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# Understanding the Design of Playful Experiences Around Ingestible Sensors

**Zhuying Li**

Exertion Games Lab  
RMIT University, Australia  
zhuying@exertiongameslab.org

## Abstract

The advancement of sensor technology has provided new opportunities for bodily play and consequently enriched our bodily experiences. The emergence of ingestible sensors supports capturing the user's body data continuously. The intimacy between ingestible sensors and human body also shapes our bodily experiences. My research focuses on utilizing ingestible sensors to facilitate playful and engaging experiences in HCI using a Research through Design approach. This will lead to the development of ingestible interfaces, which allow the creation of novel and playful experiences. My work so far has explored the playful experiences that can be designed without crafting the relationships between the user's body and ingestible sensors. This research will contribute to the understanding of how to design playful experiences around ingestible sensors and ultimately inspire designers to create a wider range of future play experiences.

## CCS Concepts

• **Human-centered computing** → **Interaction paradigms;**  
• **Applied computing** → *Computer games;*

## Author Keywords

Ingestible sensors; play; quantified self; interaction design; research-through-design.

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## Context and Motivation

Through emerging body-centered technologies, especially sensor technology, the possibility to measure users' physiological data is coming true. Prior research suggested that such technologies can increase the user's self-awareness by providing real-time feedback of body status [7, 19]. This inspires researchers in the field of Human-Computer Interactions (HCI) to increase people's self-awareness, and thus improve wellbeing via these devices. The reason is that knowing about our body can lead us to be more aware of our body and the world, making us enjoy novel, playful, engaging, and even the painful experiences [9]. The importance of this field can be reflected in the success of Fitbit which is a wearable device tracks users' physical activities such as step counts, aiming at letting users be aware of their amount of daily exercise [5].

Inspired by the above, my research explores using ingestible sensors, which are self-contained microsystems that perform a sensing or actuating function inside the body [4], to facilitate playful and engaging bodily experiences. Nowadays, ingestible sensors are mainly for medical use to support diagnosis and therapy [10]. I believe that interactive systems around ingestible sensors have the potential to affect the user's self-awareness and enrich bodily experiences as such devices are inside the human body and can provide continuous body data to users. Moreover, the distance between the body and ingestible sensors could affect the user's bodily experiences as well. I also noted that playful elements can make the sensor-based technology more engaging. So, I propose the research question: how can we design the playful experiences around ingestible sensors to enrich one's bodily experiences? I hope by introducing ingestible sensors to the field of HCI, the possibilities for interaction and playful experience can be extended, opening up new opportunities for designers to explore in inter-



**Figure 1:** We expand the current game genre by introducing ingestible sensors to the field of game design.

face design. With this research, I offer a new perspective on understanding the design of playful bodily experiences through ingestible sensors.

## Research Objectives

- Identify the design space of playful experiences around ingestible sensors by looking into related literature and presenting three design prototypes that facilitate playful experiences around ingestible sensors.
- Validate the design space by evaluating the three designed prototypes through user studies.
- Create a design framework that helps guide designers to facilitate playful experiences around ingestible sensors through the insights gained from the study of the three prototypes.

## Related Work

In the field of HCI, many researchers explored utilizing interactive technologies to improve people's self-awareness. For example, Lindström et al. designed an affective diary that gathers the user's sensor data to form a colorful body shape for improving one's self-awareness [14]. Prior work found that biofeedback systems are good at improving one's self-awareness as such systems can provide real-time body data of the users [12]. For example, Höök et al. designed a breathing light that can dim in cadence with the user's breathing [9], aiming to increase people's bodily awareness. Similarly, Nunez-pacheco and Loke proposed the *Eloquent Robes* that projects the users' heartbeat data on their body, leading to an increase in self-awareness [17]. These works highlight that there is an opportunity to design biofeedback systems, helping improve people's self-awareness. However, what remains unknown is whether the location of the sensor technology can affect people's bodily experiences.

Recent studies noted that the distance between technology and body may affect bodily experiences. Homewood [8] conducted a study that attaches a mobile device to participants' stomach. Results showed that when the device is closer to our body, we might forget the device but perceive the device as part of the body. In addition, Brolin [2] suggested that the intimacy between the technology and body is important when designing for bodily awareness. These works inspire my research: what bodily experiences can be facilitated if the technology is inside our body?

In recent years, researchers believe that digital devices that can be embedded in the human body can influence people's understandings of their own bodies. For example, Warwick suggested that he regards the implantable device insider his body as part of him rather than a separate technology [20]. Inspired by this, we believe that ingestible sensors might be perceived by users as part of their body and therefore facilitate intriguing and innovative bodily experiences. This perspective informs my research focuses on using ingestible sensors as I aim to extend the possibilities of interactions in HCI by blurring the boundary between human and technology.

Playfulness refers to a mindset whereby people approach everyday activities with an attitude of something not serious and without a clear goal [15]. Prior works suggested that playfulness can make products go beyond pure entertainment [15]. For example, Khot [11] proposed *TasyBeats*, a playful system that transforms the user's heart rate data to a fluidic spectacle of mixing drinks in order to make physical activities more engaging. These works highlight that playful elements can make the sensed data more enjoyable and enrich the experience of controlling the body. In addition, based on the PLEX framework which proposes 22 categories of playful experiences, we believe playing with

ingestible sensors could facilitate the experiences of discovery and exploration [15]. Therefore, this work asks, what if we facilitate novel bodily experiences via ingestible sensors in a playful manner?

## Research Approach and Methods

The research approach in this work is Research through Design (RtD) [13, 22]. This approach helps designers to reflect on their design and research results through prototyping, leading to the evaluation of their design [22]. The RtD approach could also help designers to generate design theories such as design frameworks based on the prototypes to guide future system design [22]. In this study, three design prototypes will be developed to facilitate novel and playful experience around ingestible sensors and by using the RtD approach, I will contribute to design theory [21] by proposing a design framework for ingestible play.

To understand the user experience of proposed design prototypes, I adopt a qualitative research approach [3] as it is usually helpful to understand technology as experience [16]. Qualitative research involves the collection of subjective data to derive a set of themes [6]. To gather the data, I conduct semi-structured interviews about the user experiences of each prototype. To understand the qualitative data gathered from the interviews, thematic analysis is conducted to interpret the data meaningfully based on the context [1].

## Dissertation Status and Next Steps

I have completed the literature review, the first case study, and the development of the second case study. Based on the related work, the first case study *Guts Game* (see Fig 2) was designed. It is a two-player mobile game where players play against each other by completing certain tasks that require players to change their body temperature.



**Figure 2:** In the *Guts Game*, the players need to change their body temperature to a certain degree. The temperature data is visualized by a virtual flame on the smartphone screen.

The temperature data is measured by an ingestible sensor. With this case study, I explored my main research question through the sub-question of “What kinds of experiences can be created in ingestible play without crafting the relationships between the player’s body and ingestible sensors?”.

Through the user study, we derived four design themes: 1) Bodily Awareness, which highlights that playful experiences can be designed around ingestible sensors to improve players’ bodily awareness; 2) Human-Computer Integration, which means the continuous working ingestible sensors can form a partnership between the human and the devices; 3) Agency, which suggests designers to consider the player’s agency of the sensed data when designing playful experiences around ingestible sensors; and, 4) Uncomfortableness, which means that interactions around ingestible sensors might cause uncomfortableness both physically and psychologically. We then articulate a set of design strategies based on the themes, guiding designers to develop playful and engaging experiences around ingestible sensors.

Based on the preliminary results, I extend the work by investigating using localized sensations to represent the data captured by ingestible sensors. I find the combination of localized sensations and ingestible sensors intriguing since it allows people to experience their body data directly through the body. To explore this opportunity, a playful system *HeatCraft* was developed to help players experience their body temperature measured by an ingestible sensor via thermal stimuli. The next step is to conduct a user study to understand the play experiences of *HeatCraft*. The results will inspire me the game idea of the third case study and help generate the final design framework. Table 1 shows the timeline of my PhD study.

<i>Progress</i>	<i>Completion Time</i>
Identify the design space	completed
First case study	completed
System development (2nd case study)	completed
User study (2nd case study)	Sep 2018
System development (3rd case study)	Feb 2019
User study (3rd case study)	June 2019
Thesis writing	Dec 2019

**Table 1:** The timeline of my PhD research.

## Contributions

This work will contribute to understanding the design of playful experiences around ingestible sensors both in practice and theory.

- This study extends the current understanding on ingestible sensors that focuses on the validity and usability by creating playful and engaging experiences around such devices. As such, this work makes the usage of ingestible sensors more pleasant and enjoyable.
- This work contributes to the field of Human-Computer Interaction and game design by investigating ingestible user interfaces. This work therefore extends the current genre of interactions and games.
- This research contributes to theory by proposing a design framework, aiming at guiding designers to create engaging and playful experiences around ingestible sensors.
- This work contributes to practice by proposing three systems that use different approaches to design playful experiences around ingestible sensors.

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