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Applying a Pneumatic Interface to Intervene with Rapid Eating Behaviour

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Abstract. Higher eating rates are positively correlate with obesity. In this paper, we propose the design of a new eating utensil that can reduce eating rate by interfering with eater's ability to eat quickly. This utensil can change its rigidity and shape by deflating itself to interfere with eating. In this study, a low fidelity proof-of-concept prototype device has been designed to provide physical resistance in order to help people reduce their eating rate. The proposed prototype could be used to demonstrate the feasibility of applying a pneumatically actuated shape-changing interface to embed physical resistance into an eating utensil.

Keywords. Technology-supported interventions, pneumatic interface, inflatable structure, shape-changing interface, eating rate, eating behavior detection

1. Introduction

Obesity is a serious epidemic in current North America [2][20], and researchers have linked eating rate, or how much food people eat within a short interval, to obesity [21]. Previous research shows that, reducing eating rate, or eating slower, could reduce caloric intake [27] and lower eating rate could minimize the risk of increasing Body Mass Index (BMI) and obesity [21]. Clearly, having good eating habits is important. To achieve this goal, numerous interventions have been applied in various settings. For instance, some studies have manipulated eating rate and investigated the energy intake in experiment [27], while others have leveraged digital interventions to help modify people's eating behavior [28]. However, these interventions are relatively difficult to be applied in everyday life. For example, some require elaborate experimental settings in a laboratory [3] while others might require setting up extra devices and equipment which is not easy to carry with, such as a special scale to record every time people eat [11,12]. Such rather burdensome tools and settings might discourage users to continue to improve their eating habits. Thus, we propose the development of an eating utensil, which is compact and easy to carry. This utensil has the important ability to intervene with users' food intake behavior to modify their eating rate. Users of the proposed utensil should be able to improve their eating behavior independently and without additional equipment.

Regarding eating utensils, the use of light and/or vibration signals are two of the most commonly applied methods to provide feedback as interference. These feedback methods have been applied to commercial eating devices such as the 10s Fork [15].

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However, studies [7,9,10] have shown such feedbacks were not obvious to the participants and that the slower eating rate induced by the device did not help to reduce the amount of their food consumption. Evidently, there is a need to embed feedback mechanisms within eating utensils, which are obvious to the users in order to effectively influence eating rate and food consumption.

We introduce physical resistance onto an eating utensil, which can physically burden the user and we hypothesize that this will slow their eating rate. This is achieved by changing the stiffness and shape of the eating utensil. To evaluate the feasibility and effectiveness of doing so, we developed a low fidelity utensil prototype, which provides physical resistance via a pneumatic shape-changing interface, whereby the handle of the eating utensil becomes soft and bends when a user is trying to eat too quickly. We plan to demonstrate the feasibility of embedding physical resistance onto an eating utensil to improve people's eating rate.

The next essential function to enable the device to improve eating behavior is to accurately detect users' food intake. Prior studies have examined various modalities, such as pictures, motion and voice, to detect eating moment [31]. Based on these projects [31], we plan to apply the Inertial Measurement Unit (IMU) to the eating utensil. This will allow us to detect users' eating behavior, which has been demonstrated in a previous project [30].

We are now in the early stages of developing the prototype, which could recognize intake behavior and provide physical resistance using a pneumatic actuation. Subsequently, we will conduct experiments to test the acceptability of our prototype, and empirically test the efficiency of the physical resistance in reducing the eating rate and food consumption. To our knowledge, this project would be the first attempt to apply a pneumatic shape-changing interface in an eating utensil to provide physical resistance in an actual eating environment.

2. Related Work

In this section, we discuss the literature on eating rate; the techniques used to detect eating and provide feedback; behavior modification technologies; and shape-changing interfaces.

2.1. Eating rate and health

Eating rate likely plays a role in personal health [21,27]. For example, Ohkuma, et al. [21] conducted a systematic review of studies focusing on the relationship between eating rate and obesity and concluded that eating quickly is positively correlated with increased BMI and obesity. Moreover, Robinson et al. [27] also systematically reviewed studies which manipulated eating rate and showed the impact on food intake and hunger; they reviewed factors such as verbal instruction from researcher(s), altering food texture, manipulating food delivery and computerized feedback. Robinson et al. [27] found that a decreasing eating rate was associated with reducing energy intake. Thus, decreasing the eating rate is a key to help reduce energy intake. Bolhuis and Keast [3] found that participants who ate with a spoon had a higher eating rate than those who used a fork in a laboratory setting; these two groups of participants spent similar time on four different lunch sessions, but generally, spoon users consumed more. These findings suggest that the choice of eating utensil likely affects users' eating rate.

2.2. Techniques to detect eating and provide feedback

Various devices exist to detect eating behavior, with a subset which provides feedback and intervention when necessary. The 10s Fork [15], a commercial smart fork mentioned earlier, can provide feedback on eating rate through vibration. The fork counts the time interval between each bite and vibrates when the interval stays within a programmed threshold. Hermans et al. [6,9] conducted a qualitative study on the 10s Fork to investigate user experience with the device and their attitudes regarding acceptability, and perceived efficacy. Hermans et al. [6,9] found the 10s Fork was comfortable to use and sufficiently accurate. However, participants felt they were not the target user and thus lacked the motivation to continue using it after experiment. Hermans et al. [7] also conducted a between-subject laboratory experiment on the effect of the 10s Fork; they found that the vibrotactile feedback on the 10s Fork could successfully reduce the number of bites per minute when users were eating quickly. However, that slower eating did not lead to a reduction in food consumption.

Kadomura et al. [17] introduced the Sensing Fork, a smart fork to recognize eating behavior and the color of food. To provide positive feedback on good eating behavior, the researchers also prototyped the Hungry Panda game [16]. This game provided users with visual feedback according to the eating behavior detected by the fork. In the second version of the game, the researchers addressed the issues of picky eating and distracted eating for Japanese children [18]. The longitudinal, in-the-field study showed that the system developed by Kadomura et al. was acceptable to the participating children and could potentially improve children's eating behavior [18].

Smartwatches have gained popularity as tools to promote and improve general health and wellness [26]. Thomaz et al. [30] presented a practical approach, which leveraged an inertial sensor from a smartwatch to identify eating moment of users; they conducted a semi-controlled lab study to train an eating moment classifier based on inertial sensor data, then validated the classifier in two in-the-wild studies. The inertial sensor was able to effectively detect user's eating behavior. Compared with other modalities such as first-person images captured by camera and acoustic sensing data captured by earbud, inertial sensing promises to be beneficial since it will not interfere with users' privacy [31]. Mirtchouk et al. [19] concluded that the combining of multiple sensing modalities and focusing on personal in-the-wild data could improve accuracy.

Several other devices have been used to measure food consumption. One such device, the Mandometer [11], employs a scale to assess food consumption by tracking the weight change of the meal and provides users with visual feedback on a smartphone. Using computer vision techniques also allows for the recognition of the food being eaten. This technique was applied to another device, SmartPlate [12]. Equipped with a weight tracking plate and a supplementary smartphone application, the SmartPlate analyzes the pictures of food, and provide visual data on meal. Devices such as Mandometer and SmartPlate require a weight scale and a smartphone.

2.3. Behavior digital interventions

Rose et al. [28] reviewed 27 studies on digital interventions for improving the diet and physical activity behaviors of adolescents. The digital interventions include web sites, text messages, games, multicomponent interventions, emails, and social media. The researchers found digital interventions that incorporate education, goal setting, self-monitoring, and parental involvement had a significant effect on behavior change.

Hermsen et al. [8] reviewed studies on digital technologies for changing habits and found that feedback generated through digital technology could effectively disrupt undesired habits.

2.4. Shape-changing interfaces

One way to modify behavior is through generating physical interference that limits users' movements. Al Maimani and Roudaut [1] explored the use of jamming technology, changing the stiffness of a suit to restrict users' body movement for a haptic game; they studied different material and particles for jamming and compared the size of patches of the suit in their experiment. Delazio et al. [4] introduced a wearable pneumatic interface to provide force and vibration to the upper body; they conducted a series of user studies to validate their approach and provided prototype applications in virtual reality. Pohl et al. [24] designed a pneumatic strap, which could provide compression feedback on the body. This device inhibits physical movements based on compression, and it was incorporated in a jogging game. These three approaches suggest that physical resistance generated in shape-changing devices, is feasible.

Regarding shape-changing interfaces design, Qamar et al. [25] reviewed material science and Human-computer Interaction (HCI) literature on various approaches for shape-changing device design, one of which being the use of pneumatic actuation. He et al. [5] introduced a pneumatic armband with tactile sensations and explored different possibilities for human-device interaction. To provide notifications, Pohl et al. [22] generated compression feedback from pneumatic actuation and an inflatable structure. They produced some prototypes to study the compression feedback, and compared compression and vibrotactile feedback [23]. Sareen et al. [29] introduced a design and fabrication technique for making pneumatic artifacts and showed that their interfaces are strong enough to withstand various weights. Several commercial eating utensils has the ability to be bendable, such as the Sure Hand Bendable Utensils [14]. It is an assistive device to aid older adults for dining food. To solve hand tremor issues, Liftware provides Liftware Steady and Liftware Level, two products to support people who experience limitations in mobility [13].

There are various technologies focusing on eating behavior, however, to date, there are no studies on applying pneumatic actuation to eating utensils. We plan to develop a utensil that can leverage a pneumatic interface to provide physical resistance to certain eating behavior.

3. Methodology

Our first goal is to validate the feasibility of embedding physical resistance into an eating utensil. We first conducted design brainstorm sessions to gather and compare different design ideas for the type of physical resistance used to intervene with a high eating rate. Based on these sessions, we decided on the shape-changing interface design, as a pneumatic actuation idea has not been explored thoroughly as an eating intervention. Also, a pneumatic actuation is safe in the eating context.

Our research team has been developing low fidelity prototypes (Figure 1) containing a small pump, a mini solenoid valve, and an air bag. The handle of the eating utensil is pneumatic, and can change its rigidity and shape by inflating and deflating. The inflating behavior of the device increases the air pressure of the pneumatic part, providing stiffness to facilitate eating. Deflation the device reduces the rigidity of the handle to interfere with eating (See Figure 1, right image).

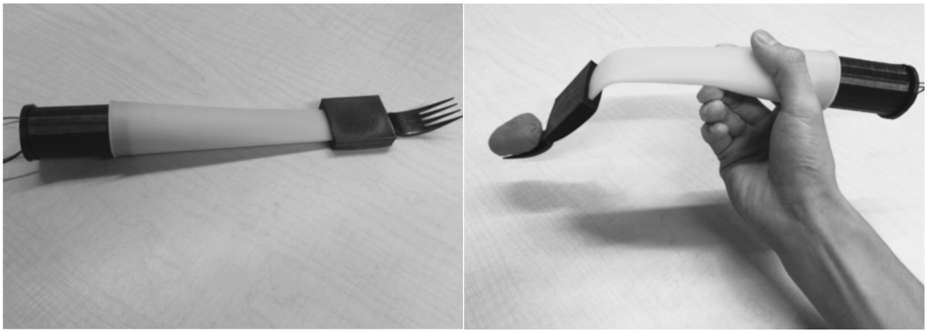

Figure 1. A very initial low fidelity prototype that shape-changes the utensil. It bends when deflated, thereby intervening with the eater's behavior.

4. Future work

As described above, although there are numerous devices that attempt to improve eating behaviors, there is a need for further exploration in identifying appropriate technological interventions for assisting with eating behaviors. For a future study, we plan to develop a prototype, which can detect eating behavior using a motion sensor, and provide various levels of physical resistance. When fast eating is detected, physical resistance should be applied via changing the stiffness and the shape of the device. The current prototype is approximately twice as a normal eating. Work is needed to reduce the device size for further studies.

Evaluation of the design will be based on the results of a series of experiments with a next-stage prototype. First, we plan to investigate the user experience as it relates to comfort and acceptability at various levels of physical resistance as the stiffness of the device changes. We will then conduct a study of the efficiency of this resistance in reducing eating rate to demonstrate the feasibility of our design idea and its potential effect for changing and improving people's eating behavior.

5. Conclusion

Eating is an important daily activity that is related to everyone's health. Improper eating behaviors can lead to various health issues such as fast eating rates have been shown to correlate with obesity [21], while a slow eating rate could reduce energy intake [27] and the risk of increasing BMI and obesity [21]. Existing approaches that introduce interventions to a user's eating behavior are either unobvious to the user, or dependent on extra devices. In our approach, we are proposing a design that embeds physical resistance into an eating utensil to help fast eaters reduce their eating rate. To verify the feasibility and effectiveness of the idea, we are building proof-of-concept prototypes that provide physical resistance to the user's eating behavior via changing the stiffness and shape of the device. To the extent of our knowledge, it would be the first prototype that leverages a pneumatic shape-changing interface to introduce physical resistance via an eating utensil. Based on the prototype, we plan to conduct a series of user studies to assess the user's experience and prove the efficiency of the solution on reducing users' eating rate. We will evaluate our design based on the results of the experiments to investigate whether the physical resistance in eating utensils could help people reduce their eating rate.

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References

[1] A. Al Maimani and A. Roudaut. Frozen suit: Designing a changeable stiffness suit and its application to haptic games. *In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, CHI '17*, pages 2440–2448, New York, NY, USA, 2017. ACM.
[2] D. B. Allison and S. E. Saunders. Obesity in North America: An overview. *Medical Clinics of North America,* **84**(2) (2000), 305 – 332.
[3] D. P. Bolhuis and R. S. Keast. Assessment of eating rate and food intake in spoon versus fork users in a laboratory setting. *Food quality and preference*, **49** (2016), 66–69,.
[4] A. Delazio, K. Nakagaki, R. L. Klatzky, S. E. Hudson, J. F. Lehman, and A. P. Sample. Force jacket: Pneumatically-actuated jacket for embodied haptic experiences. *In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, CHI '18*, pages 320:1–320:12, New York, NY, USA, 2018. ACM.
[5] L. He, C. Xu, D. Xu, and R. Brill. Pneuhaptic: Delivering haptic cues with a pneumatic armband. *In Proceedings of the 2015 ACM International Symposium on Wearable Computers, ISWC '15*, pages 47–48, New York, NY, USA, 2015. ACM.
[6] R. Hermans, S. Hermsen, E. Robinson, M. Mars, S. Higgs, and J. Frost. Take it slow! using an augmented fork to reduce eating speed: A qualitative user experience study. *Appetite*, **101 (**2016), 232.
[7] R. C. Hermans, S. Hermsen, E. Robinson, S. Higgs, M. Mars, and J. H. Frost. The effect of real-time vibrotactile feedback delivered through an augmented fork on eating rate, satiation, and food intake. *Appetite*, **113** (2017), 7–13.
[8] S. Hermsen, J. Frost, R. J. Renes, and P. Kerkhof. Using feedback through digital technology to disrupt and change habitual behavior: a critical review of current literature. *Computers in Human Behavior*, **57** (2016), 61–74.
[9] S. Hermsen, J. H. Frost, E. Robinson, S. Higgs, M. Mars, and R. C. Hermans. Evaluation of a smart fork to decelerate eating rate. *Journal of the Academy of Nutrition and Dietetics*, **116**(7) (2016), 1068.
[10] S. Hermsen, J. H. Frost, E. Robinson, M. Mars, S. Higgs, and R. C. Hermans. Take it slow! can feedback from a smart fork reduce eating speed?
[11] https://mando.se/en/. Mandometer, 2018.
[12] https://www.getsmartplate.com/index.html. Smartplate, 2018.
[13] https://www.liftware.com/. Liftware, 2018.
[14] https://www.performancehealth.com/sure-hand-bendable utensil. Sure hand bendable utensils, 2018.
[15] http://www.slowcontrol.com/en/. 10s fork, 2018.
[16] A. Kadomura, C.-Y. Li, Y.-C. Chen, H.-H. Chu, K. Tsukada, and I. Siio. Sensing fork and persuasive game for improving eating behavior. *In Proceedings of the 2013 ACM Conference on Pervasive and Ubiquitous Computing Adjunct Publication, UbiComp '13 Adjunct*, pages 71–74, New York, NY, USA, 2013. ACM.
[17] A. Kadomura, C.-Y. Li, Y.-C. Chen, K. Tsukada, I. Siio, and H.-h. Chu. Sensing fork: Eating behavior detection utensil and mobile persuasive game. *In CHI '13 Extended Abstracts on Human Factors in Computing Systems, CHI EA '13*, pages 1551–1556, New York, NY, USA, 2013. ACM.
[18] A. Kadomura, C.-Y. Li, K. Tsukada, H.-H. Chu, and I. Siio. Persuasive technology to improve eating behavior using a sensor-embedded fork. *In Proceedings of the 2014 ACM International Joint Conference*

on Pervasive and Ubiquitous Computing, UbiComp '14, pages 319–329, New York, NY, USA, 2014. ACM.

[19] M. Mirtchouk, D. Lustig, A. Smith, I. Ching, M. Zheng, and S. Kleinberg. Recognizing eating from body-worn sensors: Combining free-living and laboratory data. Proc. *ACM Interact. Mob. Wearable Ubiquitous Technol.*, **1**(3):85 (2017), 1–85.

[20] N. S. Mitchell, V. A. Catenacci, H. R. Wyatt, and J. O. Hill. Obesity: Overview of an epidemic. *Psychiatric Clinics of North America*, **34**(4) (2011), 717 – 732. Obesity and Associated Eating Disorders: A Guide for Mental Health Professionals.

[21] T. Ohkuma, Y. Hirakawa, U. Nakamura, Y. Kiyohara, T. Kitazono, and T. Ninomiya. Association between eating rate and obesity: a systematic review and meta-analysis. *International Journal of Obesity*, **39**(11) (2015), 1589.

[22] H. Pohl, D. Becke, E. Wagner, M. Schrapel, and M. Rohs. Wrist compression feedback by pneumatic actuation. *In Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems, CHI EA '15*, pages 315–318, New York, NY, USA, 2015. ACM.

[23] H. Pohl, P. Brandes, H. Ngo Quang, and M. Rohs. Squeezeback: Pneumatic compression for notifications. *In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, CHI '17*, pages 5318–5330, New York, NY, USA, 2017. ACM.

[24] H. Pohl, F. Hoheisel, and M. Rohs. Inhibiting freedom of movement with compression feedback. *In Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems, CHI EA '17*, pages 1962–1969, New York, NY, USA, 2017. ACM.

[25] I. P. S. Qamar, R. Groh, D. Holman, and A. Roudaut. Hci meets material science: A literature review of morphing materials for the design of shape-changing interfaces. *In Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, CHI '18*, pages 374:1–374:23, New York, NY, USA, 2018. ACM.

[26] B. Reeder and A. David. Health at hand: a systematic review of smart watch uses for health and wellness. *Journal of biomedical informatics*, **63** (2016), 269–276.

[27] E. Robinson, E. Almiron-Roig, F. Rutters, C. de Graaf, C. G. Forde, C. Tudur Smith, S. J. Nolan, and S. A. Jebb. A systematic review and meta-analysis examining the effect of eating rate on energy intake and hunger–. *The American journal of clinical nutrition*, **100**(1) (2014), 123–151.

[28] T. Rose, M. Barker, C. M. Jacob, L. Morrison, W. Lawrence, S. Strommer, C. Vogel, K. Woods-Townsend, D. Farrell, H. Inskip, et al. A systematic review of digital interventions for improving the diet and physical activity behaviors of adolescents. *Journal of Adolescent Health*, **61**(6) (2017), 669–677.

[29] H. Sareen, U. Umapathi, P. Shin, Y. Kakehi, J. Ou, H. Ishii, and P. Maes. Printflatables: Printing human-scale, functional and dynamic inflatable objects. *In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, CHI '17*, pages 3669–3680, New York, NY, USA, 2017. ACM.

[30] E. Thomaz, I. Essa, and G. D. Abowd. A practical approach for recognizing eating moments with wrist-mounted inertial sensing. *In Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing, UbiComp '15*, pages 1029–1040, New York, NY, USA, 2015. ACM.

[31] E. Thomaz, I. A. Essa, and G. D. Abowd. Challenges and opportunities in automated detection of eating activity. *In Mobile Health*, pages 151–174. Springer, 2017.