Multimodal Digital Taste Experience with D'Licious Vessel

Liangkun Yan(✉), Barry Chew, Jie Sun, Li-An Chiu, Nimesha Ranasinghe, and Ellen Yi-Luen Do

Keio-NUS CUTE Center, National University of Singapore, Singapore, Singapore
{idmyl, idmsunj, nimesha, ellendo}@nus.edu.sg,
{chew.barry, lian600058}@gmail.com

Abstract. Increasingly, people are replacing soft drinks with natural fruit juices, since soft drinks usually contain excessive sugar and little nutrition. This paper introduces a multimodal digital taste control system 'D'Licious Vessel' and the respective prototypes. The goal is to provide a digital solution to health concerns regarding overuse of sugar in our daily drinks by decreasing the natural sourness. The system applies gentle electrical signals to a person's tongue to trigger different taste sensations and improve the taste of drinks digitally without involving consumption of actual chemicals. We conducted user studies in a public setting to collect the experimental data and to find the system's effectiveness in improving the taste of lemon juice. During the study, participants were provided with lemon juice and asked to compare the taste difference while drinking with different settings of the taste stimulation prototype. Their opinions for different prototype designs are recorded and discussed.

Keywords: Flavor · Digital taste · Multimodal interaction · User interfaces · Virtual reality

1 Introduction

Taste is an important sensory perception for animals to judge the quality of food [1]. In addition, people enjoy taste sensations while consuming food and drinks. Condiments and artificial flavoring have been used to improve taste experience throughout human history [2]. But people today are seeking for healthier choices over food and drinks. More people are choosing natural fruit juices or water over soft drinks to avoid high sugar intake that causes obesity [3] and other health problems [4]. However, people seem to dislike sourness in many fruit juices [5] and prefer the sugar-sweetened soft drinks [3]. Our team aims to improve the taste of natural fruit juices, such as reducing the sourness or even create minor sweetness digitally without consumption of actual chemicals. Moreover, in recent years, more questions have been raised by the public on the safety and long term health effect regarding the type and amount of condiments usage. On the other hand, the elderly and particular patients after certain treatments may suffer from degrading taste reception. This paper introduces a multimodal digital

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taste control system - D'Licious Vessel, to provide a digital solution to the health concerns above.

Taste sensation is commonly triggered by chemical reactions between food particles and taste receptor cells in taste buds [6]. Shown in recent studies, by applying a gentle electric signal to the tongue, it is also possible to stimulate different taste sensations digitally without any actual chemical involved [7]. Previously, the common belief that different taste sensations are actually located on different areas of the tongue, known as the 'tongue map', has been proven to be a wrong concept [8]. Every taste bud on the tongue are now found to contain all necessary taste receptor cells responsible for the 5 basic tastes, namely sweet, sour, bitter, salty and umami [9]. Thus, by applying gentle electric signal only to the tip of tongue, it is possible to trigger different taste sensations.

Tongue stimulation is not the only factor for taste perception. Many other factors like smell, temperature and chewing texture all have their effects on taste perception [10]. Moreover, many researches have proven that there is a strong association that the color of food and drinks influences our taste perceptions [11]. Before sending anything into mouth, we actually judge the taste with our eyes first, i.e. visual influence. When drinks present with same content but in different colors, people may have different taste perceptions [12]. For example, people perceive a sourer taste when yellow is present in the drinks. Thus in D'Licious Vessel, besides tongue stimulation, visual stimulation will also be used for digital taste perception [13].

This study aims to generate the taste sensations by controlling and manipulating taste perception factors in a digital way. D'Licious Vessel contains embedded electronic control modules to achieve taste sensations enhancement by two kinds of stimulations: electronic pulses stimulation on the tongue and visual stimulations using Light-Emitting Diodes (LED). D'Licious Vessel can enhances the sweetness, sourness, saltiness or bitterness in natural fruit juices by primarily applying gentle and adjustable electrical pulses on the human tongue as shown in Fig. 1. The multi-color light emitted by LED is used to change our perception of taste as well.

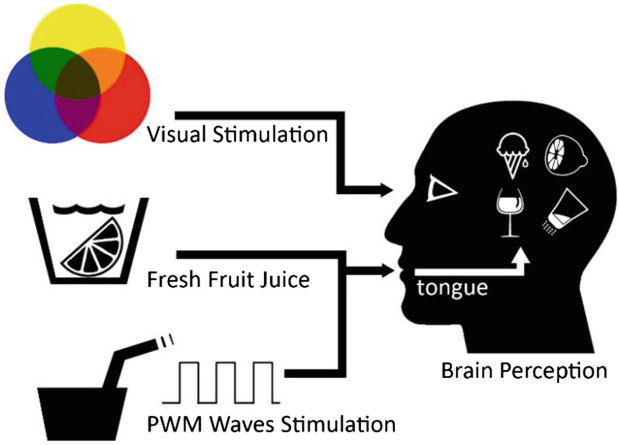

Fig. 1. Digital taste stimulation

2 System Description and Prototypes

2.1 Digital Taste Control System

By applying different electric signals, different taste sensation modes are able to be triggered [14]. The electronic signal used in the control system is Pulse-width modulation (PWM) waves. Pulse-width modulation (PWM) is a modulation technique generally used to contain information by controlling the width of the pulse (the pulse duration). The modes and their respective signal range are determined in the earlier research stage of this project [15]. The signal amplitude used in prototypes is 2 V, which means the waves contain only 2 values: 2 V (on) and 0 (off). Different taste modes are achieved by varying the duty cycle of the PWM waves, namely the respective duration of 'on' and 'off' in each period. Based on early stage research, three taste modes were categorized: salty, bitter and sour and they can be operated in a relatively lower frequency of 400-500 kHz. Thus the frequency of the system is fixed at 490 kHz (Arduino pro mini default frequency). The PWM duty cycle range for each mode is shown in Fig. 2.

The system is an embedded control module providing multimodal experience. The user interface allows users to perform mode selection by themselves using a rotary knob or push button. This mechanism also facilitates users to explore different settings of the system to find their own preferred taste sensations depending on the juice taste. D'Licious Vessel project aims to provide digital taste experience in different eating and drinking circumstances. Currently a bottle and a spoon prototype have been developed.

As shown in Fig. 3, both prototypes adopt this user interface design. Both have two outputs: (1) electrical pulses that are sent to the tongue through a pair of silver electrodes and (2) the multi-color LEDs. The two outputs are controlled by the user according to the mode selected.

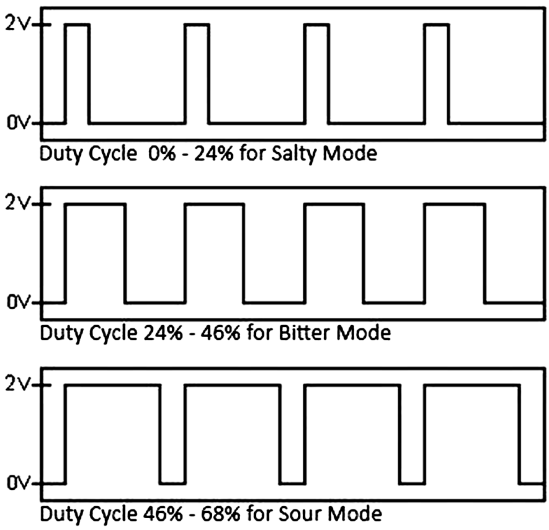

Fig. 2. PWM waves duty cycle range

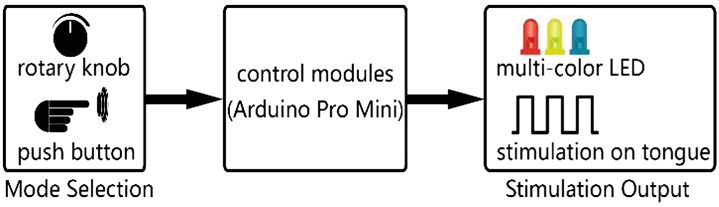

Fig. 3. User interface design

2.2 Prototypes

Bottle prototype is designed to function as a hydration vessel where it encourages people to drink via the bottle during their daily hydration. The bottle prototype has a rotary knob that corresponds to a varying intensity of the PWM waves supplied to the tongue when it is rotated. This enables the mode and its respective strength to be changed. It also allows users to find out the most suitable electric pulse strength for them to enjoy a specific taste.

Figure 4 shows the first and second version of the bottle prototypes. Both have a similar base design but different mouthpieces. For the first prototype, electrodes are (two silver rings) secured around a straw, while the second prototype uses a different design with silver electrodes attached on the rim of bottle. A rotary knob and a mode indicating scale is attached at the base for each prototype, allowing users to choose the electronic pulses according to their own preferences. LED lights are used to indicate and psychologically enhance different taste modes, blue for salty, red for bitter and

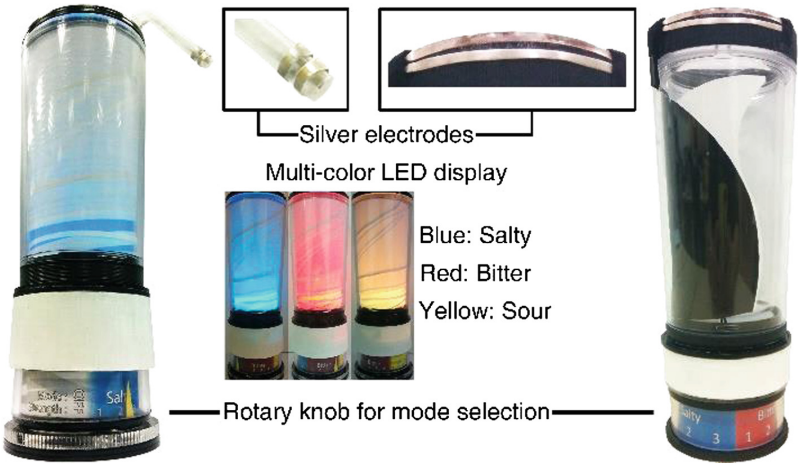

Fig. 4. Bottle prototypes with silver electrodes and rotary knob indication

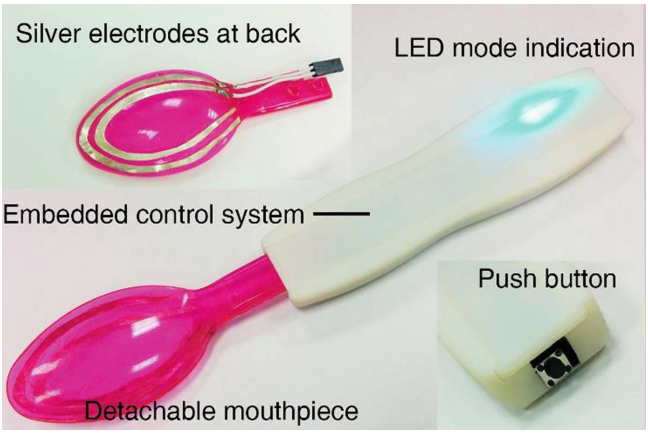

Fig. 5. Spoon type prototype

yellow for sour. The light intensity is directly linked with the electronic pulse strength for each mode.

We provided both bottle type prototypes for informal demo sessions and collected users' opinions on the design during the initial stage. Compared with the straw-type prototype, the majority stated that the second prototype provides a better user experience which is more user-friendly and has an easier cleaning procedure.

Spoon prototype is mainly designed to cater for individuals who suffer degradation in their taste sensation. It aims to enhance their taste sensations during their meal. Figure 5 shows the second version of the spoon. The first version (called Taste +) was designed by previous research team at Keio-NUS CUTE Center [16].

In both versions of spoon prototype, push button is used to toggle between three different preset modes. The preset modes correspond to three different discrete values of electronic pulse strength. This design minimizes the space required for the electronics, giving a comfortable grip for the users. The LED in the prototype serves as a mode indicator. The silver electrodes are 2 pieces follow the shape of spoon outline, attached at the back of the spoon where is usually licked by tongue. Although its appearance is greatly different from the bottle type, the internal electronic module is similar.

The main design improvement of second version compared with the first version is the detachable head part that can be replaced easily. It allows a throughout cleaning regarding hygiene concerns and can be changed into other cutlery easily if necessary. Currently, a replaceable fork mouthpiece is in production. It has an additional bitter mode besides the salty and sour mode in first version [17]. Also, the sliding cover design conceals the electric system more firmly in the handle. Besides bottle type and spoon type, other design applications also have been worked on. Lollipop and chopsticks are some of the other designs that are currently being developed.

3 User Study

3.1 Early Stage User Study

User studies were conducted using the bottle-type prototypes to investigate the effect of multimodal taste experience. Four common types of diluted fruit juices: lemon, pineapple, lime and grape were used in an early user study of 30 participants. There were a total of 3 solutions with different concentration for each kind of fruit juices. It is formulated by adding different amount of fruit into 100 ml water. Users are required to compare the change in taste with and without digital taste modes for the same diluted fruit juice, and their reactions as well as user experience were recorded. Lemon juice had the most obvious results and thus is our main focus in the following study. In the early user study, under salty mode, the majority (over 50 %) stated a better taste juice with less sourness, and minor sweeter taste were reported by 13 % of the users. Also, 6 % gave feedback that they do not know how to describe the new taste sensation but the juices tasted significantly better as compared to consuming lemon juice without digital stimulations.

3.2 User Study During the Public Exhibition

During our showcase at Singapore Art Science Museum, we conducted a larger user study with the 48 people who volunteered to try the new digital taste experience. We provided lemon juice to a particular user with same concentration: 3 g of lemon slices in 100 ml of water in our bottle type prototype. Although the bottle type provides a free and smooth mode and strength change, for better analysis purposes, we chose 6 fix mode and strength combinations for the participants. The six combinations are: weak salty, strong salty; weak bitter, strong bitter; weak sour and strong sour. Their respective duty cycles are stated below with the results. Participants were asked to provide feedback regarding the taste change of lemon juice compared with the original, as well as their opinions on the prototype design or the overall project.

Salty Mode. For weak salty mode, shown in Fig. 6, corresponding to a PWM wave with duty cycle about 10-12 %, we have identified that almost 60 % of the users registered no change in the taste of the lemon juice. Almost 25 % of the participants however did register a sourer taste in the lemon juice after drinking through the D'Licious Vessel in the experiment. Also 4 % of the users registered a taste difference but could not describe the taste. These unrecognized taste sensations are subsequently categorized under 'others'.

For strong salty mode, corresponding to a PWM wave with duty cycle about 20-22 %, we have identified that 13 % of the users responded that the lemon juice became saltier and the changes were significant. 29 % of the participants felt that the lemon juice was sourer, which was the result of the induced taste sensations when the current passed through the tongue.

Bitter Mode. For weak bitter mode, shown in Fig. 7, corresponding to PWM wave with duty cycle about 30-35 %, we have identified that there is a slight increase in the

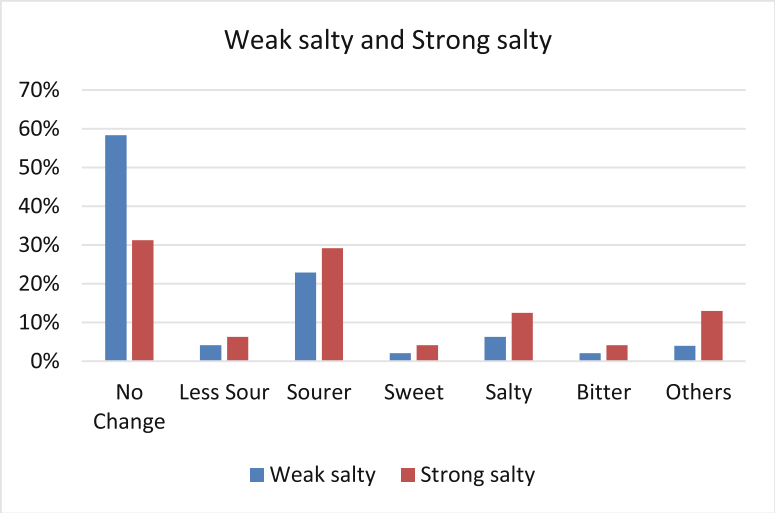

Fig. 6. Results analysis for salty modes

number of participants (10 %) who have detected bitterness in the lemon juice. However, 23 % of the participants still managed to register an increase in sourness of the lemon juice, where some participants labelling the lemon juice as more 'lemony'.

For strong bitter mode, corresponding to PWM wave with duty cycle 40-45 %, we have identified that almost 10 % of the participants responded a sweeter taste in their lemon juice. The slight sweetness was detected when the participants consume the lemon juice while touching the silver electrodes. 13 % of the participants' responded that the taste of the juice was awful.

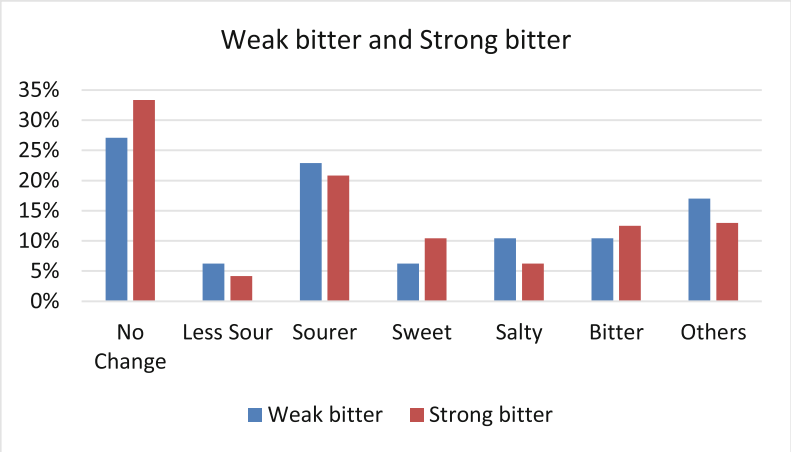

Fig. 7. Results analysis for bitter modes

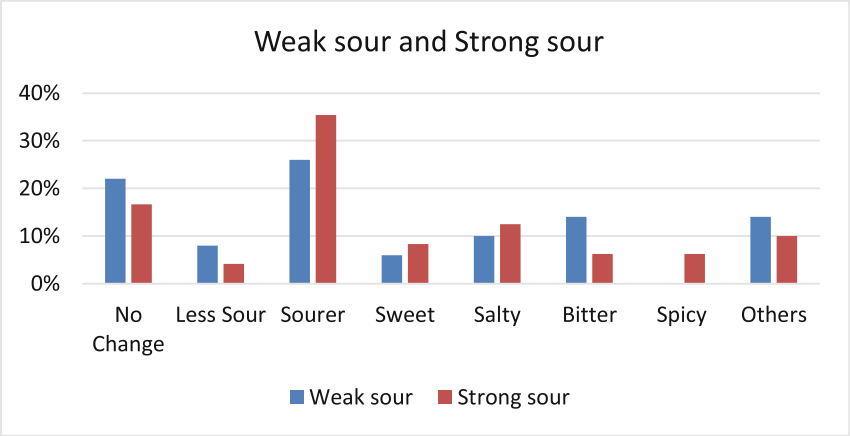

Fig. 8. Results analysis for sour modes

Sour Mode. For weak sour mode, shown in Fig. 8, corresponding to a PWM wave with duty cycle about 50-55 %, we have identified that 14 % of the participants registered a bitter taste. Another 8 % of the users detected a slightly less sour taste in the same cup of lemon juice.

For strong sour mode, corresponding to a PWM wave with duty cycle about 60-65 % there is a significant increase in the number of participants detecting an increase in sourness of the lemon juice. Some of the users found the sourness unbearable and described the juice as 'definitely more lemony'. 8 % of the participants found it amusing and delightful to detect a slight increase in sweetness while drinking the lemon juice in this mode.

Furthermore, we also categorized the results based on their native region (Table 1) and age group (Table 2) of the participants.

Based on the results in Table 1, we realized that Westerners have sensitive taste receptors in their taste buds and were able to detect most of the taste sensations when their tongues are being electrically stimulated. They were more likely to detect sweetness (63 %) and bitterness (63 %) when drinking via the prototype compared to participants from other native regions.

Based on the results in Table 2, the age group of 18-30 is proven to be most successful in detecting an increased in sourness of the lemon juice when they drink

Table 1. Results analysis according to native region

Native Region	No.	Detect sweet	Detect more sour	Detect bitter	Detect salty
Westerner	11	63 %	54 %	63 %	45 %
Chinese	26	11 %	73 %	42 %	38 %
Indian	5	40 %	60 %	40 %	40 %
Japanese	4	33 %	100 %	33 %	66 %

Table 2. Results analysis according to age group

Age Group	No.	Detect sweet	Detect more sour	Detect bitter	Detect salty
<18	16	25 %	63 %	38 %	19 %
18-30	16	13 %	94 %	25 %	38 %
31-50	12	25 %	83 %	50 %	50 %
>50	4	0	25 %	50 %	0

from the prototype. Another interesting result was that the participants from the age group between 31-50 have a higher tendency to detect a different taste as compared to the other age groups during the experiments.

4 Conclusions

Although the user study results are not highly consistent yet, from the overall user study results, we may conclude that the prototype is able to improve the drinking experience for a number of users.

Also, participants (regardless of their tasting results) all showed interests in this new digital sensation experience. They supported the idea of digitally stimulated taste sensation, as they will be able to enjoy food with less health concerns.

In order to provide a more consistent user experience for everyone, more user studies and further investigation is required. Prototype development is also worked on to provide users with a more divergent and more pleasant experiences.

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References

1. Huang, A.L., Chen, X., Hoon, M.A., Chandrashekar, J., Guo, W., Tränkner, D., Ryba, N.J. P., Zuker, C.S.: The cells and logic for mammalian sour taste detection. Nature **442**(7105), 934–938 (2006)
2. Farrell, K.T.: A brief look at the long history of spices. In Spices, Condiments and Seasonings, 2nd edn., pp. 5–6. Springer Science & Business Media (1998)
3. Vartanian, L.R., Brownell, K.D., Schwartz, M.B.: Effects of soft drink consumption on nutrition and health: A systematic review and meta-analysis. Am. J. Pub. Health **97**(4), 667–675 (2007)

4. Harnack, L., Stang, J., Story, M.: Soft drink consumption among US children and adolescents: nutritional consequences. J. Am. Diet. Assoc. **99**(4), 436–441 (1999)
5. Mela, D.J.: Why do we like what we like? J. Sci. Food Agric. **81**(1), 10–16 (2001)
6. Chiras, D.D.: The senses. In: Human Biology, 5th edn., p. 201. Jones & Bartlett Publishers, Sudbury (2005)
7. Ranasinghe, N., Nakatsu, R., Nii, H., Ponnampalam, G.: Tongue mounted interface for digitally actuating the sense of taste. In: 2012 16th International Symposium Wearable Computers (ISWC), pp. 80–87. IEEE Computer Society (2012)
8. Wanjek, C.: The Tongue Map: Tasteless Myth Debunked (2006). http://www.livescience.com/7113-tongue-map-tasteless-myth-debunked.html. Accessed 14 November 2014, from livescience
9. O'Connor, A.: The Claim: Tongue Is Mapped Into Four Areas of Taste (2008). http://www.nytimes.com/2008/11/11/health/11real.html?_r=2&. Accessed 10 November 2014, from The New York Times
10. Auvray, M., Spence, C.: The multisensory perception of flavor. Conscious. Cogn. **17**(3), 1016–1031 (2008)
11. Shankar, M.U., Levitan, C.A., Prescott, J., Spence, C.: The influence of color and label information on flavor. Chem. Percept. **2**, 53–58 (2009)
12. King, B., Duineveld, C.: Factors affecting the perception of naturalness and flavor strength in citrus drinks. Ann NY Acad. Sci. **855**, 847–853 (1998)
13. Zampini, M., Wantling, E., Phillips, N., Spence, C.: Multisensory flavor perception: Assessing the influence of fruit acids. Food Qual. Pref. **19**, 335–343 (2008)
14. Ranasinghe, N., Cheok, A.D., Fernando, O.N.N., Nii, H., Gopalakrishnakone, P.: Digital taste: electronic stimulation of taste sensations. In: Keyson, D.V., Maher, M.L., Streitz, N., Cheok, A., Augusto, J.C., Wichert, R., Englebienne, G., Aghajan, H., Kröse, B.J. (eds.) AmI 2011. LNCS, vol. 7040, pp. 345–349. Springer, Heidelberg (2011)
15. Ranasinghe, N., Lee, K., Do, E.Y.L.: FunRasa: an interactive drinking platform. In: Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction, pp. 133–136. ACM (2014)
16. National University of Singapore: Electronic spoon helps the elderly age tastefully (2014). http://news.nus.edu.sg/highlights/7686-electronic-spoon-helps-the-elderly-age-tastefully. Accessed 17 Feburary 2015
17. Ranasinghe, N., Lee, K.Y., Suthokumar, G., Do, E.Y.L.: Taste +: digitally enhancing taste sensations of food and beverages. In Proceedings of the ACM International Conference on Multimedia, pp. 737–738. ACM (2014)
18. Stanford Center on Longevity: Design Challeng Winners Announced (2014). http://longevity3.stanford.edu/design-challenge-winners-announced/. Accessed 17 Feburary 2015