experience a bit unsettling. Nevertheless, after getting used to the idea, they enjoyed the experience and described the video as fascinating, novel, intriguing, pleasant, and playful. We propose that playing with one's interior body can facilitate what we call fearful joy. In design practices, the balance between fear and joy needs to be considered. In InsideOut, some players described the experience as too intense because watching the video raised their awareness of their interior body. In response, they sometimes sought relaxation by using play modes that do not show a realistic interior body. We found that two of InsideOut's six play modes provided opportunities for players to relax. One transforms the video image in an artistic and ambiguous way, using environmental data such as the strength of the surrounding magnetic field. The other employs sensors embedded in the display to detect the player's movements, enabling interaction with the video. In these two modes, players do not see a realistic video of their GIT. Therefore, their attention is directed not so much inward, toward their interior body, but rather outward, to the play or the video. This outward direction resulted in decreased fear and increased joy, reaching an appropriate level of "fearful joy."

Knowing the interior body status can facilitate spontaneous bodily explorations. It appears that people are motivated to explore how they can affect their interior body with ingestible sensors [6]. Players spontaneously used InsideOut to explore their capacities to influence their interior bodies by eating, drinking, and moving. Players experimented with different types of food and drinks to observe the effect on their digestion. They also moved their bodies to move the residual food and drink in their GIT and to change the shape of their GIT. These explorations began even before the imaging capsule was swallowed. Some players were interested primarily in the appearance and structure of their GIT, rather than its digestive behaviors. To obtain a clear view of their GIT, they chose not to eat anything and to drink only clear fluids the day before the study. It is not surprising, then, that player's explorations of their GIT resulted in increased bodily knowledge. Players

reported that they knew more about their digestive system and their GIT's structure after their InsideOut experience. They also reported that the extended and pervasive experience of playing with their interior body, and the experience of swallowing a "foreign" object, increased their bodily awareness. Ultimately, InsideOut allowed players to become more intimate with their bodies, deepening their understanding of the human body.

SUMMARY AND FUTURE DIRECTIONS

With the aim of increasing designers' awareness of the interior body as a potential design material for play, we explored the design of a digital play experience with one's interior body, resulting in a wearable system called InsideOut that allows players to play with a video of their GIT, sourced from an ingested imaging capsule. This novel interaction design could facilitate intriguing and playful bodily experiences, satisfying players' eagerness to become familiar with their seemingly mysterious interior body and shape their understanding of it. Using the insights we gained from designing InsideOut and the associated study, we are speculating on several future research directions that might benefit playful design involving the interior body.

Design. We might investigate the practical design of playful interactions with the interior body to maximize its potential as a design material. Potential investigations include examining the feasibility of bodily play design strategies in the context of interior-body play and exploring specific design opportunities of designing with the interior body. Particular design challenges with the interior body could also be tackled; for example, how to balance the degree to which playing with the interior body is simultaneously unsettling, engaging, and informative.

Engineering. We might investigate the engineering of novel systems to support play with the interior body. For example, we could explore the design of always available systems for playing with the interior body. Opportunities include, but are not limited to, how to develop a robust system for operation in a real-world setting; how to combine pervasive technologies such as skin interfaces and augmented reality with ingestible systems; and how to minimize the ingestible system's size and weight.

Technology. To support play with the interior body, the developers of ingestible sensors might need to think beyond medical contexts, needs, and applications. For example, developers could embed additional sensors into the ingestible capsule to provide more information about the user's interior body and support a playful exploration. Future applications might even extend to embedding actuators in the capsules to provide force feedback (e.g., a sensor that vibrates inside the user's GIT to provide outputs for the system).

Applications. Researchers could also consider the functional perspective of playing with the interior body. Health professionals, for example, might embrace such game design thinking to improve the user experience of medical imaging procedures to achieve better clinical outcomes. Future research could employ InsideOut in a clinical context, comparing patients' experience of capsule endoscopy with and without InsideOut.

Ethics. Future work could explore the ethical issues associated with playing with the interior body, including health concerns and the use and ownership of personal data.

Outlook. Looking to the more distant future, we expect our work might generate more questions, including: What does a future of interaction look like as technology gets closer to and even enters our body? What design opportunities and challenges arise if electronics can be produced at nanoscale levels and enter any part of the body? What if users gain greater agency over the mobility of ingestible devices? What if the ingestible devices could wirelessly connect to the devices inside other people's bodies? And how might bodily integrated technologies change the nature of play? Our work is in part a call for further research into these questions. Ultimately, we wish to advance our understanding of the design of playful experiences associated with the interior body and to advance a more playful and humanized self-care agenda.

ENDNOTES

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