Guts Game – A Game using Ingestible Sensors

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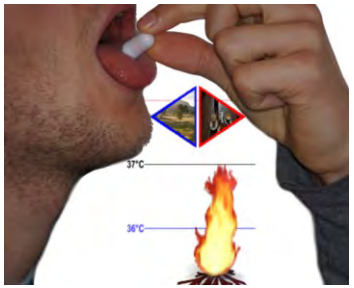

Figure 1: Exploring ingestible sensors for games

Abstract
Guts Game is a two-player mobile game that uses ingestible sensors to capture players' gut temperature as core game mechanic. It involves changing one's gut temperature to outscore an opponent and to win a race.

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Unlike most games that are controlled via external controllers, Guts Game makes a novel contribution by using an ingestible sensor, in the form of a pill, with which the players control the game by varying their gut temperature. This can occur either through food intake of different temperatures, exercising or changing environmental conditions. With the Guts Game, we show that the usage of gut temperature as a game input is feasible and demonstrate that experiencing your body as play, via an ingestible sensor, can be a mesmerizing play experience.

Author Keywords
Ingestible sensors; gut temperature; gastrointestinal temperature; games.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Imagine you are playing a digital game. However, you are not holding a controller, nor have any wearable attached to your body or are tracked by any sensor in the room. Instead, you have just swallowed a sensor in order to play the game, i.e. the controller is now inside you…

Figure 2: The pill's measurements are: 23 mm in length and 10.25 mm in diameter [1].

This paper explores this scenario of using an ingestible sensor to play a digital game through a fully-functional implementation: the "Guts Game".

Prior work suggests that the intuitiveness of game control can enhance the degree of a players' enjoyment [15]. We were inspired by this and wonder how having a sensor inside a player's body as part of digital play affords novel ways to play and experience the body as play [13]. Would a controller inside the body engender a human-controller identity, where instead of playing a game, the feeling of being part of a game is increased?

Related work

We learned from prior work, especially human-computer interaction and digital health, which we detail next.

Even though sensors for inside the human body (such as wireless pills, but also pacemakers, cochlear and dental implants) were originally designed for medical purposes, nowadays, more and more people are using them for non-medical reasons [4]. For example, Professor Warwick implanted a silicon chip into his body, to open the door to his lab and start his computer automatically when he enters [17].

We focus on ingestible and insertable devices, and note that there is an increase in the varieties of sensors available, allowing to obtain, for example pH readings, gut imagery and pressure measurements [7,16]. It has therefore been proposed that besides medical professionals, laypeople might also like to use these devices as part of the quantify-self movement, collecting their body data through these devices to manage their health [14]. As a result, these devices might become more popular and hence cheaper as well as more accessible.

Temperature as input

Our game uses an ingestible sensor (figure 2) to measure gut temperature. Gut temperature or gastrointestinal (GI) tract temperature is, in the absence of external manipulation such as food-intake, equivalent to the core body temperature [1]. The measurement approach is similar to a medical thermometer, but has specific characteristics.

Traditional thermometers that measure body temperature can be unpleasant to place or restricting body movement. For example, even though arterial measurement is very accurate [9], it is invasive and natural movement is restricted. Furthermore, axillary measurements such as underarm can be inaccurate [9], while rectal measurements may cause discomfort [10]. In contrast, ingestible sensors can provide accurate data while not causing uncomfortable experiences to the users [7]. Moreover, the sensor is in vivo and therefore invisible to the user, making people feel like it is part of their body [14].

An ingestible sensor may collect data of each individual organ as it passes through the GI tract [7]. Thus, it has been used in several medical projects [1,2,6,8]. However, such devices still have limitations. Swallowing a wireless pill, which sends signals through the body, may result in some people feeling uncomfortable [5]. Additionally, people might fear that the size of the pill – 23 mm in length and 10.25 mm in diameter [1] (figure 2) – will make it hard to swallow. We had this in mind when we created the game.

Figure 3: Hardware needed for the game: Mobile phone, the pill (located on top of the mobile phone), the receiver for the pill, a bag to carry the receiver and a waterproof bag for water based activities, e.g. showering (yellow bag).

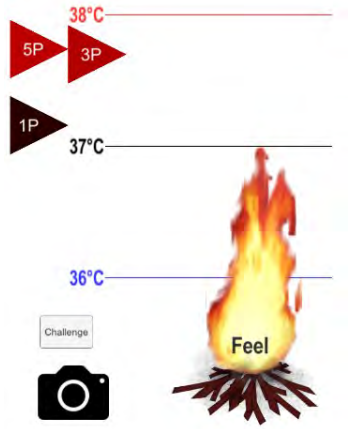

Figure 4: Task selection (up left) (1, 3 and 5 Points; the 3 Point Button is shifted to reduce occurring overlays) as well as selection of "Feeling", "Challenge" mode and the Photo button

The Guts Game

To capture the temperature we use an ingestible pill which stays 24 to 36 hours in the digestive system until excretion. After swallowing the pill, it measures the gut temperature every 10 seconds and sends it wirelessly to the receiver.

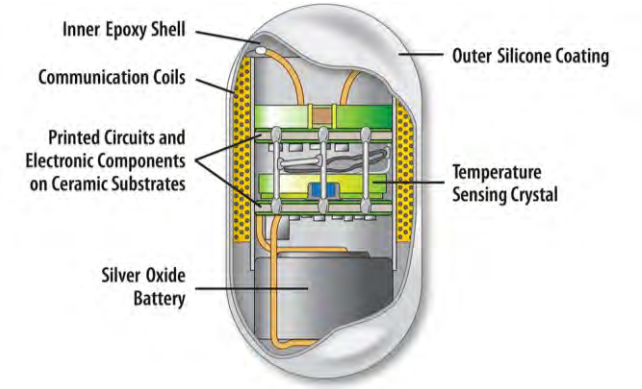

Figure 5: Profile of the pill with description of the containing parts, ©HQInc [19].

The system (figure 3) consists of an ingestible sensor (figure 5) (*CorTemp*® by *HQInc* [19]), a receiver (which is about 150 x 75 millimetres in size and weighs about 200 grams) and communicates via Bluetooth to a mobile phone, an app to retrieve the data, a bag to carry the receiver and also our custom software that reads the data from the pill-app running on the same mobile phone.

The Guts Game is a two-player game in which the players have to outscore each other by gaining points that depend on whether they achieve tasks that require reaching a certain temperature, all awhile they are engaging in their regular day-to-day activities.

Tasks

The players can choose between 3 different tasks (figure 4) with different levels of difficulty, which corresponds to different points (easy: 1 point, medium: 3 points and hard: 5 points). After 10 minutes every task can be aborted. After the task is either accomplished or aborted, a new one can be chosen. All tasks have goals within an achievable temperature spectrum (36°C-38°C). Typical goals are: "37.2°C (easy)", "36.5°C (medium)" and "38°C (hard)". From our experience, between 10 and 40 tasks are commonly accomplished by players, with most tasks achieved while the pill is inside the stomach, as there the measured temperature is easier to manipulate.

After both players have swallowed the pill and been informed about possible ways to influence their temperature, they leave the lab. A typical scenario could look like this: *"After arriving at home, player A receives a picture of ice cream informing her/him that player B started a low temperature task worth 3 points. In order to compete with the opponent, player A decides to start a high temperature task worth 5 points and eats a bowl of hot soup for lunch".* Later, once the pill moved further down the GI tract and hence the sensor is less affected by food intake, the players engage in physical activity in order to change their temperature.

Swallowing the pill starts the game

After arriving in our lab, the players get told by the researchers, that they can be selected for a mission to Mars, but since on Mars temperature changes rapidly, temperature control is very important. Therefore the game objective is to outscore the opponent, by accomplishing tasks in the game (figure 6). We included

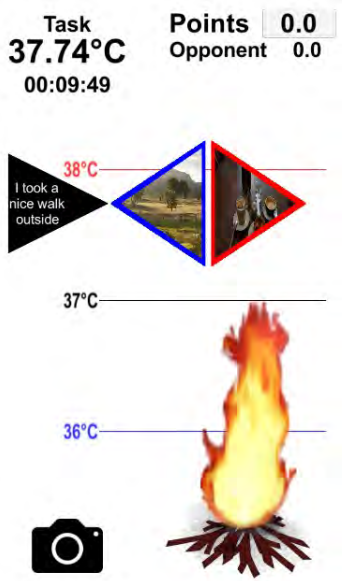

Figure 6: The Guts Game with the current task's goal (up left) and the chat elements (triangles), displaying the player's photos. Their y-position represents the task goal. The flame height indicates the current temperature.

this narrative in order to motivate the players' willingness to swallow the pill.

The pill travelling through the body
The pill takes usually 24-36 hours to travel through the GI tract before getting excreted. However, every person's digesting speed is different, hence even if players are ingesting the pill at the same time, they will have different excretion times, which the game needs to consider.

Excretion of the pill means game over
The game ends when one player excretes the pill. We think this can add excitement to the game, because in addition to not knowing when one is going to excrete the pill, the player also does not know when the opponent excretes the pill. This could lead to situations where players are consuming digestive-stimulating foods (e.g. coffee) to end the game if they are in the lead in terms of points.

When the pill is excreted, a message will appear stating the player should see the researcher, indicating the game is over. Additionally, all in-game elements are locked, except for the chat (see below). We believe this might encourage the players to chat with each other upon excretion and facilitate a reflection on their in-game actions. Although the players know their points, the "looser" does not have to lose, if the researchers were satisfied by the results of this player. Therefore the players will only learn who won the game by coming back to the lab, where the game begun. There, players are interviewed as part of our research.

Ambiguous output
Since the pill's transmission technology is based on radio frequency, the quality of the signal suffers from interference factors such as electrical currents and other obstructions within the antenna beam [18]. For this reason the measured values fluctuate. To ensure such fluctuating values do not confuse the players (thinking their gut temperature has such fluctuations), we chose to represent this ambiguous data with a similar ambiguous output in the form of an animated flame. This approach is also in line with prior work that suggests to not provide plain numbers when it comes to body data, as this could make bodily activity such as exercise feel like work [3].

The flame varies in height (figure 7) in response to the temperature changing. The game uses this abstract but absolute temperature approach because every person is different and therefore also the perception of temperature is different. This means that perception based representations such as, e.g. "freezing cold" and "burning hot" might not be suitable.

The target temperature of the task is shown above the messages. Showing the target temperature as a specific number, rather than in another abstract form, may help the player to qualify the task goal.

The goal for every task is to change the temperature, so that the top of the flame crosses the task goal, which is represented via the height of the messages.

Modes
Prior work suggests that the provision of choice can enhance a player's intrinsic motivation [15]. We hence decided to offer the players choices in the form of two different modes, called feeling and challenge mode. They can be chosen upon task selection.

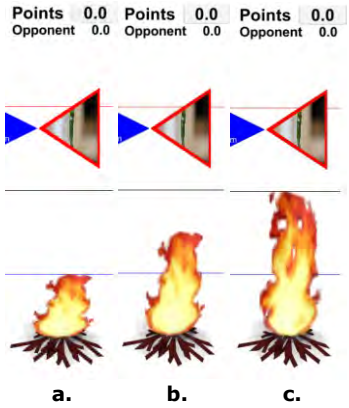

Figure 7: Images a – c show how the flame height is increased when the temperature increases. The objective is to align the flame with the centre of the messages.

FEELING MODE

In the *feeling mode* the flame is not displayed, leaving players not knowing what their temperature is. The players need to rely on their own senses and try to estimate their temperature. The flame is replaced by two buttons, one to espy the flame height (only available once) and one to say that the player thinks she/he reached the target temperature and therefore completed the task. This will unveil the true temperature, awarding points depending on how close the player's temperature was to the goal. For example, when the difference is less than 0.1°C all points are granted, but with increasing difference, points decrease drastically ($0.01 / diff^3$). To increase the stimulus of using this mode, each task can be worth 5 times the normal amount, if achieved successfully. This mode could help to explore if such a game could aid players' ability around estimating their own body temperature.

CHALLENGE MODE

In the *challenge* mode players can challenge each other by proposing their own goals. After one player defines and achieves such a goal, the game then automatically challenges the other player to also accomplish this goal. While getting challenged the gameplay gets locked. For example, after player A sets up a challenge, player B's gameplay gets locked right away and he/she has no other choice than to either also master the goal or wait a specific time (displayed via a "locking timer"). The duration of the locking timer depends on the level of difficulty. For example, if the task's target is 38°C, which is considered "hard", the opponent's gameplay is locked for 1.5 hours. The locking durations are based on our own experience. After a task is completed (irrespective of points scored), a message invites players to take a photo of how they engaged with their task and send it to the other player. This mode could help explore how to support a social aspect of the game, as prior work suggests that body-focused play experiences lend themselves to social interactions [11,12].

Temperature sensing via an ingestible pill

Under laboratory conditions gut temperature is equivalent to core body temperature [1] and due to the role of core body temperature to maintain the body's functionality [1], using a gut sensor means designers have a slowly changing input (in contrast to, for example designers who sense body movement using a Kinect). But while the pill is inside the stomach, the impact of temperature-manipulating actions, such as ingestion of ice cream, is by far greater.

Using ingestible sensor data

Working with ingestible sensor data, we have learned some lessons, which we share here with other game designers interested in using ingestible sensor data.

We needed to use filtering to deal with erroneous data, such as resulting from interference (as described above). We first use a threshold filter to exclude outliers. Then we apply a window function with a first-order derivative edge detector and downsample the collected values. With this, we can detect edges in the temperature function and if there are too many, which means too much false data, exclude the calculated value. Because of the slow changing nature of gut temperature, we find that one value per minute is sufficient to use for goal attainment.

It was also useful to provide players with device usage instructions in order to improve the quality of the sensor data. We asked players to a) avoid exposing the system to

electrical currents and b) adjust the receiver to a specific position on their lower back, which we showed them beforehand, using a small bag we provide (figure 3).

Future work

A preliminary study with 2 participants gave insight into the user experience. Some players were uncomfortable with taking many pictures. Also players' seem to be more aware of their temperature and how body processes change it. Another study with 12 participants will follow, helping us to further understand the player experience of ingestible games.

Conclusion

We believe that by using the game as research vehicle to study ingestible games, we can gain a game design understanding that opens many exciting opportunities for future ingestible games. In particular, although the Guts Game was not designed for serving a health purpose, ingestible games may be effective to positively influence heat related illnesses such as heat exhaustion or in the most severe form, heat stroke. Furthermore, even though our game does not make any recommendations on how to change gut temperature, we envision that similar games could also be used to motivate exercise as a way to change body temperature. We can also envision such games helping people learn about their body temperature. Additional sensors will offer additional body understanding opportunities.

In sum, this paper described the first game using ingestible sensors. With the Guts Game, we show that the usage of gut temperature as a game input is feasible and demonstrate that experiencing your body as play via an ingestible sensor can be a mesmerizing play experience.

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