Ingestible Games - Swallowing a Digital Sensor to Play a Game

Zhuying Li
Exertion Games Lab
RMIT University
Melbourne, VIC 3000
Australia
zhuying@exertiongameslab.org

Florian 'Floyd' Mueller
Exertion Games Lab
RMIT University
Melbourne, VIC 3000
Australia
floyd@exertiongameslab.org

Felix Brandmueller
Exertion Games Lab
RMIT University
Melbourne, VIC 3000
Australia
felix@exertiongameslab.org

Stefan Greuter
VxLab
RMIT University
Melbourne, VIC 3000
Australia
stefan.greuter@rmit.edu.au

CHI PLAY'17 Extended Abstracts, October 15-18, 2017, Amsterdam, Netherlands

ACM ISBN 978-1-4503-5111-9/17/10.
https://doi.org/10.1145/3130859.3131312

Abstract
Interactive devices are increasingly used inside human bodies, such as pace makers and wireless pills. This trend has led to novel experiences with ingestible devices in the field of human-computer interaction on novel experiences people have with ingestible devices. We believe there is a missed opportunity to facilitate innovative game experiences using such devices. However, there is a lack of understanding on how to design games around ingestible devices. Therefore, this research investigates the design of ingestible games by using a wireless pill that can measure the user's core body temperature. We designed a game called "Guts Game". By investigating the game experience, we aim to gain an understanding towards ingestible game design and build a theoretical design framework around it. This research will contribute to a better understanding of ingestible game design and ultimately help designers to create a wider range of future play experiences.

Author Keywords
Ingestible sensors; Body temperature.

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

Introduction

In recent years, wearable devices have become increasingly popular. In fact, they have become small enough to be insertable into the human body or be even ingestible [7]. The most common example is probably a pacemaker, but there are also other devices such as pill cameras that serve as endoscopes [10].

This work proposes the concept of "ingestible games", a new game genre that involves ingestible devices. The research aims at exploring the design space and play experience of such games through designing a game prototype. The results will help to build a design framework for ingestible games in future work.

Related Works

We learn from five different areas of prior work: HCI work around ingestible devices, ingestibles and user experience, pervasive games, health games and biofeedback games.

Ingestibles and HCI

Ingestible sensors are devices that integrate a wireless sensor system into a non-invasive capsule to perform different functions, such as measuring pH values, pressure, or core body temperature data (see Fig.1) [1, 10]. Unfortunately, there is little research about ingestible sensors in the HCI area. However, we can learn from previous studies about insertables. Insertables are digital devices that go through the skin, under the skin, or even inside a human's body [7]. Therefore, we regard ingestible sensors in the category of insertables.

Figure 1: The ingestible sensor continuously captures the user's body data and transmits it to a smartphone wirelessly.

To understand the motivations for non-medical uses of insertables, Heffernan et al. interviewed 17 people who voluntarily inserted devices into their bodies [8]. The results suggested that hobbyists choose to use insertables mostly for convenience or to extend their senses [8]. For example,

Reasons for inserting devices	*Motivations for ingestible players*
Convenience	Play at any time in any place
Unencumbered feeling	Operate without peripherals
New body modification	Body as interface
Next big thing	New game genre
Extend human function	Extend the capability of player/avatar

Table 1: Potential motivations for players to participate in ingestible games

Prof. Kevin Warwick implanted a RFID tag into his body to open his office door and switch the lights on [25].

In addition, we find that the discomfort caused by wearable devices could also boost the popularity of insertable devices. Many people who prefer insertables regard a wearable device as encumbrances [8]. For example, the skin contact with wearable devices may cause discomfort. In contrast, ingestibles may be seen as part of the user's body [8] and thus offer alternative engagement opportunities. Although today's ingestible devices mostly require users to carry a signal receiver which may also cause discomfort, we believe products that can directly connect to smartphones or other alike will appear with the advancement of technology.

In light of the above, the motivations for the non-medical uses of insertable devices may be extended into the gaming area. Table 1 shows what we think could be the corresponding motivations of ingestible games for each reason of inserting digital devices into bodies as outlined by Heffernan et al. [8].

Ingestibles and User Experience

Studies showed that the type of game controller could affect the player experience [24], thus it would be reasonable to assume that using an ingestible sensor has an im-

pact on the player experience. Furthermore, game controllers that exploit natural mappings lend themselves to social fun, whereas traditional controllers can be preferred for highly competitive games [24]. Therefore, we believe that ingestible games should consider the social aspect of gameplay.

In addition, we find that designers need to consider the emotional connections between players and ingestible sensors when designing such games. Prior work suggests that digital technology may be used to create deeply emotional and sensory experiences to help users understand their bodies [14]. In addition, social networks including online forums, blogs and social media sites can provide vital emotional support [17, 14]. Therefore, we believe that designing social experiences around bodily issues within a technology-context is important for ingestible games.

Figure 2: The players need to wear a waist bag containing the receiver. An iPhone is used to play the game. We also prepare a water-proof bag for the player in case they swim or shower during the gameplay. The pill is placed on top of the iPhone for size comparison.

Moreover, to facilitate positive play experiences, prior work suggests it is important to produce a feeling of security for players when using health monitoring devices [14, 18]. First, users should feel that the data provided by the ingestible sensor is reliable [13]. Second, users could be concerned about how they can retain ownership and control over their data [20]. Any health risk is another major concern [7]. For example, the casing of the insertables may break inside the body if the body suffers a severe impact [8]. However, it has been recognized that wireless pills, the most popular form of ingestible sensors, are 100% safe for healthy users if the sensor is less than 11 mm in diameter and 28 mm in length [10]. For example, researchers used wireless pills to measure the colonic pH value, temperature, and intraluminal pressure in an extensive study. There was no safety issue reported and no serious adverse event of sensor retention [5]. Therefore, we believe designers should aim to facilitate a feeling of safety for players.

Ingestibles and Pervasive Games

We believe ingestible game design may learn from pervasive games. The major features of pervasive games are place-independent gameplay, social interaction between players, and integration of the physical and virtual worlds [9]. Place-independent means that pervasive games can be played at any place instead of sitting in front of the computer or game console. Furthermore, social interaction amongst players is usually a core to gameplay. These features may inspire the design of ingestible games. For example, it usually takes 2-3 days before the ingestible sensor leaves the user's body. As a result, ingestible games could be played anywhere where the user might be while the sensor is still inside the player's body.

Ingestibles and Health Games

As ingestibles are coming from the health domain, we also looked at health games to see what can be learned from them. Furthermore, we believe ingestible game design and health game design can inform each other as ingestible games are also very body-focused. In particular, prior work suggests that games have great potential to improve health outcomes [19], including enhancing exercise [11], as they can shift a user's attention away from physical discomfort [19]. Thus, we propose that ingestible games could make health-related activities more enjoyable and thus provide benefits to a player's wellbeing.

Ingestibles and Biofeedback Games

Ingestible sensors are used to capture users' body data and thus we can also learn from biofeedback game design. Many games have already adapted a biofeedback loop to the gameplay that use sensors to capture players' psychological responses and transmits it back to the game system [12]. Prior studies show that biofeedback games are attractive as players can learn how to control their body [16].

Figure 3: The Cortemp sensor is approximately 22mm in length.

Figure 4: The device on the left is the receiver for the pill data. It passes the data on to the phone via bluetooth. The screen of the phone shows the interface of the game.

Researchers found that players prefer direct control and explicit biofeedback in such games [12][16]. For example, to control the walking speed of the game character, players prefer to control their muscle activation rather than heart activity [16]. Therefore, ingestible game design requires suitable sensors that can capture data resulting from activities that can be directly controlled by users.

Potential of Ingestible Games

Learning from previous work, we believe that there is great potential for ingestible games. We now list some of the future uses of such games. First, ingestible sensors can provide multiple kinds of body data for users who want to subscribe to the quantified-self movement [20, 10]. As future work on quantified-self is believed to integrate work and play [26], we believe ingestible games have great potential to lifelogging.

Second, ingestible sensors have been demonstrated to be safe and easily accepted by patients when monitoring medication adherence [3]. Medication adherence is "the extent to which patients follow the instructions they are given for prescribed treatments" [6]. We believe games are particularly suitable for improving medication adherence as they can make repetitive tasks more attractive [19]. Therefore, ingestible games have the potential to support patients in taking their medication timely.

Third, games can be effective in changing health-related behaviors through enhancing motivation [2, 23]. Therefore, ingestible games may have the potential to change the attitudes and behaviors towards ingestible devices for those people who feel uncomfortable with them.

In summary, we find there is great potential for ingestible games. However, what we do not yet know is how to design such games. Although there is research from related fields we can learn from, there is no systematic understanding on how to design games that use ingestible sensors. Therefore, we hope with this work, we can help towards answering the research question: How to design ingestible games?

Guts Game

To explore the design space of ingestible games, we designed a game we call the "Guts Game". It is a two-player iOS mobile game. The game centres around a set of goals that require players to change their core body temperature, which is measured through an ingestible sensor called Cortemp (see Fig.3). It is a pill-like device that wirelessly transmits core body temperature as it travels through the digestive tract for approximately 24-36 hours. The CorTemp sensor is FDA cleared [15].

Personal User Experience

We swallowed the wireless pill ourselves to understand the device better. On reflection of this experience we found:

- As long as the sensor is in the user's stomach, the sensor is able to record temperature changes caused by the ingestion of food. However, after the sensor leaves the stomach, it is harder to change the core temperature simply by eating or drinking. Once the sensor is in the intestinal tract, the more effective way to change the body temperature then is through exercises or through changing the environment temperature.
- When the sensor is in the intestinal tract, only about 2 minutes after entering the sauna room or starting exercise, the change in core body temperature can be detected by the sensor.
- While the sensor is in the stomach, the data captured by the sensor can vary between 27 °C and 40 °C.

Figure 5: Players will be invited to a meal.

Figure 6: Players will be told that they have been infected by a parasite after the meal.

- While the sensor is in the intestinal tract, the variation of the data is rather small. For example, we were able to raise the temperature by approximately 1 °C through exercising and 0.6 °C by going into a sauna.

Gameplay

With our "Guts Game", players will be provided with all the items they might need (see Fig.2): a mobile phone, the pill, a receiver for the pill, a small bag, and a waterproof bag. On the mobile phone (see Fig.4), the target body temperature is shown at the top of the screen as well as represented by the height of a frying pan above a fire. The animated flame represents the player's current temperature. There are several tasks the player needs to accomplish throughout the player's day, and upon completion of the task, the player receives points. The player can choose when to engage in a task, but can only do one task at a time. The goal for each task is to change the core body temperature to move the top of the flame as close as possible to the frying pan. As mentioned in the previous section about the Personal User Experience, the degree of difficulty to change the data captured by the Cortemp sensor is different depending on the location of the sensor in the player's digestive tract. This feature naturally provides different levels of difficulty for the game. The gameplay in this game does not change according to the location of the sensor because it is hard to estimate when the sensor leaves the player's stomach automatically. However, we believe that this feature can be adapted to the gameplay in future designs of the game. For example, different gameplay can be designed based on the location of the sensor which may be determined by a camera or positioning system.

Narrative

We created a background story for the game, as narrative content has been demonstrated to be effective in engaging players in health-related games [2]. First, the players will be invited to our lab and have a meal together (see Fig.5). The researchers will be dressed as medical doctors and tell players that the meal has led to them being infected by a virtual parasite (see Fig.6). The only way to get rid of the parasite is by changing their core body temperature to a set of specific values. Therefore, the players have to swallow the Cortemp sensor and play the game to "survive". We included this story to further motivate players to swallow the sensor.

Points and Tasks

There are three levels of tasks: easy, medium and hard. For each level, the player can earn 1, 3 or 5 points. Players can choose their task, as we aimed to support achieving the right balance between game challenge degree and the player's capability in order to facilitate the emergence of flow [22]. Additionally, all task goals are within an ethical and achievable temperature spectrum (36 °C-38 °C). For example, typically tasks would be: "Reach 37.2 °C (easy)", "Reach 36.5 °C (medium)" and "Reach 38 °C (hard)". The game does not restrict the method players use to complete the task and thus players can choose any of the activities they want such as eating, drinking and jogging. The game uses a flame animation to provide feedback to help players gauge their progress and assist them in making game decisions [26].

In addition to the general tasks mentioned above, there are another two task modes: feeling mode and challenge mode. For each task, the player can change to the feeling mode freely. In the "feeling" mode, the flame that represents the player's body temperature will not be displayed. The flame animation is replaced by two buttons, one for displaying the flame (only available once) and one for completing the task. The player needs to click the button when he or she feels

the goal is reached. The points the player earns in the feeling mode depends on how close the player's temperature is to the goal. The feeling mode is designed to explore if the game can help players to learn how to accurately sense their body temperature.

In the "challenge" mode, players can challenge each other by proposing their own tasks (e.g. Rise your temperature to 37.5 °C and then drop to 36.7 °C). After setting and achieving the task, the player can challenge the opponent to also accomplish it. After the other player receives the task, he or she needs to complete the task first as other general tasks are locked. The amount of time for locking depends on the difficulty of the challenge task. This mode is designed to promote social interaction between players.

Game Time

As the game time depends on the duration that the sensor stays inside the players' bodies, we do not stipulate a specific end time. The two players may not play at the same time, which the game supports. The game ends when one of the players excretes the sensor, and the player who gains more points wins the game. Players can see their own points as well as the partner's points during the gameplay. This is designed to make the game end time be a playable part as players can partly control the time to excrete the sensor. We speculate that if one player performs better, he/she will try to excrete the sensor as soon as possible, for example by eating bananas [21].

Social Interaction

The two players can chat with each other using photos and text through a dedicated chat window. After a player completes a task, a message will be sent to the other player with an invitation to take a photo of how he/she feels. With this, we try to encourage the players to provide feedback to each other.

Future Work

In future work, we will recruit 12 participants to play the game as part of their everyday lives. A semi-structured interview will be conducted before the game. The interview will ask open-ended questions on how the players feel about ingesting the sensor and what they expect from ingestible games. During the game, the temperature data, game performance, play time and chat interaction will be logged. The post-game interview will focus on their feelings about ingesting the sensor and the experiences during the game. After the data collection, thematic analysis will be conducted. Interviews will be transcribed by two reseachers independently and codes will be generated after the discussion between the two researchers. The coding categories will be further analysed to understand the factors that affect play experience. Strategies to design ingestible games will then be proposed based on the results.

Conclusion

Our work contributes towards understanding novel interactions between humans and digital devices, in particular it offers an initial understanding of ingestible game design. With this, we hope to extend current genres of games and help game designers create a wider range of future play experience.

Acknowledgements

We thank the reviewers and all the members of the Exertion Games Lab at RMIT. We also thank Kyle Berean and Kouroush Kalantar-zadeh from RMIT's School of Engineering for giving us plenty of advice, and we also thank Patrick Baudisch for support.

REFERENCES

1. N. Aydin and T. Arslan. 2009. Review of Communication Systems for Ingestible Miniaturized

Integrated Sensor Microsystems. In *Proceedings of the 2009 Advanced Technologies for Enhanced Quality of Life (AT-EQUAL '09)*. IEEE Computer Society, Washington, DC, USA, 91–95. DOI: http://dx.doi.org/10.1109/AT-EQUAL.2009.28

2. T. Baranowski, R. Buday, D. I. Thompson, and J. Baranowski. 2008. Playing for Real: Video Games and Stories for Health-Related Behavior Change. *American Journal of Preventive Medicine* 34, 1 (2008), 74–82.e10. DOI: http://dx.doi.org/10.1016/j.amepre.2007.09.027

3. R. Belknap, Weis. S., A. Brookens, AY. K. Yee, G. Moon, L. DiCarlo, and R. Reves. 2013. Feasibility of an Ingestible Sensor-Based System for Monitoring Adherence to Tuberculosis Therapy. *PLoS One* 8, 1 (1 2013).

4. M. Camilleri, L. J. Colemont, S. F. Phillips, M. L. Brown, G. M. Thomforde, N. Chapman, and A. R. Zinsmeister. 1989. Human gastric emptying and colonic filling of solids characterized by a new method. *American Journal of Physiology - Gastrointestinal and Liver Physiology* 257, 2 (1989), G284–G290. http://ajpgi.physiology.org/content/257/2/G284

5. M. Camilleri, N. K. Thorne, Y. Ringel, W. L. Hasler, B. Kuo, T. Esfandyari, A. Gupta, S. M. Scott, R. W. Mccallum, H. P. Parkman, E. Soffer, G. E. Wilding, J. R. Semler, and S. S.c. Rao. 2010. Wireless pH-motility capsule for colonic transit: prospective comparison with radiopaque markers in chronic constipation. *Neurogastroenterology & Motility* 22, 8 (May 2010), 874 – e233.

6. R. B. Haynes, X. Yao, A. Degani, S. Kripalani, A. Garg, and H. P. McDonald. 2008. Interventions to enhance medication adherence. *The Cochrane database of systematic reviews* CD000011 (2008). DOI:http://dx.doi.org/10.1002/14651858.cd000011.pub2

7. K. J. Heffernan, F. Vetere, and S. Chang. 2015. Insertables: I'Ve Got It Under My Skin. *interactions* 23, 1 (Dec. 2015), 52–56. DOI: http://dx.doi.org/10.1145/2843588

8. K. J. Heffernan, F. Vetere, and S. Chang. 2016. You Put What, Where?: Hobbyist Use of Insertable Devices. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 1798–1809. DOI: http://dx.doi.org/10.1145/2858036.2858392

9. K. Jegers. 2007. Pervasive Game Flow: Understanding Player Enjoyment in Pervasive Gaming. *Comput. Entertain.* 5, 1, Article 9 (jan 2007). DOI: http://dx.doi.org/10.1145/1236224.1236238

10. K. Kalantar-zadeh, N. Ha, J. Z. Ou, and K. J. Berean. 2017. Ingestible sensors. *ACS Sensors* (2017), acssensors.7b00045. DOI: http://dx.doi.org/10.1021/acssensors.7b00045

11. H. Kharrazi, A. S. Lu, F. Gharghabi, and W. Coleman. 2012. A Scoping Review of Health Game Research: Past, Present, and Future. *Games for health journal* 1, 2 (April 2012). DOI: http://dx.doi.org/10.1089/g4h.2012.0011

12. Kai Kuikkaniemi, Toni Laitinen, Marko Turpeinen, Timo Saari, Ilkka Kosunen, and Niklas Ravaja. 2010. The Influence of Implicit and Explicit Biofeedback in First-person Shooter Games. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '10)*. ACM, New York, NY, USA, 859–868. DOI: http://dx.doi.org/10.1145/1753326.1753453

13. D. Lupton. 2014. Self-tracking Cultures: Towards a Sociology of Personal Informatics. In *Proceedings of the 26th Australian Computer-Human Interaction Conference on Designing Futures: The Future of Design (OzCHI '14)*. ACM, New York, NY, USA, 77–86.

14. D. Lupton. 2017. How does health feel? Towards research on the affective atmospheres of digital health. *Digital Health* 3 (2017), 2055207617701276.

15. J. E. McKenzie and D. W. Osgood. 2004. Validation of a new telemetric core temperature monitor. *Journal of Thermal Biology* 29, 7 (2004), 605 – 611. DOI:http://dx.doi.org/10.1016/j.jtherbio.2004.08.020 International Thermal Physiology Symposium: Physiology and Pharmacology of Temperature Regulation.

16. Lennart Erik Nacke, Michael Kalyn, Calvin Lough, and Regan Lee Mandryk. 2011. Biofeedback Game Design: Using Direct and Indirect Physiological Control to Enhance Game Interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)*. ACM, New York, NY, USA, 103–112. DOI: http://dx.doi.org/10.1145/1978942.1978958

17. A. Nash. 2012. Affect and the Medium of Digital Data. *The Fibreculture Journal* 21 (Dec. 2012).

18. N. Oudshoorn. 2016. The Vulnerability of Cyborgs. *Science, Technology, & Human Values* 41, 5 (2016), 767–792.

19. B. A. Primack, M. V. Carroll, M. McNamara, M. Lou Klem, B. King, M. Rich, C. W. Chan, and S. Nayak. 2012. Review and special article. *American Journal of Preventive Medicine* 42, 6 (2012), 630–638. DOI: http://dx.doi.org/10.1016/j.amepre.2012.02.023

20. E. Rich and A. Miah. 2017. Mobile, wearable and ingestible health technologies:towards a critical research agenda. *Health Sociology Review* 26, 1 (2017), 84–97. http://opus.bath.ac.uk/51536/

21. K. P. Sampath Kumar, D. Bhowmik, S. Duraivel, and M. Umadevi. 2012. Traditional and Medicinal Uses of Banana. *Journal of Pharmacognosy and Phytochemistry* 1, 3 (2012), 51–63.

22. P. Sweetser and P. Wyeth. 2005. GameFlow: A Model for Evaluating Player Enjoyment in Games. *Comput. Entertain.* 3, 3 (July 2005), 3–3. DOI: http://dx.doi.org/10.1145/1077246.1077253

23. D. Thompson, J. Baranowski, K. Cullen, and Baranowski. T. 2007. Development of a theory-based internet program promoting maintenance of diet and physical activity change to 8-year-old African American girls. *Computers & Education* 48, 3 (2007), 446 – 459. DOI: http://dx.doi.org/10.1016/j.compedu.2005.02.005

24. V. Vanden Abeele, B.J. Gajadhar, and B. De. Schutter. 2009. Gaming Naturally is More Fun Together: the Influence of Controller Type on Player Experience. *International Conference on Advances in Computer Entertainmant Technology* (29-31 Oct 2009).

25. K. Warwick. 2003. Cyborg morals, cyborg values, cyborg ethics. *Ethics and Information Technology* 5, 3 (01 Sep 2003), 131–137. DOI:http://dx.doi.org/10.1023/B:ETIN.0000006870.65865.cf

26. J. R. Whitson. 2013. Gaming the Quantified Self. *Surveillance & Society* 11, 1/2 (2013), 163–176. https://ojs.library.queensu.ca/index.php/surveillance-and-society/article/view/gaming