1st Workshop on Multi-sensorial Approaches to Human-Food Interaction
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1st Workshop on Multi-sensorial Approaches to Human-Food Interaction
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Editorial

Eating and drinking are, perhaps, some of the most multisensory events of our everyday life. Take, for instance, flavor, which is one of the most important elements of such experiences. It is known that flavor is the product of the integration of, at least, gustatory and (retronasal) olfactory cues. Nevertheless, researchers have suggested that all our senses can influence the way in which we perceive flavor, not to mention our eating and drinking experiences. For instance, the color and shape of the food, the background sonic cues in our eating environments, and/or the sounds that derive from the food's mastication can all influence our perception and enjoyment of our eating and drinking experiences.

In this workshop, we were particularly interested in new systems that were designed to enhance people's eating experiences in the context of HFI and which were based on the principles that govern the systematic connections that exist between the senses (e.g., spatiotemporal congruence, semantic congruence, and crossmodal correspondences. This included the experiencing food interactions digitally in remote locations, sensing flavor information from one place, transferring them over the internet digitally, and effectively regenerate at the destination. Further, we were interested in digital interfaces that would bring advantages such as precious controlling, cheaper maintenance, avoid refilling, and avoid calories. Therefore, in this workshop we called for studies on flavor sensing and actuation interfaces, new communication mediums, and persisting and retrieving technologies for HFI. Enhancing social interactions to augment the eating experience was another issue we intended addressed in this workshop. In addition, we wanted to discuss what is possible through multimodal technology and what is not possible without it during this workshop. Factors such as measurement techniques (e.g. mastication, eating speed, food tracking, psychophysiological responses to food consumption), potential for interactivity, and potential for customized experiences were taken into consideration. Finally, applications of multisensory approaches to HFI were also encouraged to submit since they can promote healthy eating habits, design of food-related products (e.g. packaging) and more compelling eating experiences.

A number of researchers from multiple disciplines contributed their work from topics such as taste technologies, multisensory flavor perception, sound enhancing food and drink experiences, and multisensory product design. An invited talk was presented by Dr. Takuji Narumi from the University of Tokyo. In addition to the regular paper presentations there was also a presentation by Dr. Harold Bult (NIZO food research, Ede, The Netherlands) and demonstrations by Dr. Kasun Karunanayaka and Dr. Harold Bult.

We are grateful to our PC members who were responsible for reviewing the submitted papers: Professor Charles Spence (University of Oxford), Professor Dirk Heylen (University of Twente), Dr. Merijn Bruijnes (University of Twente), Professor Kees de Graaf (Wageningen UR), Professor Rick Schifferstein (TU Delft), Dr. Andy Woods (University of Oxford), Professor Xiaoang Wan (Tsinghua University), Dr. Nimesha Ranasinghe (National University of Singapore), Dr. Olivia Petit (INSEEC Business School). The wonderful MHFI logo was designed by Simplicio Michael Luis Herrera (M).

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Multi-sensorial Virtual Reality and Augmented Human Food Interaction

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ABSTRACT

In the field of virtual reality (VR) research, media technologies to create a realistic feeling of being present in a real/virtual world by duplicating multi-sensory information have been studied over a long period. Recently, technologies for multi-sensory feedbacks achieved a major breakthrough by utilizing cross-modal interactions. By changing sensory stimuli through only one modality using these technologies, the impression from our experience can be modified significantly. These novel technologies have a great potential in changing our food consumption experience and behavior. For example, "MetaCookie" is a flavor augmentation system that enables us to change the perceived taste of a cookie by overlaying visual and olfactory information onto a real cookie. "Augmented Satiety" is a system that enables us to control the perception of satiety and food intake implicitly by changing the apparent volume of food with augmented reality and computer vision techniques. This paper introduces such novel techniques that augment our eating experience by using multimodal VR techniques and discusses the future of Human Food Interaction.

CCS Concepts

• **Human-centered computing→Virtual reality**

Keywords

Human Food Interaction; Virtual Reality; Augmented Reality; Multi-sensory; Cross-modal effects

1. INTRODUCTION

Our perception of reality is determined by our senses. In other words, our entire experience of reality is simply a combination of sensory information and sense-making mechanisms related to that information in our brain. This implies that if a person's senses are exposed to computer-generated information, their perception of reality would also change in response to it.

Technologies that duplicate multi-sensory information and simulate a realistic experience of being present in a place in the real or virtual world have been studied over a long period. Virtual Reality (VR) and Augmented Reality (AR) are some examples of such technologies. Particularly, AR has recently been the focus of significant growth in numerous fields. VR entails the simulation of our senses with a computer generated virtual environment, which we can explore in some fashion. On the other hand, AR enhances and modifies our perception of reality by presenting computer-generated virtual sensations in a semantic context with real environmental elements. The latest VR/AR offerings deal primarily with visual experiences that are displayed either on the screen of a mobile device or through head-mounted displays. However, they have great potential to change perceptions in applications other than that of vision.

In order to realize multi-sensory feedback, multi-sensory information associated with a place must be simulated. Thereafter, the stimuli associated with each simulation and sensory organ are generated using specialized display systems for each measured modality. This simulation and feedback via multi-modal display is normally performed separately for each modality. This modularity leads to the design of complex multi-modal systems.

Traditionally, perception has been regarded as a modular function. It has long been thought that the different sensory modalities operate independently of each other. This is because multi-modal systems deal with each modality separately. However, recent behavioral and brain imaging studies suggest that cross-modal interactions play an important role in our perception [1]. Cross-modal interactions are a type of perceptual illusion. In cross-modal interactions, the perception of a sensation through one sense is changed by stimuli received through other senses simultaneously. For example, the ventriloquist effect involves an illusory experience about the location of a sound that is produced by the sound's apparent visible source. The effect is neither inferential nor cognitive; instead, it results from cross-modal perceptual interactions. However, cross-modal interactions are not limited to the impact of vision upon the experience perceived through other sense modalities.

By utilizing this illusionary effect, we might be able to provide people with a multi-modal experience with a combination of limited sensory feedbacks. In this context, since VR/AR changes our perception by providing sensory information in a semantic context, these technologies can be used to induce cross-modal effects.

Eating is a perceptual experience that involves the integration of various sensations including vision, hearing, olfaction, and trigeminal sensations. Different flavors and palatability are experienced by different people when consuming the same food or even by the same person at different times. Moreover, flavor and palatability perception are based not only a food's ingredients,

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but also on various factors such as physiological states, eating environment, understanding of the food, and previous experiences related to food [2-5]. By eliciting such effects using media technologies, we can realize novel “Human Food Interaction” techniques that induce people to experience different flavors and palatability without altering the food itself. In this paper, I introduce a novel multi-sensorial VR/AR system, which is capable of changing user perception related to eating experiences.

2. VIRTUAL FLAVORS WITH AUGMENTED HUMAN FOOD INTERACTION

Humans receive gustatory inputs through sensory organs called taste buds, which are concentrated on the top surface of the tongue. Taste is physiologically defined as a minor sensory modality, comprising a limited number of sensations: sweetness, sourness, bitterness, saltiness, and umami. Thus, a taste can be duplicated if the basic constituent taste components are combined in the quantities measured. Using this as the underlying concept, Maynes-Aminzade [6] proposed the idea of "edible user interfaces" and developed several low-resolution gustatory simulations. More recently, a number of researchers have tried to make a “Food Printer” that can “print” food by combining basic taste components [7]. However, synthesizing a specific taste on demand by combining basic tastes is difficult because the sense of taste is a multi-modal sensation and is not determined solely by a combination of the basic tastes.

The term "taste" signifies a perceptual experience that involves the integration of various sensations. When we use the common word "flavor" in place of taste, we refer to what is a very multi-faceted sensation. Auvray et al. reviewed the literature on multisensory interactions underlying the perception of flavor. They concluded that flavor is not defined as a separate sensory modality but as a perceptual modality that is unified by the act of eating, and it should be used to describe the combination of taste, scent, touch, visual cues, auditory cues, and the trigeminal system [8]. These definitions suggest that the flavor experience can be modified by changing the stimuli received through modalities other than the sense of taste.

Based on this knowledge, some flavor simulation systems have been developed. Iwata et al. developed the "Food Simulator" [9] using an interface that integrates and simulates biting force, auditory information, and chemical sensation of taste. In this, the chemical sensation of taste is evoked by the release of prepared taste components using a micro injector. Even though this study did not focus on the various tastes synthesized by using this system, it revealed that texture has an important role in identifying food. Another example is Hashimoto’s “straw-like user interface,” which allows users to experience the sensations of drinking by representing data in terms of actual pressures, vibrations, and sounds produced when drinking through an ordinary straw [10]. The experimental results indicate that users can experience the sensation of drinking, even though they are not consuming any liquid. “Chewing Jockey” [11] uses the cross-modal effect between sound and haptics to change the perceived food texture. It measures bites using a photo reflector and presents a filtered and designed sound effect through a bone-conduction speaker. This auditory feedback evokes the cross-modal effect that changes the perception of food texture without any complex mechanical structures to represent the biting forces.

Under most conditions, humans have a tendency to rely on vision more than the other senses. Several studies have explored the effect of visual stimuli on our perception of flavor. However, according to Spence et al., the empirical evidence regarding the role that food coloring plays in the perception of the intensity of a particular flavor or taste to which it is attributed is rather ambiguous, although food coloring certainly influences how people identify flavor [12].

Figure 1. MetaCookie+: Flavor display based on cross-modal interaction among vision, olfaction, and gustation.

Nevertheless, their survey results suggest that it is possible to change the flavors perceived by changing the appearance of the food. Many studies support the claim that the identification of flavor is influenced by the color of the food. For example, DuBose et al. showed that people attempt to identify the flavors of a variety of fruit-flavored drinks using their different colors, to the extent that some participants misidentified the flavor of the drinks when the color was inappropriate (e.g., when an orange-flavored drink was colored purple) [13]. Narumi et al. designed a pseudo-gustatory simulation that allows users to feel various tastes without changing its chemical composition by superimposing virtual color onto a drink [14]. In this system, they used light-emitting diodes (LEDs) to change the color of the drink interactively. They showed that our perception of the intensity of fundamental tastes is not changed by the variation in the appearance, but that the identification of the flavor is changed when the color of the drink is changed, whether using LEDs or using dyes.

Among the other senses, the sense of smell is most closely related to our perception of taste. This relationship between gustatory and olfactory sensations is commonly known and is illustrated by the fact that we pinch our nostrils when eating food that we find displeasing. One method that utilizes this effect is “Meta Cookie+” (Fig. 1), proposed by Narumi et al. [15]. It is an AR system that changes the flavor of a real cookie by overlaying visual and olfactory information onto it. The results of a user study they conducted indicated that the system can change the perceived taste, with over 70% of their participants associating various flavors with a plain cookie. This was achieved by simply changing of visual and olfactory information without changes to the chemical ingredients of the cookie.

Although these pseudo-gustatory simulations allow us to experience various flavors by changing only the visual and olfactory stimuli, conventional simulations require one olfactory stimulus for each flavor, which imposes a limit on the number of flavors that can be stimulated. A method to simplify the olfactory simulations for the pseudo-gustatory simulation based on the work by Nambu et al. [16] was also proposed by Narumi et al. In their simulation, they built a map of perceived similarities among scents and selected a few aromatic chemicals as the set of key aromatic chemicals based on the clustering of scents. In the experimental evaluation, various pictures and select key aromatic chemicals were presented to subjects who were then asked to identify the scent. The results demonstrate that the participants experienced a greater number of scents than the actual number of selected key aromatic chemicals because of the effects of visual stimulation. Although they used only four key aromatic chemicals, the participants identified 13 kinds of scents on an average. Based on this knowledge, Narumi et al. proposed visual-olfactory simulation method which can present more patterns of scents than the actual number of key scent components because of the visual-olfactory cross-modal effect and similarity-based replacement of scent, and proved its effectiveness [17].

Some other technologies try to change the flavor and palatability perception by changing a person's physiological state. People regard food as being more appetizing when they are hungry. Similarly, people regard drinks as being more appealing when they are hot and perspiring. It is believed that the body makes demands to avoid shortages and unhealthy or dangerous conditions by providing cues to eat and drink. In particular, our body changes our flavor perception in order to return the physiological state to a proper condition. When people consume food, their physiological state changes. For example, a solution including fat, sugar, and *umami* is believed to stimulate the secretion of pleasure-producing chemical substances [18]. When people experience this, pleasurable feelings are evoked directly and people exhibit stronger perceptions of food palatability.

Physiological change is not only a matter of nerve system communication. Recent physiological research has demonstrated that there are some specific bodily reactions associated with flavor perception. A representative example is the temperature change of the skin around the nose. Asano et al. demonstrated the possibility of quantitative evaluations of flavor and palatability based on measured changes in nasal skin temperature because these can be considered as types of pleasant or unpleasant feelings experienced during eating [19].

In the field of cognitive science, numerous researchers argue that changes in physical and physiological responses can unconsciously evoke an emotion. W. James aptly expressed this phenomenon, stating "We don't laugh because we're happy—we're happy because we laugh" (James-Lange Theory [20]). Many works based on the James–Lange theory demonstrate that changes in physiological states affect feelings. For example, Yoshida et al. constructed a system that manipulates an emotional state via visual feedback from artificial facial expressions [21]. By using this system, they arrived at the conclusion that not only our emotions but also preference assessments can be affected by the system.

Based on this knowledge, Suzuki et al. developed an "Affecting Tumbler," which induces thermal sensations on the skin around the nose to simulate the skin's temperature response during drinking [22]. Their user study suggested that flavor richness and aftertaste strength were significantly improved by heating up the skin around the nasal region.

Some researchers have also tried to display/change the taste by changing the physiological state with electric stimulation. For example, Nakamura et al. proposed a method to change the perceived taste of foods and drinks by using the electric taste evoked by electrically stimulating the tongue [23]. Ranasinghe et al. digitally simulated multiple taste sensations using electrical and thermal stimulations on the tongue [24]. Sakurai et al. demonstrated the inhibition of sweet, salt, and umami perception by applying cathodal current electrical stimulation to the tongue. By focusing on the electrophoresis of ions generated by the dissolution of taste-inducing substances in water, they demonstrated how human gustation is inhibited by electrical stimulation. This is a key addition to the knowledge base for achieving control of the five basic tastes. These kinds of emerging technologies may become a key component in simulating taste in a future virtual environment.

3. PLEASURE AND SATISFACTION IN HUMAN FOOD INTERACTION

The purpose of eating is not limited to the intake of energy. Pleasure and satisfaction are also important factors that motivate human consumption. Consequently, many researchers have studied the enhancement of pleasure and satisfaction in eating by augmenting Human Food Interaction.

Contemporary humans enjoy gourmet food. Humans have improved culinary techniques and the food production system in pursuit of delicious food. On the other hand, obesity has become a serious public health issue worldwide, with one of the major causes being overeating. Consequently, systems that make diners aware of the amount of food being consumed have been developed. However, adequately sustaining a highly conscious effort to control the amount of food consumed is difficult because eating a meal is a daily activity and is often pleasurable.

To decrease rates of obesity, many researchers have developed systems to change our eating behavior. Mankoff et al. developed a system that analyzes individuals' food purchases at grocery stores and suggests a method for users to make healthier selections from logs of receipts [25]. Noronha et al. developed a crowdsourcing nutritional analysis system that estimates users' food intake (and the types of food eaten) in order to change their eating habits [26]. One limitation of these methods is that they are based on conscious education. This requires continuous effort on the part of the consumer to change their eating habits. Sustaining highly conscious effort when performing an intended behavior can be difficult.

On the other hand, humans cannot accurately assess the volume or nutrition value of the food they consume. Therefore, humans estimate their fullness by using indirect cues such as distension in the stomach and bowels, elevated blood-glucose levels, and apparent amount of food. This estimation is inaccurate because some types of cues are evaluated relative to an individual's surroundings. Recent studies in psychology and economics have revealed that the amount of food consumed at a given time is influenced by characteristics of the food itself as well as environmental factors during eating. These include plate size, package size, type of food, lighting, and social company [27-30]. These indicate that the satisfaction of eating can be modified by changing these environmental factors using VR/AR.

Narumi et al. utilized this finding in their "Augmented Satiety" system, which controls nutritional intake by changing the apparent size of food (Fig. 3) [31] or volume of a cup of liquid [32]. This system uses a method for food-volume augmentation using shape deformation processing in real-time [33] to simulate the cross-modal effects between vision and the perception of satiety. Their user study showed that the system could change the consumption volume of a food item by changing only its apparent size with augmented reality. This suggests that the technology will enable us to control the perception of satiety and nutritional intake while providing the satisfaction of eating. Moreover, Sakurai et al. constructed a tabletop system called “CalibraTable” that projects virtual dishes around a food platter in order to change the perceived food volume interactively [34, 35] (Fig. 4). This system also increases/ decreases the amount of food intake unconsciously without compromising on the perceived palatability and satisfaction of the food. The size of the virtual dish can be variedto control the amount and types of food consumed, thereby appropriately balancing the nutritional intake. This enables us to use the system with any kind of solid food. It also eliminates the need to use a wearable device. Interactive projection techniques at a table can also be used for making meals appetizing or for facilitating communication.

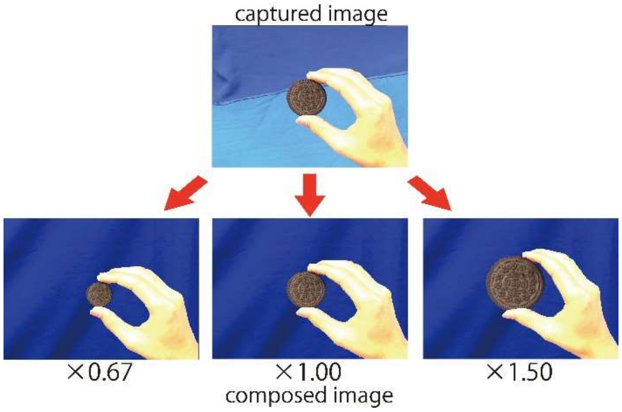

Figure 3. Augmented Satiety: An AR system to control our food consumption by changing the visual size of food.

Meal satisfaction is influenced not only by the food itself, but also by external factors such as the location of restaurants, public reputations, and so on. Particularly, social influence is an important factor in determining the pleasure and satisfaction of eating. The term "food porn" refers to images of food across various social media platforms such as television, cooking magazines, online blogs, and websites [36]. People share food porn to derive satisfaction by demonstrating conspicuous consumption.

This type of behavior changes our satisfaction and eating behavior since the satisfaction derived from a meal is influenced not only by taste but also by external information. In behavioral science, findings on Expectation Assimilation (EA) have revealed that the imagined palatability of a meal changes one’s perception of the actual meal. Wansink described EA as the unconscious expectation about how satisfactory or appetizing a meal will be, which affects how appetizing it is [37]. He noted that something that was anticipated to be delicious was perceived as being more delicious than was something that was not anticipated to be delicious.

Takeuchi et al. proposed a social media system, Yumlog (Fig. 3), for improving eating habits without conscious effort using EA [38]. They focused on others’ evaluations on social media as a trigger of EA. Social media has become increasingly popular in recent years, and many users share their meals with others virtually. Good evaluations by others please a user and the user’s satisfaction with the meal increases. In addition, others’ evaluations are versatile as they can be added to all meals uniformly. An interesting feature of Yumlog is the secret replacement of a “Looks healthy” evaluation with a “Looks yummy” one. For example, if others evaluate a shared meal as having a score of +1 yumminess and +3 healthiness, an evaluation of +3 yumminess is delivered to a person who eats the meal. This manipulation enables the user to experience greater satisfaction with healthy meals. The researchers confirmed the efficacy of their proposal through a controlled user study as well as a real-world user study by releasing their system on a smartphone application store. They also revealed that a feedback method corresponding to individual taste for meals further improves users’ eating habits [39].

4. CONCLUSION

Our perceptual experience involves the integration of various sensations including vision, hearing, haptics, olfaction, gustation, and other sensations. Moreover, external information such as the reputation of the food also changes our perception of the eating experience. The studies discussed here indicate that Human Food Interaction techniques that modify not only the taste/flavor but also external information related to food have a potential to augment our eating experience. Hence, I believe that Human Computer Interaction studies should be considered in Human Food Interaction research along with cognitive science, phycology, and economics. While research on Human Food Interaction in HCI is currently in its infancy and has its limitations, I believe that these technologies can enhance the well-being of humans. For example, augmented Human Food Interaction techniques will help individuals control their food consumption more effortlessly without losing the pleasure of eating and have significant effects in promoting nutritional health. I hope that Human Food Interaction research brings about a new interest in multi-sensory systems and VR/AR technologies and contributes to the promotion of human happiness.

5. REFERENCES

[1] S. Shimojo S and L. Shams: Sensory modalities are not separate modalities: plasticity and interactions, Current Opinion in Neurobiology 2001 Aug;11(4):505-9, 2001.

[2] B. Wansink, K.V. Ittersum and J.E. Painter: How descriptive food names bias sensory perceptions in restaurants. *Food Quality and Preference*, Vol.16, No.5, pp.393-400, 2005.

[3] R.I. Allison and K.P. Uhl: Influence of beer brand identification on taste perception. *Journal of Marketing Research*, pp.36–39, 1964.

[4] P. Rozin: Family resemblance in food and other domains: the family paradox and the role of parental congruence. *Appetite*, Vol. 16, No. 2, pp. 93-102, 1991.

[5] Y. Matsushita, M. Ohta, M Sato, N. Mishima, S. Sasaki, A. Nanri, Y Kimura and T. Mizoue: Dietary patterns and depressive symptoms among Japanese men and women. *European Journal of Clinical Nutrition,* 64(8), pp.832-839, 2010.

[6] D. Maynes-Aminzade: Edible Bits: Seamless Interfaces between People, Data and Food, ACM CHI 2005 Extended Abstracts, pp.2207-2210, 2005.

[7] A. Zoran and M. Coelho: Cornucopia: The Concept of Digital Gastronomy, in Leonardo: Journal of the International Society for the Arts, Sciences and Technology, Volume 44, Number 5, pp. 425-431, 2011.

[8] M. Auvray and C. Spence: The multisensory perception of flavor, Consciousness and Cognition. 17(2008), pp. 1016-1031, 2008.

[9] H. Iwata, H. Yano, T. Uemura and T. Moriya: "Food Simulator: A Haptic Interface for Biting", Proceedings of IEEE Virtual Reality 2004, pp.51-57, 2004.

[10] Y. Hashimoto, M. Inami and H. Kajimoto: Straw-like User Interface (II): a new method of presenting auditory sensations for a more natural experience, Euro Haptics 2008, pp.484-493, 2008.

[11] N. Koizumi, H. Tanaka, Y. Uema, and M. Inami: Chewing jockey: augmented food texture by using sound based on the cross-modal effect, In Proc. of the 8th International Conference on Advances in Computer Entertainment Technology (ACE '11), 21:1-4, 2011.

[12] C. Spence, C.A. Levitan, M.U. Shankar, and M. Zampini. Does food color influence taste and flavor perception in humans? Chemosensory Perception, Vol. 3, No. 1, pp. 68-84, 2010.

[13] C.N. DuBose, A.V. Cardello, O. Maller: Effects of Colorants And Flavorants on Identification, Perceived Flavor Intensity, And Hedonic Quality of Fruit-Flavored Beverages and Cake, Journal of Food Science, Volume 45, Issue 5, pp. 1393-1399, 1980.

[14] T. Narumi, M. Sato, T. Tanikawa and M. Hirose: Evaluating Cross-Sensory Perception of Superimposing Virtual Color onto Real Drink: Toward Realization of Pseudo-Gustatory Displays, ACM the 1st Augmented Human International Conference, 18:1-6, 2010.

[15] T. Narumi, T. Kajinami, S. Nishizaka, T. Tanikawa and M. Hirose: Pseudo-gustatory display system based on cross-modal integration of vision, olfaction and gustation,In Proc. of IEEE Virtual Reality Conference (VR) 2011, pp.127-130, 2011.

[16] A. Nambu, T. Narumi, K. Nishimura, T. Tanikawa, and M. Hirose: Visual-olfactory display using olfactory sensory map. In Proc. of IEEE Virtual Reality 2010, pp. 39-42, 2010.

[17] T. Narumi, M. Miyaura, T. Tanikawa, and M. Hirose: Simplification of olfactory stimuli in pseudo-gustatory displays. IEEE transactions on visualization and computer graphics, 20(4), pp. 504-512, 2014.

[18] M. Imaizumi, M. Takeda, S.Sawano and T. Fushiki: Opioidergic contribution to conditioned place preference induced by corn oil in mice. Behavioural brain research, Vol.121, No.1, pp.129-136, 2001.

[19] H. Asano, T. Mizuno, A. Nozawa and H. Ide: Comparison with Amount of Gustatory Sense and Nasal Skin Temperature. Journal of Robotics and Mechatronics 21.1, pp.81, 2009.

[20] W. James: The principles of psychology, New York, Dover Publications, Vol.2, 1950.

[21] S. Yoshida, S. Sakurai, T. Narumi, T. Tanikawa and M. Hirose: Manipulation of an Emotional Experience by Real-time Deformed Facial Feedback, Augmented Human 2013, pp.35-42, Mar. 2013.

[22] C. Suzuki, T. Narumi, T. Tanikawa, and M. Hirose: Affecting tumbler: affecting our flavor perception with thermal feedback. In Proceedings of the 11th Conference on Advances in Computer Entertainment Technology, 19, 2014.

[23] H. Nakamura, and H. Miyashita: Augmented gustation using electricity. In *Proceedings of the 2nd Augmented Human International Conference*, p. 34, 2011.

[24] N. Ranasinghe, K. Karunanayaka, A.D. Cheok, O.N.N. Fernando, H. Nii, and P. Gopalakrishnakone: Digital taste and smell communication. In *Proceedings of the 6th International Conference on Body Area Networks*, pp. 78-84, 2011.

[25] S. Sakurai, K. Aoyama, N. Miyamoto, M. Mizukami, M. Furukawa, T. Maeda, and H. Ando: Mechanism of inhibitory effect of cathodal current tongue stimulation on five basic tastes. In *Virtual Reality (VR), 2016 IEEE*, pp. 279-280, 2016.

[26] J. Mankoff, G. Hsieh, HC. Hung, S. Lee and E. Nitao: Using Low-Cost Sensing to Support Nutritional Awareness. In Proceedings of Ubicomp 2002, pp. 371-378, 2002.

[27] J. Noronha, E. Hysen, H. Zhang and KZ. Gajos: Platemate: crowdsourcing nutritional analysis from food photographs. In Proceedings of the 24th annual ACM symposium on User interface software and technology (UIST '11), pp. 1-12, 2011.

[28] B. Lyman: A Psychology of Food. More Than a Matter of Taste. Van Nostrand-Reinhold, 1989.

[29] R. Bell and PL. Pliner: Time to eat: the relationship between the number of people eating and meal duration in three lunch settings. Appetite 41:215-218, 2003.

[30] BJ. Rolls, EL. Morris and LS. Roe: Portion size of food affects energy intake in normal-weight and overweight men and women, American Journal of Clinical Nutrition, Vol. 76, No. 6, pp.1207-1213, December 2002

[31] BJ. Rolls, LS. Roe, TVE. Kral, JS, Meengs and DE. Wall: Increasing the portion size of a packaged snack increases energy intake in men and women, Appetite, Vol. 42 Issue 1, pp. 63-69, 2004.

[32] E. Suzui, T. Narumi, S. Ssakurai, T. Tanikawa, and M. Hirose: Illusion Cup: Interactive Controlling of Beverage Consumption Based on an Illusion of Volume Perception, Augmented Human 2014, Article.41:8, Mar. 2014.

[33] Y. Ban, T. Narumi, T. Tanikawa, M. Hirose: Modifying perceived size of a handled object through hand image deformation. Presence: Teleoperators and Virtual Environments, 22(3), 255-270, 2013.

[34] S. Sakurai, T. Narumi, Y. Ban, T. Tanikawa, M. Hirose: CalibraTable: tabletop system for influencing eating behavior. In SIGGRAPH Asia 2015 Emerging Technologies, 4, 2015.

[35] S. Sakurai, T. Narumi, Y. Ban, T. Tanikawa, M. Hirose: Affecting our perception of satiety by changing the size of virtual dishes displayed with a tabletop display. In International Conference on Virtual, Augmented and Mixed Reality, pp. 90-99, 2013.

[36] Y. Mejova, H. Haddadi, A. Noulas, and I. Weber: # FoodPorn: Obesity patterns in culinary interactions. In *Proceedings of the 5th International Conference on Digital Health 2015*, pp. 51-58, 2015.

[37] B. Wansink, Mindless eating: Why we eat more than we think, Bantam, 2007.

[38] T. Takeuchi, T. Fujii, K. Ogawa, T. Narumi, T. Tanikawa, and M. Hirose, “Using Social Media to Change Eating

Habits Without Conscious Effort," in Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication, 2014, pp. 527-535.

[39] T. Takeuchi, T. Fujii, T. Narumi, T. Tanikawa, and M. Hirose: Considering individual taste in social feedback to improve eating habits. In 2015 IEEE International Conference on Multimedia & Expo Workshops (ICMEW) , pp. 1-6, 2015.

Saltiness and *Umami* Suppression by Cathodal Electrical Stimulation

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ABSTRACT

In this work, we demonstrate that cathodal direct current stimulation to the tongue suppresses the perception of saltiness and *umami*. This work also investigates the relationship between the amplitude of the stimulation current and the magnitude of the taste suppression. With this technique and extensions to it, any tastes would be able to be reproduced or modified virtually, which would be helpful to reduce excessive intake of substances causing lifestyle disease.

CCS Concepts

・Applied computing → Health care information systems ・ Hardware → Bio-embedded electronics ・Human-centered computing → Virtual reality

Keywords

Taste; electric stimulation; taste suppression

1. INTRODUCTION

Excessive intake of salt causes lifestyle diseases like hypertension. In order to address such diseases, suppression of salt intake by modified dietary habits is required. However, tasteless salt-free diet does not provide enough gastronomic satisfaction, which is a great obstacle to maintain the salt intake suppression. If tastes for the restricted diet can be modified, it would support sustaining the restrictions.

Especially from the view point of the treatment of hypertension, excessive intake of salt is blamed mainly because it causes over-intake of sodium ion[1]. This means that monosodium glutamate, the origin of *umami* taste, is also responsible for the disease. Therefore, there is a big interest to modify the strength of both saltiness and *umami* arbitrary.

For the modification of saltiness, previous works introduced several methods to virtually suppress or present the taste using electrical stimulation[2,3]. Hettinger et al. (2009) reported that cathodal current stimulation to the tongue can suppress the perception of saltiness caused by sodium chloride[4]. Nakamura et al. (2013) showed that the perceived strength of the taste of a sample increases after stopping the cathodal current stimulation for taste suppression[5]. They also insisted that the enhancement effect is a counter effect of the taste suppression effect caused by the electrical stimulation[6]. Thus, any material which would be affected by electrical taste suppression are highly assumed that the taste of them can be enhanced by an electrical stimulation, even though the previous work by Nakamura focused only on saltiness.

Previous studies show that humans perceive saltiness by direct entry of Na^+ through the specialized membrane channel on the apical surface of the taste-cell. On the other hand, umami is presented by L-amino acid and it is accepted by T1R1 and T1R3 GPCRs (G protein coupled receptors) – the umami receptors[7]. GPCR can be divided into T1R family and T2R family. T1R family has larger extracellular region. T1R family also can be divided into T1R1, T1R2 and T1R3.

Based on the above, the mechanism of the taste modification by electrical stimulation can be described with the electrophoresis hypothesis[4]. This hypothesis describes the mechanism as

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follows: Ionized materials, which trigger taste receptors, move away from the surface of the tongue by an electrical stimulation, as shown in Fig.1, and the decrease of ions on the tongue results in the taste suppression. This hypothesis implies that the taste of any substances which ionize in a liquid can be suppressed by electrical stimulation to the tongue. Moreover, since, in this hypothesis, the force to move ions is generated by the electric field yielded by the stimulation, the magnitude of the taste suppression should be freely controlled by the amplitude of the stimulation current.

In this work, we demonstrate that the perception of both saltiness and *umami* can be suppressed by cathodal direct current stimulation to the tongue, as the first step to develop a method to enhance those tastes for sodium-ion-free diet. This paper also investigates the relationship between the amplitude of the stimulation current and the magnitude of the taste suppression, in order to demonstrate that the taste suppression effect can be freely controlled by the strength of the stimulation.

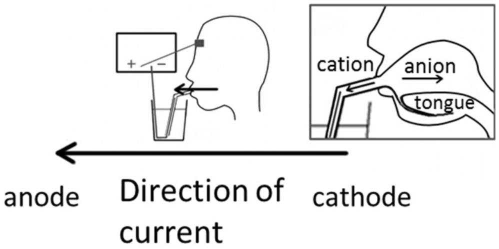

Figure 1. Electrophoresis during cathodal stimulation

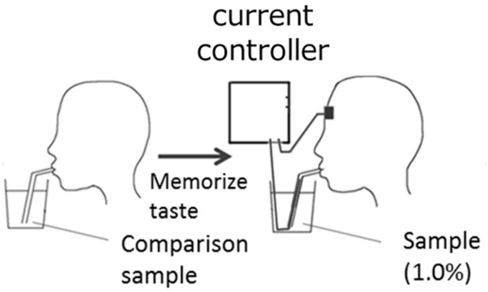

Figure 2. Experimental condition

2. EXPERIMENT

2.1 Apparatus

Our experiment system is shown in Fig.3. Hereby we attached a lead as the cathode on a straw (6 mm diameter and 200 mm length), from which subjects ingested materials into mouth. The anode was attached on the forehead of subjects, using a gel electrode. This configuration is based on the hypothesis, introduced above, that the taste suppression is caused by electrophoresis of ions which wipes substances triggering taste receptors away from the tongue.

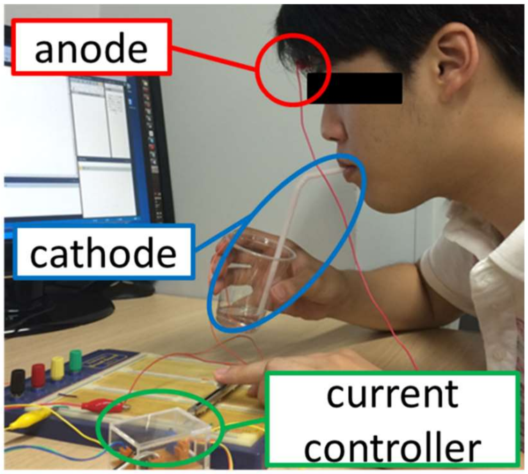
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Figure 3. Experimental condition

2.2 Procedure

Six male adults in their 20s participated in our experiment. Note that two of them tested only one out of the two tested substances due to the schedule. All of the participants consented to join the experiment.

The model of our experiment is shown in Fig.2. Before the experiment, we prepared comparison samples and stimulation samples. Comparison samples were aqueous solution of either sodium chloride (NaCl) for saltiness or monosodium glutamate ($C_5H_8NNaO_4$) for *umami* with density of 0.2, 0.4, 0.6 or 0.8%. Stimulation samples were 1.0 % aqueous solution of either sodium chloride or monosodium glutamate. Subjects then were given one of the comparison samples, which was chosen randomly. After dumping the comparison sample, subjects were told to ingest and hold the stimulation sample in their mouth. Thereafter, the electrical stimulation was applied. After the stimulation started, subjects were instructed to quickly adjust the slide bar, which is the controller of the stimulation current, so that perceived density of the stimulation sample equaled to that of the comparison sample.

For each stimulation sample, there were four conditions of the comparison samples and each condition was examined six times: Namely, each subject had 24 trials for each stimulation sample. Subjects rinsed their mouths between trials using purified water. In order to ensure that the taste comparison within each trial was unaffected, they were not allowed to rinse their mouths during a trial. Subjects were instructed to keep 1 – 2 cm of their tongue tip dipped into the ingested solution and not to choke the end of the straw during the stimulation. Subjects were also told not to move their tongues during trials. The temperature of the samples was 25 ± 3 ℃.

3. RESULTS

Table. 1 shows average measured amperage for each comparison sample. Values in parentheses are the standard deviations.

Fig.4 and Fig.5 show average normalized amperage for sodium chloride and monosodium glutamate, respectively. The horizontal axis represents the density of the tested comparison sample and the vertical axis represents normalized amperage. Namely, the graphs show required stimulation amperage to yield the taste equivalent to the respective 1.0-% solution. Error bars show standard deviations. Asterisks (∗) on Fig.4 and Fig.5 indicate respective significant differences calculated by ANOVA ($p<0.05$). Note that the normalized amperage I_{norm} is calculated with Equation 1 for each subject, where I_{max} is the average measured amperage of the condition which records the highest amperage throughout the conditions.

$$I_{norm} = \frac{I_{obs}}{I_{max}} \qquad (1)$$

The plots with blank circles (○) represent the assumed amperage for the conditions where the comparison sample and the stimulation sample had the same density of 1.0 %, i.e. 0.

		Density of comparison sample (%)			
		0.2	0.4	0.6	0.8
taste	saltiness	667.9 (309.9)	526.3 (272.6)	318.2 (163.0)	180.2 (130.6)
	umami	563.7 (305.9)	371.0 (197.9)	289.8 (152.7)	276.2 (125.8)

Table 1. I_{obs} value for the concentration and taste quality

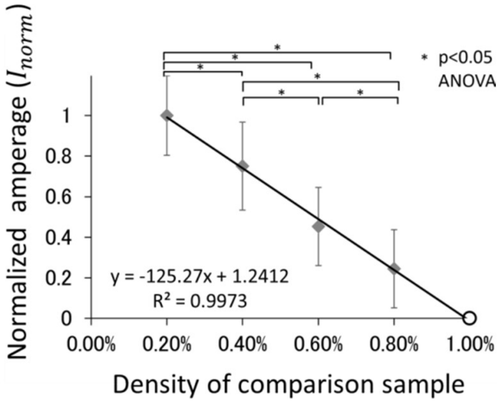

Figure 4. Correlation between the normalized magnitude of current and the perceived intensity of saltiness

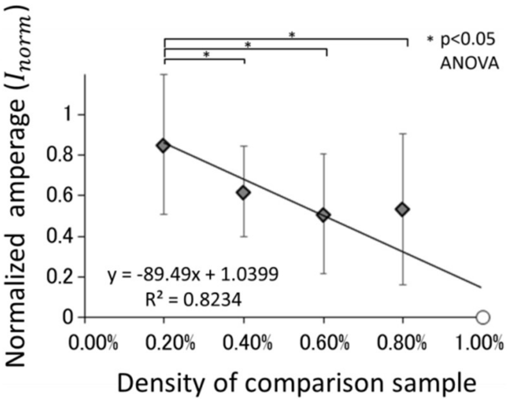

Figure 5. Correlation between the normalized magnitude of current and the perceived intensity of umami

4. DISCUSSIONS

The results clearly indicate that the perception of both saltiness and *umami* can be suppressed by cathodal electrical stimulation to the tongue. We also calculated linear approximation with the method of least squares, which is shown in Fig.4 and Fig.5. The coefficients of determination were 0.997 (saltiness) and 0.823 (*umami*). These high coefficients indicate that there is a linear relation between the amplitude of the stimulation current and the magnitude of the taste suppression of saltiness or *umami*. These results are another good evidence that the "electrophoresis hypothesis" discussed above is valid.

The data points in Fig.5 suggest non-linear relation between the amplitude of the stimulation current and the magnitude of the taste suppression. We calculated cubic curve approximation for Fig. 5 and got a high coefficient of determination (0.982). However, it must be an apparent result as there are only 4 points and the number is not enough for appropriate cubic curve approximation. We need further experiments and increase the number of data for the explanation.

As saltiness and *umami* have been revealed that perception of them can be suppressed with electrical stimulation, now we have our interest in enhancement of those taste qualities. If taste enhancement indeed occurs as a counter effect of the taste suppression, it is highly expected that *umami* can be enhanced with electrical stimulation, which helps sustaining sodium-ion-free diet.

The taste enhancement as a counter effect is considered to be caused as a result of adaptation to the taste suppression stimulation. Therefore, the magnitude of the taste enhancement effect should correlate to the magnitude of the taste suppression effect. The investigation on the relationship between those two magnitudes will be one of our future works.

The results show that the magnitude of the taste suppression caused by stimulation with a specific amperage depends on the substance used along with the electrical stimulation. Therefore, it would be possible to manipulate relative strength of a particular taste quality against each other quality. Once techniques to manipulate strength of other basic taste qualities, i.e. sweetness, sourness and bitterness and a technique to control these strengths independently and concurrently, it would be possible to virtually reproduce an arbitrary taste using "standard material" which contains triggers for each type of taste receptor. Development of these techniques will be our another future work.

5. CONCLUTION

In this work, we demonstrated that perception of both saltiness and *umami* can be suppressed by electrical stimulation. It also revealed that there is a linear relation between the amplitude of the stimulation current and the magnitude of the taste suppression. These findings lead development of techniques to enhance those quality of taste and techniques to manipulate strength of any qualities of taste, which can be used to enrich taste of restricted diet.

6. ACKNOWLEDGMENTS

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REFERENCES

[1] Tatsuo, S., Mu, S., Toshiro, F. 2012. High Salt Intake and Hypertension. *Japan Society for Bioscience, Biotechnology, and Agrochemistry*. 50. 4, 250-254.

[2] Satoru, S., Kazuma, A., Masahiro, F., Hideyuki, A. and Taro, M. 2014. The Effect of Electric and Thermal Stimulation to the Tongue about Five Basic Tastes. In *Proceedings of the Virtual Reality Society of Japan. Annual Conference 19*(September. 2014), 94-97.

[3] Nimesha, R., Adrian, C., Ryohei, N. and Ellen, Y.D. 2013. Simulating the sensation of taste for immersive experiences. In *ImmersiveMe'13 Proceedings of the 2013 ACM international workshop on Immersive media experiences*, 29-34.

[4] Thomas, P. H. and Marion, E. F. 2009. Salt taste inhibition by cathodal current. BRAIN RES BULL, 80, 3, 28 (September. 2009), 107-115.

[5] Hiromi, N. and Homei, M. 2013. Proposition of Single-pole Electric Taste Apparatuses for Drink and Food and Evaluation of Changing Taste Quality of Polarity Change. In Information Processing Society of Japan. 54. 4 (April. 2013), 1442-1449.

[6] Hiromi, N. and Homei, M. 2013. Salinity Control by Applying and Stopping Cathodic Stimulus to Food and Drink. Information Processing Society of Japan. 2013-Interaction (13INT014), 103-110.

[7] Chandrashekar, J., Hoon, M. A., Ryba, N. J. and Zuker, C. S. 2006. The receptors and cells for mammalian taste. Nature. 444, 7117, (November. 2006), 288-294.

Visual Search for Triangles in Wine Labels

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ABSTRACT

Visual search for a downward-pointing triangle among upward-pointing triangles is faster than vice versa, a phenomenon referred to as the downward-pointing triangle superiority (DPTS) effect. Here, we report two new experiments designed to investigate whether this phenomenon also emerges when a triangle appears as a local feature within a wine label. The experimental task was to identify whether all of the wine bottles in a store display were the same or not, while each wine bottle had either a downward- or upward-pointing triangle displayed on its label. The results of Experiment 1 revealed that the participants responded more rapidly when searching for a wine bottle with a downward-pointing triangle on its label than when the target had a triangle pointing upward, indicating the presence of a DPTS effect. In Experiment 2, the DPTS effect was replicated while varying the set size. The magnitude of the DPTS effect increased with increasing set size. Taken together, these results revealed similar visual search results for pictorial stimuli with triangles as local features as for geometric triangular shapes. The implications of these findings for the design of product labels are discussed.

CCS Concepts

- **Applied computing~Psychology**

Keywords

visual search; set size effect; wine label

1. INTRODUCTION

Larson and colleagues [2007] reported that searching for a target consisting of a downward-pointing triangle was faster than searching for an upward-pointing triangle or a circle, an effect they referred to as the downward-pointing triangle superiority (DPTS) effect. According to the "Shape of Threat" account, this phenomenon can be attributed to the possibility that downward-pointing triangles might be perceived as conveying threat-related information and therefore capture attention more readily than do neutral stimuli [Larson et al. 2007, 2012; Watson et al. 2012]. One of the reasons for this might be that a downward-pointing triangle resembles an angry face in which the muscles are pulling down to form the ''V'' shape [Larson et al. 2012; Toet and Tak 2013] and therefore perceived as negative [Lundqvist et al. 1999]. It has been suggested that the rapid detection of such potentially threatening stimuli is vital to survival and has its evolutionary advantage. Nevertheless, this account cannot easily interpret the comparable DPTS effect observed recently by Shen et al. [2015] with images of triangular-shaped foods and pizza packaging which were presumably entirely non-threatening. Alternatively then, the DPTS effect documented with desirable food images and product packaging might be better attributed to the special perceptual features of downward-pointing triangles, e.g., their lack of stability and people's expectations of the consequences of that perceived instability.

Even though previous research has revealed the DPTS effect when the stimuli were in the triangular form, it remains unclear whether the DPTS effect also emerges when a triangle is only used as a local feature within pictorial stimuli. To answer this question, two experiments were conducted in which downward- or upward-pointing triangles were shown as local features of the wine labels. Specifically, we first examined whether the DPTS effect would emerge in Experiment 1; and then, in Experiment 2, we examined the set size effect by varying the number of items of each display to investigate whether the orientation of the triangles influences the search efficiency. Wine labels were chosen as the experimental stimuli for three reasons: First, the wine labels (attached to the bottles) are typically presented vertically in real life, so the triangles presented on them actually do point downward or upward. Second, searching for a specific wine amongst all the many other, ever-changing wines in the wine aisle is especially difficult/challenging as compared to other categories of product search. Third, the downward-pointing triangular shape is actually used in wine labels [see also Shen et al. 2015]. Hence, the potential benefit of an especially attention-capturing figure on the label (such as a downward-pointing triangle) might be particularly advantageous in the wine aisle, as compared to the others in the supermarket.

2. EXPERIMENT 1

2.1 Method

2.1.1 Participants

Twenty Chinese participants (24.0±1.7 years on average, ranging from 20 to 28 years; 10 female) took part in this experiment in exchange for 25 CNY. All of the participants reported having normal or correct-to-normal visual acuity, and no color blindness.

2.1.2 Apparatus and Stimuli

The experiment was run on Pentium-based computers, and the stimuli were presented on 16-inch monitors set to a resolution of 1024×768 pixels and a refresh rate of 60 Hz. MATLAB 2009b

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and PsychToolbox 2.54 were used to control the experimental process and collect the data. The participants viewed the display at a distance of approximately 50 cm, and responded by pressing a key on the keyboard.

As shown in Figure 1, each experimental display consisted of four grayish white shelves (against a white background) and 16 bottles of liquid on it. Each bottle had a downward- or upward-pointing triangle (in black) on its white label. The images were edited via Adobe Photoshop; whereas the scene images were edited via Maya 2009 to simulate the light and shadows that are present in natural scenes. The bottles were in clear glass to show the colour of the liquid (approximately crimson, beige, or brown), implying that the liquid inside the bottles might be red wine, white wine, or whisky, respectively. The colour of the liquid in bottles remained the same within each trial and within each block, but varied between blocks.

In each display (subtending 20.51° horizontally and 20.01° vertically on the screen), bottles (each subtending 1.02° horizontally and 4.11° vertically) on the same shelf were 5.23° from each other, while a bottle on one shelf was 1.20° apart from another one on the adjacent shelf. All of the bottles in each display presented the same wine, though different displays could be classified into oddball-absent in which all the bottles had the same label (i.e., all the triangles pointed downward or upward), and oddball-present displays in which one of the bottles had a different label from the others (i.e., one had a downward-pointing triangle on its label among others having upward-pointing ones, or vice versa).

Figure 1. An Illustration of the Two Types of Oddball-Present Displays used in Experiment 1.

2.1.3 Procedure

The task was to identify whether all of the bottles were the same or not. After finishing a practice block of 10 trials, each participant completed 6 blocks (2 blocks of each type of wine), each of which consisted of 64 trials (32 oddball-present and 32 oddball-absent trials) presented in a random order. Within each block, an equal number of oddball-present trials with a downward- and upward-pointing oddball were mixed, and each target only appeared once in each location; as for the oddball-absent trials, all the triangles pointed downward in one half of the trials and upward in the remainder.

At the beginning of each trial, a blank screen with a centered black circle fixation (0.36°×0.36°) was presented for 1-1.5 s. Next, the display was presented until the participants made a response. The participants were instructed to respond as accurately and quickly as possible. A beep was presented over the headphones to alert the participant to an incorrect response. After a response was made, the next trial started after 1s.

2.2 Results and Discussion

Mean accuracy was 92.6% correct. RTs that were two standard deviations beyond the means were discarded from the data analyses, accounting for 3.2% of all the data. Mean RTs (calculated based on the correct trials) and accuracy in each condition were calculated and analyzed. Importantly, searching for a downward-pointing oddball (2455 ms) was faster than searching for an upward-pointing oddball (2619 ms), $t(19)=5.61$, $p<.001$, Cohen's $d=1.30$, indicating a DPTS effect of 164 ms; whereas the accuracy difference between these two conditions did not reach significance (86.1% and 88.6%, respectively), $t(19)=1.52$, $p=.145$. What is more, the participants were slower (3893 ms) and less accurate (97.7%) in their responses to the oddball-absent trials consisting of downward-pointing triangles than to those consisting of upward-pointing ones (3380 ms, 99.5%), RTs: $t(19)=9.67$, $p<.001$, Cohen's $d=2.16$, accuracy: $t(19)=2.85$, $p<.01$, Cohen's $d=.70$. These results suggested that it might be more difficult to disengage attention from those wine bottles with downward-pointing triangles on their labels than from those with upward-pointing ones. Taken together, these results reveal that the wine bottle with a downward-pointing triangle on its label might attract attention more readily and make it more difficult for the participants to disengage their attention from it. In Experiment 2, we further examined the effect of set size (i.e., the number of items) in the display in order to investigate whether the visual search for these wine labels was efficient, and whether the orientation of the triangular shapes influenced the search efficiency.

3. EXPERIMENT 2

3.1 Method

Twenty Chinese participants (21.2±2.1 years on average, ranging from 19 to 25 years; 10 female) took part in this experiment in exchange of 25 CNY. All of the participants reported having normal or corrected-to-normal visual acuity. None of them took part in Experiment 1. The methods were the same as those in Experiment 1 except for the changes specified below. In this experiment, the number of wine bottles on each display could be 4, 8, or 16. In order to control the influence of the size of the visual search field, we used the same shelves for different sizes; and when there were 4 bottles in one display, they were presented at the top left, top right, bottom left, and bottom right corners of the shelf; when there were 8 bottles in one display, they were presented at the leftmost and rightmost locations of each shelf (see Figure 2).

Figure 2. Displays of set size 4 and 8 used in Experiment 2.

After a practice block consisting of 10 trials, each participant completed 6 blocks of 72 trials. Within each block of trials, an equal number of trials with 4, 8 and 16 bottles were mixed and presented in a random order. The location of the oddball for each oddball-present trial was also determined randomly.

3.2 Results and Discussion

The participants showed a high level of accuracy (92.4%). RTs two standard deviations beyond the means were discarded, accounting for 0.5% of all the data. Mean RTs for the correct trials and accuracy in each condition were calculated and analyzed, and the RT data were plotted in Figure 3.

We first conducted 2(Oddball Orientation: downward- or upward-pointing) × 3(Set Size: 4, 8, or 16) ANOVAs on the RT and accuracy data from the oddball-present trials. The results revealed a significant main effect of set size on the RT and accuracy data, both Fs>19.65, ps$<.001$. Pairwise comparisons with Bonferroni correction revealed that the participants were faster and more accurate when the set size increased from 4 to 8, and to 16, all ts>3.45, ps$<.01$, Cohen's ds$>.82$. Importantly, the results also revealed a significant main effect of Oddball Orientation on the RT data, $F(1,19)=25.04$, $p<.001$, $\eta_p^2=.569$, qualified by the significant interaction term on the RTs, $F(2,38)=4.69$, $p=.015$, $\eta_p^2=.198$. Neither of other main or interaction effects was significant, both Fs < 1.14, ps $> .30$.

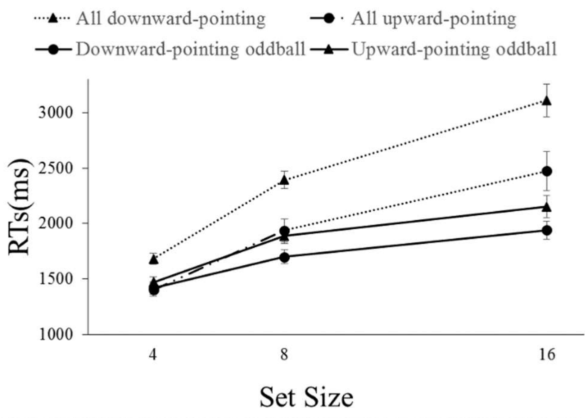

Figure 3. The effect of set size on RTs in Experiment 2 (with SE shown by error bars).

In order to interpret the significant Oddball Orientation × Set Size interaction in the RT data, the data were further broken down based on the set size of the trials, and then compared the RTs for those trials with a downward-pointing oddball to those with an upward-pointing oddball. The results revealed significant DPTS effects of 46 ms, 175 ms, and 191 ms, for the 4, 8, and 16 item set size, respectively, all ts>2.40, ps$<.03$, Cohen's ds$>.63$. Pairwise comparison with Bonferroni correction revealed that DPTS value was the smallest when the set size was 4, both ts>2.64, ps$<.05$, Cohen's ds> 0.80, whereas the DPTS effects were comparable when the set size was 8 and 16, $t(19)=.26$, *n.s*.

Considering the increase in the overall RTs with greater set size, we also calculated the ratio score for the DPTS effect (by dividing the magnitude of the DPTS effect by the overall RT). The ratio scores were smaller when the set size was 4 (3.6%) than when it was 8 (10.0%), $t(19)=3.1$, $p=.018$, Cohen's $d=.71$. Yet, the differences did not reach significance when the ratio scores for the set size of 16 (9.2%) was compared to the other two scores, both ts<2.07, ps$>.156$. These results confirmed that the DPTS effect increased with set size from 4 to 8, though the increase in the DPTS effect when the set size increased from 8 to 16 might be proportional to the increase in the overall RTs.

Orientation × Set Size ANOVAs were also performed on the data of the oddball-absent trials. The main effect of Set Size was significant on the RTs, $F(2,38)=91.03$, $p<.001$, $\eta_p^2=.827$, and marginally-significant on the accuracy data, $F(2,38)=3.22$, $p=.051$, $\eta_p^2=.145$. Specifically, the participants were faster when the set size increased from 4 to 8, and then 16, all ts> 7.66, ps$<.001$, Cohen's ds>2.49; whereas these differences were not significant for the accuracy data, all ts<2.21, ps$>.12$. The results revealed a significant main effect of Orientation on the RT data, $F(1,19)=214.92$, $p<.001$, $\eta_p^2=.919$, and on the accuracy data, $F(1,19) =6.95$, $p=.016$, $\eta_p^2=.268$, but they were both qualified by significant interaction terms, both Fs>4.11, ps$<.024$.

In order to interpret the significant interaction effects between Orientation and Set Size, we further broke the data down based on the set size of the trials, and then compared the data from those trials consisting of downward-pointing items with those with upward-pointing ones. The results revealed that the participants were slower to respond to the oddball-absent trials consisting of downward-pointing triangles than to those consisting of upward-pointing ones when the set size was 4, 8, and 16, all ts>10.32, ps$<.001$, Cohen's ds>2.45. Yet, the RT difference between these two conditions was greater when the set size increased from 4 (281 ms) to 8 (448 ms), and then to 16 (604 ms), all ts>2.64, ps$<.048$, Cohen's ds$>.62$. What's more, the participants were also less accurate in responding to those trials consisting of downward-pointing stimuli than those consisting of upward-pointing ones when the set size was 4 and 8, both ts>2.49, ps$<.05$, Cohen's ds$>.60$, whereas this effect was not significant when the set size was 16, $t(19)=.21$, $p=.839$.

Combining the data from the oddball-present and oddball-absent trials, we also calculated the search slopes for all four conditions (i.e., RTs were plotted as a function of set size). As can be seen in Figure 3, the search slope for trials with a downward-pointing oddball (40 ms/item) was smaller than those with an upward-pointing oddball (51 ms/item), $t(19)=2.20$, $p=.04$, Cohen's $d=.54$; and the search slope for trails with all downward-pointing triangles (111 ms/item) was larger than those with all upward-pointing ones (85 ms/item), $t(19)=5.31$, $p<.001$, Cohen's $d=1.21$. On the one hand, these results suggest that the visual search for these wine bottles with triangles on their labels involved serial processing [Treisman 1988], as the ratio of the search slopes for the oddball-present and oddball-absent trials were 0.47 and 0.46 for the downward- and upward-pointing oddballs, respectively. On the other hand, the results also confirmed that the stimuli with a downward-pointing triangle as a local feature might be processed more readily and make it more difficult to disengage attention from them.

4. GENERAL DISCUSSION

The results of the present study revealed that searching for a wine bottle with a downward-pointing triangular shape on its label was significantly easier than for the same bottle with the same triangle oriented in an upward-pointing direction instead. These results suggest that the DPTS effect emerges not only when the shape of the stimuli are triangular, but also when the triangular shape is used as a local feature within the stimuli on product packaging. The results of Experiment 2 also revealed that the visual search for these wine bottles with triangles on their labels likely involved serial processing. The DPTS effect observed with non-threatening stimuli in the present study and Shen et al.'s [2015] study cannot easily be incorporated within the "Shape of Threat" account [e.g., Larson et al. 2007, 2012; Watson et al. 2012], but are more in line with the account that search advantage for the downward-pointing triangle might be related to its perceptual features.

What is more, our results also demonstrated how the appearance of the bottles, in particular, the design of the wine labels, might guide consumers' attention when searching for the product presented on the store shelves [for more evidence regarding the influence on consumers' perception, see also Elliot and Barth 2012; Thomas and Pickering 2003]. Instead of changing the appearance of the product, changing the design of the packaging and labels might be a more efficient and effective method of attracting the attention of consumers. Attention–capture on shelf displays that are both complex and ever-changing (such as represented by the typical wine aisle) is important, and figures presented on the wine labels have been shown to influence the visual appeal of the product and consumer's liking of the product [Labroo et al. 2007]. Nevertheless, Westerman et al. [2013] reported that bottles of drinks with angular shapes on the labels were rated to be less preferred than those with round ones, and those with downward-pointing triangles on their labels were rated as being less liked, less appealing, and less likely to be purchased than those with upward-pointing ones. Taken together, these findings demonstrate the dissociation between attracting consumers' attention and promoting greater purchase intent when using the triangular shapes in the wine labels.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Elliot, S. and Barth, J. E. J. 2012. Wine label design and personality preferences of millennials. *J. Prod. Brand. Manage.* 21, 3, (May. 2012), 183-191.

Labroo, A. A., Dhar, R. and Schwarz, N. 2008. Of frog wines and frowning watches: Semantic priming, perceptual fluency, and brand evaluation. *J. Consum. Res.* 34, 6, (Apr. 2008), 819-831.

Larson, C. L., Aronoff, J., and Stearns, J. J. 2007. The shape of threat: Simple geometric forms evoke rapid and sustained capture of attention. *Emotion.* 7, 3, (Aug. 2007), 526-534.

Larson, C. L., Aronoff, J., and Steuer, E. L. 2012. Simple geometric shapes are implicitly associated with affective value. *Motiv. Emotion.* 36, 3, (Sep. 2011), 404-413.

Lundqvist, D., Esteves, F., and Öhman, A. 1999. The face of wrath: Critical features for conveying facial threat. *Cognit. Emot.* 13, 6, (Oct. 1999), 691-711.

Shen, X., Wan, X., Mu, B., and Spence, C. 2015. Searching for triangles: An extension to food & packaging. *Food. Qual. Prefer.* 44, (Sep. 2015), 26-35.

Thomas, A. and Pickering, G. 2003. The importance of wine label information. *Int. J. Wine Market.* 15, 2, (Dec. 2003), 58-74.

Treisman, A. 1988. Features and objects: The fourteenth Bartlett memorial lecture. *Q. J. Exp. Psychol-A,* 40, 2, (May. 1988), 201-237

Westerman, S. J., Sutherland, E. J., Gardner, P. H., Baig, N., Critchley, C., Hickey, C., Mehigan, S., Solway, A. and Zervos, Z. 2013. The design of consumer packaging: Effects of manipulations of shape, orientation, and alignment of graphical forms on consumers' assessments. *Food. Qual. Prefer.* 27, 1, (Jan. 2013), 8-17.

Tasty Tech: human-food interaction and multimodal interfaces

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ABSTRACT

The perception of food involves, not just taste, but all senses. We describe several interactive and novel mixed reality systems designed to enhance or change a dining experience by using computer generated visual, audio, and tactile stimuli. We describe how ideas from these playful designs can influence the perception of, and the interaction with food, and can inform the design of studies into human-food interaction.

Categories and Subject Descriptors

H.5.1. [**Information Interfaces and Presentation (e.g. HCI)**]: Artificial, augmented, and virtual realities

Keywords

Mixed reality technology; Multimodal flavour perception; Technological Cuisine; Projection mapping

1. INTRODUCTION

Research has shown that all of the senses contribute to the perception of flavour [2, 5, 30, 37]. A clear example of the influence of other senses on the perception of flavour is the popular maxim 'we eat with our eyes first' [6]. Indeed visual impressions of food drive expectations of what the food will taste like, and can influence the actual taste [6, 19, 39]. In addition, the sounds that are audible while chewing can make a crisp seem either fresh or stale [17], and even certain musical compositions can affect the perception of certain tastes, such as sweetness or bitterness, in chocolate [26]. Not only that, but the weight of a piece of cutlery [11] can affect how people perceive the food consumed from such a utensil.

The notion that flavour is a multi-sensory percept has been exploited in modernist restaurants that typically aim to stimulate all the diners' senses [33], and has thus inspired creative and novel dishes by famous chefs. For example, in the 'Sounds of the Sea' dish, served at The Fat Duck restaurant, a seafood dish is accompanied by an MP3-player that plays ocean sounds, purportedly transporting diners to the seaside [33]. This not only underlines the multi-sensory nature of flavour, but also indicates another opportunity: the use of technology to influence food experiences.

The combination of food and technology can be interesting for the introduction of stimuli that may be difficult to introduce in a dining environment otherwise. Here, there are clear opportunities for the use of mixed reality technology, which can introduce digital elements into the real world [22]. This combination of mixed reality technology and food is especially tantalizing because it allows for digital cues to be presented in combination with actual food items. The use of digital visual cues, for example, could allow for visual enhancements of food items in order to make them look more appealing, tasteful, or interesting [32]. Projection mapping, a technique where projections are adjusted to exactly fit an area of projection, can be used to alter the colour of a food item, the colour and shape of the setting in which the food item is presented [32], and could even be used to project animations onto the food [16].

Sensor technology combined with computation and various outputs, be they visual, auditory, or tactile, can also allow for interesting, useful, or novel human-food interactions. Technology that monitors the food intake as well as the eating speed of diners is for example already being used for monitoring a persons eating habits [12]. Nevertheless, the same technology could be used to for example alter projections, and music, creating rich multi-modal eating environments that have the potential to enhance a person's experience with food.

In this paper we present a number of student projects that were created with the idea of introducing multi-modal interfaces into the dining experience. We will discuss these installations based on a categorization of approaches to multi-modal interfaces in human-food interaction that was identified in the literature. We outline the ideas behind these installations as well as their general design, and we will discuss public reactions to these installations gathered during an informal event. We will show how these installations can not only offer interesting human-food interactions, but could also serve to inform the design of studies into the perception of flavour.

2. RELATED WORK

The use of multi-modal technology in combination with food, begs the question of exactly how technology can be used to enhance the experience of food. To provide a tentative answer to this question we conducted a literature study [1] of which a selection is listed below, and held discussions with experts from leading food companies. Using these methods, we identified five approaches for the use of technology to enhance food experiences:

- **Technology with food as the medium**: with aid of technology, food itself can be used as a medium, for example as a way to display data [15], or for communication purposes [21].

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- **Technology and cooking/dining rituals**: technology can be introduced into the rituals that surround the preparation and the consumption of food at the dinner table. For example, dining together in remote locations using technology for telepresence [38], using augmented reality to teach cooking skills [20], and making the act of cooking more fun and enjoyable through augmented appliances [9]. Many of the works found in this area are aimed at existing social structures, such as family dinner time [29].

- **Technology to change eating behaviour**: by leveraging the measurement capabilities and interactive nature of mixed reality technology, interventions can be created with the goal of changing eating behaviours. Here, there is an almost exclusive focus on healthier eating behaviours. Three subcategories can be distinguished, namely: teaching basic good eating habits to children [7], behaviour change for healthy eating in general, such as eating more slowly [14], and technology used to change eating behaviour in a clinical setting, such as treating obesity [3].

- **Technology to change flavour experiences**: inspired by findings from research on cross-modal perception, technology can be used to augment the way the flavour of actual food items is experience. For example using top-down projection techniques to enhance colour saturation of food [16], or augmenting the sound of chewing the change food texture perceptions [17], both which can influence the taste of the food.

- **Technology to simulate flavour**: technology can be used to fully simulate eating or drinking, without actual consumption of food items. An example is a digital taste simulator using electrodes placed on the tongue that can produce mint or lemon flavours [25].

The approaches listed above should help researchers and professionals think about ways in which technology can be used for enhancing food experiences. Technology can enable food itself to become an expressive medium, and can help to maintain social structures surrounding the preparation and consumption of food. Mixed reality technology can be a powerful tool to help people eat healthier, and might help to combat food related health issues. Technology can be used to enhance the flavour of food, making modernist restaurants an interesting application area, where perhaps in the future we may experiences flavours without the presence of any actual food!

3. INSTALLATIONS

The installations we will describe in this section were created by students who followed who followed Media Technology course from the Human Media Interaction masters program and were demonstrated to the general public at a food court[1]. In this section, we will describe *anecdotally* the experiences the guests of Fooddock had with the installations and what implications this has for designing mixed reality installations for food. These anecdotes are based on the observations of the authors.

3.1 Experience Dining: Ørbit

The Ørbit installation delivered a unique experience using storytelling, molecular cooking, and a nice design. It featured a private darkened room with a rotating platform on a table where two guests would sit opposite each other and listen to a story. The middle of the platform had an area where animations were displayed. Several cups holding edible 'orbs' were placed on the rotating platform, see Figure 1. The orbs were created with spherification [23], a molecular cooking technique popularized in 2003 by Ferran Adrià, the legendary chef of El Bulli restaurant. The orbs are flexible spherical membranes surrounding a flavoured liquid that release the flavour at once when pierced in the mouth. When the rotating platform stopped, a light under the cup facing the guest illuminated the orb, inviting the guest to consume it.

Guests took place opposite each other at the table and put on head phones. The setting of the story was a blind date in a bar. Each guest heard their version of the story through a first person perspective interior monologue, specifically a stream-of-consciousness narrative voice. The voice was intended as the guest's own thoughts. The voice gave comments about the history leading up to the blind date, the situation, the restaurant, the food and drinks, and the date (who is 'played' by the other guest). During the story there were moments where the voice, or the date, ordered food or a beverage and these moments were synchronised in the story of both guests. At such a moment the platform stopped rotating and the orb that represents the food or drink item that fits the story at that moment faced the guests and was illuminated. The projection on the platform fitted the food or beverage with an animation of colour and shape [27, 10]. After consumption, the platform restarted rotating and the story continued. There were two versions of the story: a good date and a bad date. The progress of the story was driven by the interior voice's desire to please the other to get a follow-up date in the good date condition, or to get out without hurting the other's feeling in the bad date condition. Both versions of the story followed a similar pattern, in ordering food items and provoking guests' behaviour, but differed on the mood and frame of mind. Also there were gender specific versions of the story where the voice actor is male or female to fit the gender of the guests. The duration of the experience was 6 minutes. The reception of the Ørbit installation was overwhelmingly positive. Guests recommended it to peers, there was a line, interest exceeded the amount of orbs that were prepared, and guests often inquired when and where the installation would be showed again.

Story-telling techniques and using a narrative voice allowed us to change the mood of the user and to investigate whether the mood of the user influenced the perception and experience of flavours.

Figure 1: The Ørbit installation. The each cup holds an orb: a spherified liquid.

3.2 Playful Dining: Hunger Games

The Hunger Games installation featured a dining table that emphasised the social aspect of having dinner together by creating a shared challenge. The plate of each guest was placed in an aperture in the table in front of the guest, see Figure 2. These apertures could be covered with an diaphragm making the plate and the food

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[1] http://www.fooddock.nl

on the plate inaccessible. Cutlery was placed on conductive areas next to the aperture, making it possible for the installation to sense whether the cutlery was picked up. When a guest picked up his or her cutlery the system closed a diaphragm: the cutlery controlled the irises that cover the food. The algorithm that determined which plate was covered was unknown to the guests and the rules could change. Guests had to work together, using careful observation and experimentation, to figure out what the relation was between picking up cutlery and the closing of the irises. The installation emphasised the social aspect of having dinner together as only by collaborating all guests could eat.

Introducing a challenge or gaming aspect to a dining installation created positive social interaction. Having a common goal or a shared challenge and being dependent on each other is a good recipe for group creation [34]. Guests who interacted with our Hunger Games installation engaged in enthusiastic conversation and collaboration despite never having met before. This effect was particularly pronounced in a group of children, who seemed to remain in the group that formed at the Hunger Games table while they visited the other installations. Additionally, the installation had an effect on the eating behaviour of some of the guests. Some guests tried to beat the system by very quickly taking the food when the diaphragm started to close.

Figure 2: The Hunger Games installation. The aperture on the left is closing and the aperture on the right is already closed. The conductive sensor that can detect the presence of cutlery can be seen next to the apertures (grey areas).

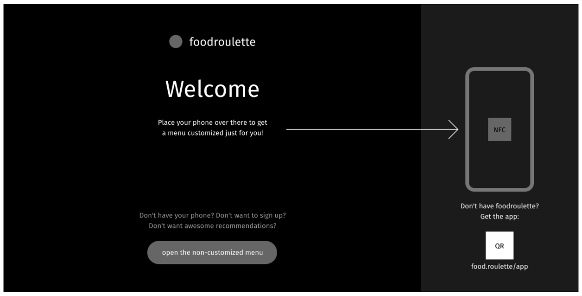
3.3 Ordering: 'Tinder' for Food & Interactive Tables

Systems where restaurant guests could autonomously order from a digitally presented menu were patented as early as 1985 [18]. This included an entertainment system where patrons could "interactively play a variety of remotely retrievable interactive entertainment activities using the video monitor while waiting for the food to arrive"[18]. While major improvements were made in the area of graphics and interactivity, the underlying concept has remained the same for most systems where guests can autonomously order their food (e.g. [4]). A next step in the ordering process is a system that can make an automatic (pre-)selection of the menu items that fit a guest best. Some items from the menu can be hidden or given a less prominent spot on the menu based on the profile of the guest. For example items that a guest cannot consume due to allergies, does not wish to consume due to convictions, or simply does not like can be hidden. The Foodroulette ordering system presented such a menu based on food preference.

Getting the preferences of a guest is another matter. This was solved by creating an app that followed the interaction paradigm of popular dating apps like Tinder[2]. In such apps the user is presented with a picture of a person of the preferred gender accompanied with a short description. The user can 'swipe' the picture to the right to show interest and to the left to indicate no interest. This paradigm was used in the app Foodroulette. Foodroulette was used to obtain a food preference profile of guests, see Figure 3. A guest could put his or her smartphone with the app on an NFC enabled touch table to upload his or her preferences, see Figure 4. The table then showed a selection of the restaurant's menu where the dishes that the guest might like get a prominent place, see Figure 5. The guest could explore the personalised menu and select a dish through a touch interface. The preparation of the selected dish could be presented on the table, which gave a new meaning to an open kitchen, for example through a live camera feed of the chef preparing the food or a pre-recorded clip, see Figure 6. Additionally, an indication of the remaining waiting time was indicated with a picture of the selected dish that was slowly moving towards the guest on the table.

The ordering process might benefit from interactive tables, especially when combined with automated adaptation of the menu to preference and allergies. However, beyond the novelty effect of flashy designs and smooth interactions with touch tables the added benefit compared to traditional ordering methods was limited. In our opinion such technology should not be intended as a replacement for waiting staff as guests often enjoy the social interaction with the staff.

Figure 3: The smart-phone app Foodroulette.



Welcome

Place your phone over there to get
a menu customized just for you!

Don't have your phone? Don't want to sign up?
Don't want awesome recommendations?

Don't have foodroulette?
Get the app:
food.roulette/app

Figure 4: Placing a smart-phone that has the Foodroulette app on an interactive table.

3.4 Behaviour Change Support: Thunder Dinner

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[2] www.gotinder.com

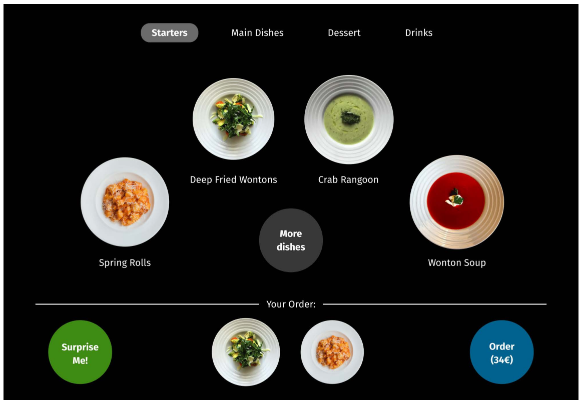

Figure 5: Ordering on an interactive table.

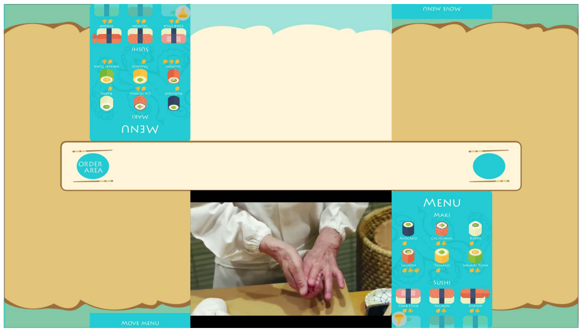

Figure 6: Ordering on an interactive table, visualising the time before the order arrives.

Technology can play an important role in aiding and stimulating healthy eating behaviours. This can take many forms, for example helping disabled people consume food autonomously [35], teaching basic good eating habits to children [7], or eating more slowly [14].

In the Thunder Dinner installation the eating behaviour of the guest was observed, and auditory, visual, and tactile stimuli were used to indicate that the guest was eating too quickly. During the demonstration of the installation guests were invited one at a time in a private room where they were presented with a bowl of soup and a spoon. Unbeknownst to them, they were being observed through a Microsoft Kinect. The Kinect data was combined with the data from an accelerometer embedded in the handle of the spoon to allow the installation to guess the eating speed of the guest. When a guest was eating to fast the illusion of a thunder strike was created by flashing the lights, playing sound of a thunder strike, and vibrating the spoon with an actuator embedded in the handle. The initial effect of the thunder was surprise followed by investigating what triggered the thunder. Some guests lowered their eating frequency to avoid being 'Thundered'. Inadvertently sometimes guests started eating faster to induce the thunder, perhaps to repeat the experience.

The Thunder Dinner is an example of an installation that can be used to change the eating behaviour of a user in a playful manner. However, care should be taken that the stimulus, intended to reduce a behaviour, is not so interesting that it is sought. Alternatively, an interesting stimulus might be used to promote wanted behaviour.

3.5 Tasty Projections: Projection Mapping on Food

Research indicates that visual cues, such as colour and shape, contribute strongly to expectations about taste and taste perception during consumption [8, 13, 24, 28, 31, 36, 11]. For example, the colour of drinks showed consistent colour-flavour associations: red was associated with cherry and strawberry, whereas green was associated with mint and lime [28]. In an installation demonstrated to the general public at 'The Future of High Tech'[3], the guests were asked to select combinations of visualizations and animations to be projected on a cup of yoghurt to make it appear as appealing as possible, see Figure 8. It was suggested guests try to create the sweetest and the most sour projections. Guests could select the properties of the projection from three categories, see Figure 9: shape (rounded or spiked), speed of a pulsating animation (fast, slow, or still), and colour (red, green, or grey).

Figure 7: A guest eating soup with the actuated spoon in the Thunder Dinner installation.

This installation allowed guests to show what they thought a sweet or sour yoghurt should look like by manipulating its appearance. The yoghurt itself became the medium of this message.

Figure 8: The installation where guests could select their preferred 'tasty' projection.

3.6 Research-based Approach: Projection Mapping on Food

Designing recipes, especially in the commercial sector, is a tedious process. To investigate small changes in recipe several batches have to be created and tested in subsequent iterations: a time-consuming and expensive process. Mixed reality technology can address this problem by offering structured and easy examination of effects of colour and animation on certain types of food. In another study we demonstrated associations between taste perceptions and projections. We showed associations between sweetness and

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[3] www.thefutureofhightech.com

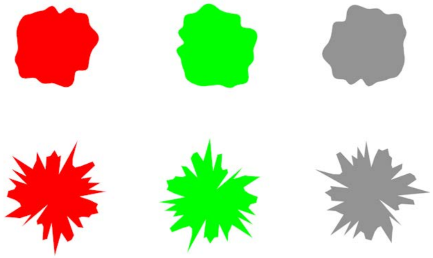

Figure 9: Examples of amorphous shapes that guests could select.

red rounded shapes, and sourness and green angular shapes with a fast animation speed [1]. In that study, the visualizations that were projected around a cup of yoghurt that participants tasted confirmed that specific combinations of visualizations and animation types influence taste perceptions of the yoghurt. In particular, while the colour and shape of the visualizations did not influence taste perception of the yoghurt after tasting, an interaction effect was found that showed that specific combinations of the visualizations with animation type did influence taste perception of the yoghurt. Yoghurt that was presented with a red/rounded still visual was rated as more sour than when presented with a green/angular still, but when the visualization was animated (i.e. fast motion) this effect reversed: when yoghurt was presented with a green/angular animated visual the yoghurt was rated as more sour than when it was presented with a red/round animated visual, see Figure 10. This indicates that projected animations can influence the taste perception of yoghurt, but that the effect depends on the design of the visualizations in terms of their colour and shape. For more details on this study, refer to [1].

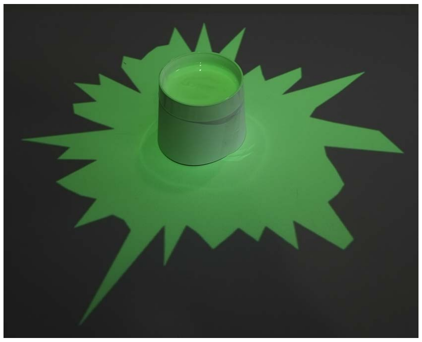

Figure 10: A photo of a projection of a green angular shape on a cup of yoghurt.

4. DISCUSSION AND CONCLUSION

In this paper we discussed installations that used technology to enhance food experience. These installations used technology to change how guests experienced food: by using the food as a medium; by changing the rituals of cooking, ordering, or dining; by changing the eating behaviour; or by changing the flavour experience.

We showed that food can be a medium to display information. In the Ørbit installation, the food conveyed information about a story that the guest was experiencing. In the Tasty Projections installation, the yoghurt became the medium with which guests could convey their message of what they perceived to be an appearance of sweet or sour.

The rituals of cooking, ordering, and dining could be influenced by technology. In the Hunger Games installation the potential awkwardness of dining with strangers was mitigated by creating a shared challenge that required cooperation to solve. Also for familiar diners the installation created a new dining experience. The Foodroulette app and interactive tables changed the ritual of ordering food. In particular, personalised menus based on a guest's food preference and allergies could streamline the ordering process. However, it should be noted that replacing the human waiter with an impersonal system for placing an order makes ordering a less social process. To us it seems very unlikely that this would become a trend in a sector where the difference is made through personal attention and heartfelt hospitality.

Changing the eating behaviour of guests proved possible as seen by the Thunder Dinner installation. However, care should be taken when designing the stimulus that is meant to change the behaviour. We observed that our stimulus, that was meant to be a deterrent for fast eating, was sometimes perceived as interesting or fascinating leading to behaviour intended to trigger the stimulus.

We were able to change the flavour experiences with installations that create cross-modal stimuli. Projecting a coloured animated shape on a food item, in this case yoghurt, changed the taste. The taste of yoghurts that were presented with red/rounded still visuals were rated as more sour than when presented with green/angular stills, but when the visualizations were animated (i.e. fast motion) this effect reversed: when yoghurts were presented with green/angular animated visuals the yoghurts were rated as more sour than when they were presented with red/round animated visuals. Results from our lab study, see [1], showed that mixed reality technology in the form of projection mapping offered unique ways in which the taste perception of food items could be influenced, in this case through carefully designed animated visualizations. The implication is that mixed reality technology can be utilized to systematically investigate taste associations and taste perceptions. This multi-modal approach could not only result in fascinating installations and food experiences, but could also shed further light on the multi-modal perception of flavour.

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5. REFERENCES

[1] A. Anonymous, B. Anonymous, and C. Anonymous. A moving feast: Effects of color, shape and animation on taste associations and taste perceptions. In *proceedings of Advances in Computer Entertainment (in press)*, 2016.

[2] M. Auvray and C. Spence. The multisensory perception of flavor. *Consciousness and cognition*, 17(3):1016–1031, 2008.

[3] P. S. Bordnick, B. L. Carter, and A. C. Traylor. What virtual reality research in addictions can tell us about the future of obesity assessment and treatment. *Journal of diabetes science and technology*, 5(2):265–271, 2011.

[4] S. N. Cheong, W. W. Chiew, and W. J. Yap. Design and development of multi-touchable e-restaurant management system. In *Science and Social Research (CSSR), 2010 International Conference on*, pages 680–685. IEEE, 2010.

[5] J. Delwiche. The impact of perceptual interactions on perceived flavor. *Food Quality and preference*, 15(2):137–146, 2004.

[6] J. F. Delwiche. You eat with your eyes first. *Physiology & behavior*, 107(4):502–504, 2012.

[7] S. Ganesh, P. Marshall, Y. Rogers, and K. O'Hara. Foodworks: tackling fussy eating by digitally augmenting children's meals. In *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational*, pages 147–156. ACM, 2014.

[8] L. L. Garber Jr, E. M. Hyatt, and R. G. Starr Jr. Placing food color experimentation into a valid consumer context. *Journal of food products Marketing*, 7(3):3–24, 2001.

[9] V. Halupka, A. Almahr, Y. Pan, and A. D. Cheok. Chop chop: a sound augmented kitchen prototype. In *Advances in Computer Entertainment*, pages 494–497. Springer, 2012.

[10] G. Hanson-Vaux, A. S. Crisinel, and C. Spence. Smelling shapes: Crossmodal correspondences between odors and shapes. *Chemical Senses*, 38(2):161–166, 2013.

[11] V. Harrar and C. Spence. The taste of cutlery: how the taste of food is affected by the weight, size, shape, and colour of the cutlery used to eat it. *Flavour*, 2(1):21, 2013.

[12] 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*, 2016.

[13] R. Hurling and R. Shepherd. Eating with your eyes: effect of appearance on expectations of liking. *Appetite*, 41(2):167–174, 2003.

[14] 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*, pages 1551–1556. ACM, 2013.

[15] R. A. Khot, J. Lee, D. Aggarwal, L. Hjorth, and F. Mueller. Tastybeats: Designing palatable representations of physical activity. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, pages 2933–2942. ACM, 2015.

[16] Y. Kita and J. Rekimoto. Spot-Light: Multimodal Projection Mapping on Food. In C. Stephanidis, editor, *HCI International 2013 - Posters' Extended Abstracts: International Conference, HCI International 2013, Las Vegas, NV, USA, July 21-26, 2013, Proceedings, Part II*, pages 652–655. Springer Berlin Heidelberg, 2013.

[17] N. Koizumi, H. Tanaka, Y. Uema, and M. Inami. Chewing Jockey: Augmented Food Texture by Using Sound Based on the Cross-modal Effect. In *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology*, 2011.

[18] L. G. Kurland and E. Gilbert. Integrated interactive restaurant communication system for food and entertainment processing, Nov. 12 1985. US Patent 4,553,222.

[19] C. A. Levitan, M. Zampini, R. Li, and C. Spence. Assessing the role of color cues and people's beliefs about color-flavor associations on the discrimination of the flavor of sugar-coated chocolates. *Chemical Senses*, 33(5):415–423, 2008.

[20] S. Mennicken, T. Karrer, P. Russell, and J. Borchers. First-person cooking: a dual-perspective interactive kitchen counter. In *CHI'10 Extended Abstracts on Human Factors in Computing Systems*, pages 3403–3408. ACM, 2010.

[21] H. Nakamura and H. Miyashita. Communication by change in taste. In *CHI'11 Extended Abstracts on Human Factors in Computing Systems*, pages 1999–2004. ACM, 2011.

[22] Y. Ohta and H. Tamura. *Mixed reality: merging real and virtual worlds*. Springer Publishing Company, Incorporated, 2014.

[23] W. J. S. Peschardt. Manufacture of artificial edible cherries, soft sheets, and the like, July 9 1946. US Patent 2,403,547.

[24] B. Piqueras-Fiszman and C. Spence. Colour, pleasantness, and consumption behaviour within a meal. *Appetite*, 75:165–172, 2014.

[25] N. Ranasinghe, A. Cheok, R. Nakatsu, and E. Y.-L. Do. Simulating the sensation of taste for immersive experiences. In *Proceedings of the 2013 ACM international workshop on Immersive media experiences*, pages 29–34. ACM, 2013.

[26] F. Reinoso Carvalho, R. Van Ee, M. Rychtarikova, A. Touhafi, K. Steenhaut, D. Persoone, C. Spence, and M. Leman. Does music influence the multisensory tasting experience? *Journal of Sensory Studies*, 30(5):404–412, 2015.

[27] H.-S. Seo, A. Arshamian, K. Schemmer, I. Scheer, T. Sander, G. Ritter, and T. Hummel. Cross-modal integration between odors and abstract symbols. *Neuroscience letters*, 478(3):175–178, 2010.

[28] M. U. Shankar, C. A. Levitan, and C. Spence. Grape expectations: The role of cognitive influences in color-flavor interactions. *Consciousness and Cognition*, 19(1):380–390, 2010.

[29] M. Snyder, J. Zimmerman, and J. Forlizzi. Your dinner's calling: supporting family dinnertime activities. In *Proceedings of the 2007 conference on Designing pleasurable products and interfaces*, pages 485–489. ACM, 2007.

[30] C. Spence. Multisensory flavour perception. *Current Biology*, 23(9):R365–R369, 2013.

[31] C. Spence, C. A. Levitan, M. U. Shankar, and M. Zampini. Does food color influence taste and flavor perception in humans? *Chemosensory Perception*, 3(1):68–84, 2010.

[32] C. Spence, K. Okajima, A. D. Cheok, O. Petit, and C. Michel. Eating with our eyes: From visual hunger to digital satiation. *Brain and Cognition*, 2015.

[33] C. Spence and B. Piqueras-Fiszman. *The perfect meal: the multisensory science of food and dining*. John Wiley & Sons, 2014.

[34] C. Stangor. *Social groups in action and interaction*. Psychology Press, 2004.

[35] Y. Takahashi, N. Hasegawa, K. Takahashi, and T. Hatakeyama. Human interface using pc display with head pointing device for eating assist robot and emotional evaluation by gsr sensor. In *Robotics and Automation, 2001. Proceedings 2001 ICRA. IEEE International Conference on*, volume 4, pages 3674–3679. IEEE, 2001.

[36] C. Velasco, A. T. Woods, O. Deroy, and C. Spence. Hedonic mediation of the crossmodal correspondence between taste and shape. *Food Quality and Preference*, 41:151–158, 2015.

[37] J. V. Verhagen and L. Engelen. The neurocognitive bases of human multimodal food perception: sensory integration. *Neuroscience & biobehavioral reviews*, 30(5):613–650, 2006.

[38] J. Wei, X. Wang, R. L. Peiris, Y. Choi, X. R. Martinez, R. Tache, J. T. K. V. Koh, V. Halupka, and A. D. Cheok. Codine: an interactive multi-sensory system for remote dining. In *Proceedings of the 13th international conference on Ubiquitous computing*, pages 21–30. ACM, 2011.

[39] M. Zampini, D. Sanabria, N. Phillips, and C. Spence. The multisensory perception of flavor: Assessing the influence of color cues on flavor discrimination responses. *Food Quality and Preference*, 18(7):975–984, 2007.

Sound-enhanced Gustatory Experiences and Technology

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Abstract

We discuss whether sound can add value to people's tasting experiences. The results presented here may be a source of inspiration for experience designers in the food industry wanting to add value to food/beverage products and/or to enhance multisensory tasting events. The available new technologies allow people to use sound as an input for moments associated with our eating and drinking habits. Here, we review three studies that used chocolate as taste stimulus. In general, the results revealed that sound can, in some cases and in different ways, modulate the taste/flavor of food (i.e., sweetness, bitterness, creaminess). These results also suggest that popular songs and soundscapes can add significant hedonic value while tasting. We discuss our results in light of new technologies (e.g., virtual reality), which offer both companies and consumers potential means for bringing customized multisensory eating and drinking experiences. We also discuss how this knowledge could be further applied – and perhaps improved – in order to make these experiences more scalable and applicable for the general public.

CSS concepts

- **Human-centered computing Interaction design process and methods User interface design**

Keywords

sound, music; taste; chocolate; beer; perception; multisensory experiences

1. Introduction

Research has shown that the sounds that accompany our eating and drinking habits can affect the way in which we perceive tastes and flavors (see [30,32,33] for reviews). Think, for example, of the sounds that derive from mastication (e.g., crisp, crunch), the background music used in a restaurant, or the loud noise that sometimes goes hand-in-hand with street food. Indeed, the reverberation time of a room and/or the level of background noise, both acoustic parameters that can define the quality of an auditory space (see Astolfi & Filippi 2004; [8]), have an effect on people's gustatory experiences. Such features could potentially modify the perception of food/beverage attributes as well, such as, for example, bitterness (e.g., [5,29,37,41]; see [31], for a review of the influence of noise on food and drink perception).

Many food experience designers and chefs, among other professionals working in the food industry, now look into the recent scientific advances in multisensory flavor perception as source of inspiration while developing novel experiences and products for their customers ([18,22,25,26,27]; see [38] for a review). Sound, for example, can add significant value (both sensory and hedonic) to the consumer's overall multisensory eating/drinking experience (e.g., [23,24,28,29,24,35]; see [32] for a review). With this idea in mind, we summarized the latest research led by the first author of this manuscript, whose studies have looked at the influence of sound on the perception of chocolates' taste/flavor.

Given the wide variety of applications of such research, we believe that it is also important to consider the role of new technologies as platforms for multisensory food and drink experience design, in particular, when they relate to sound [11,13]. Given the recent technological advances as well, researchers are thinking of, lets say, 'digitizing' all the senses [14], designing mixed-reality food and drink experiences [39], and capitalizing on the marketing applications that these technologies may offer for the food and drink industry [15]. In that sense, the customization of multisensory experiences for the consumer is around the corner. We believe that, in the future, we will observe products that come with customized multisensory experiences in mixed/virtual reality, customized music playlists, and multisensory immersive dining experiences, among others.

In order to design meaningful multisensory tasting experiences, one first needs to better understand the role of sound while we taste. For that purpose, we first review three studies, where chocolates were used as taste stimuli, and songs/soundscapes were used as auditory stimuli. In the first study, customers evaluated a chocolate's taste under four different multisensory conditions. The shop's own soundscape and a pre-recorded piece of popular music were used as sonic stimuli. In the second experiment, the participants paired three soundscapes with three chocolates (on a

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bitter-sweet dimension). The impact of the soundscapes on the participants' ratings of the chocolates' taste was also analyzed. In the third experiment (still under peer review), two soundscapes were produced to be congruent with creaminess and/or roughness. Here, the soundscapes were ranked in a rough-creamy scale by a control group, and later experienced by another group of participants, that ate chocolates while listening to them. The idea behind this manipulation was to assess their potential modulatory effects on the chocolate's flavor.

After presenting the aforementioned studies, we discuss the role of new technologies in sound-taste/flavor experiences, and introduce applicable future work, mostly related to blending the latter insights with state-of-the-art technology, such as algorithms, gadgets, virtual reality, and/or wearable sensors.

2. Enhancing the subjective value of tasting experiences by means of sound-taste correspondences

This study, investigated, for the first time, whether participants would be willing to pay more for a chocolate that comes with its own customized soundscape [21].

The chocolate sample used as taste stimuli was developed based on an existing Belgian praline that is part of Dominique Persoone's collection - the reference praline is named 'Brasil'[1]. A fragment of "Vem Morena, Vem", a composition by the Brazilian artist Jorge Ben[4] (produced by Armando Pittigliani, Philips, Universal, re-mastered and re-released by Polysom in 2012), was chosen as the song to be used as one of the sound stimulus of this experiment. Note that the name of the chocolate, title, and origins of the used song were undisclosed during the experiment, in order to avoid bias. The second auditory stimulus used in this experiment was the ambient soundscape of the production kitchen of this chocolate shop.

A within-participants experimental design was implemented. Participants responded to a number of questions before and after eating the chocolate in one of the four experimental conditions that they were assigned to. In the first condition (A), the participants tasted the chocolate while listening to the song, without extra information about the stimuli being presented. The second condition (B) involved tasting the chocolate while listening to the ambient soundscape of a production kitchen. The participants in the third condition (C) ate the chocolate while listening to the song. In this condition, the participants were also told that this song had been the chocolatier's source of inspiration for the creation of the chocolate sample that they were about to taste. For the fourth condition (D), the participants ate the chocolate while listening to the song, and they were told that the song had been chosen by a team of scientists due to its enhancing effect on the chocolate's taste.

Table 1. Ratings (Means and SD) before and after tasting the chocolate. Values in bold were reported after the participants had tasted the chocolate. If comparing the answer to the pre-questionnaire 'tastiness' item with their 'liking' while eating (post-questionnaire), revealed statistically significant results for each condition, when considered individually (p < .05). The corresponding statistical analysis is based on a comparison of means between the related groups (paired samples t-test, using SPSS). Table source: [21], open access.

	Mean and SD of liking, per condition			
	A	B	C	D
Pre-tasting	3.8 (1.5)	4.6 (1.6)	4 (1.5)	3.9 (1.4)
Post-tasting	**4.9 (1.5)**	**5.3 (1.6)**	**5.4 (1.3)**	**4.9 (1.4)**

Table 2. In conditions A and B, the participants were willing to pay approximately 10% more for the chocolate when listening to customized sonic stimuli. In condition C, they were willing to pay almost 20% more for such an experience. A comparison of means was obtained to assess the difference of prices between the willingness to pay prior tasting and conditions A-D, individually. Significant differences were found for all cases for p < .05 (p_{PA} = .014, p_{PB} = .018, p_{PC} = .001, p_{PD} = .002). Table source: [21], open access.

Willingness to pay, per condition	Pre-tasting	A	B	C	D
Mean (SD)	0.59 (0.16)	0.65 (0.20)	0.65 (0.20)	0.71 (0.20)	0.61 (0.20)

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[1] This praline consists of a colored mass based on white chocolate, together with a mixed filling of lime jelly and coriander 'ganache' (Link to visual aspect of chocolate: http://www.thechocolateline.be/en/chocolates/product/brasil-2; Retrieved on April, 2016).

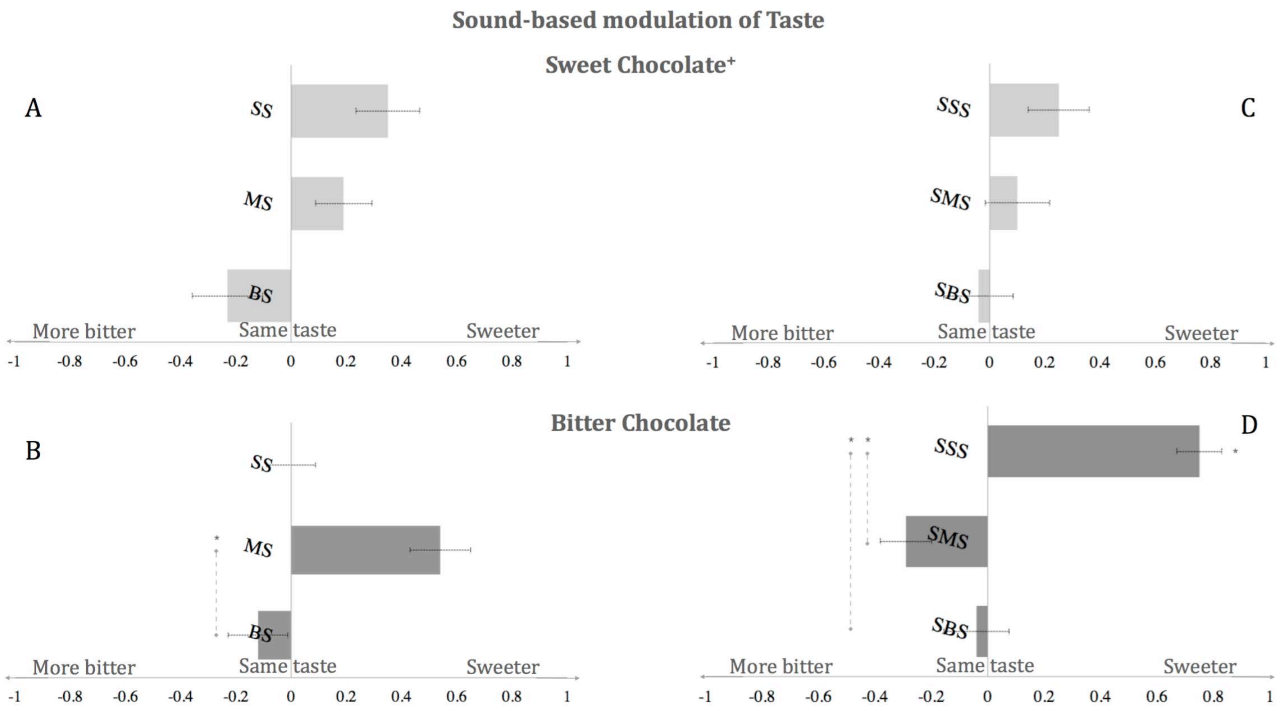

Figure 1. Sound-based modulation of taste for the sweet^{+} and bitter chocolates - considering the three soundscapes. Panels A and B follow the chocolate/ soundscape pairing found in the group average. In C and D, the data were reorganized based on the pre-test results, in which the participants made their own pairs**.** Thus, in A and B the soundscapes are always the same for each chocolate, for every participant. In C and D what the theoretical baseline pre-defined as a sweet soundscape could be sweet, medium or even bitter, depending on the participant. The asterisks highlight a significant difference between the conditions ($p<.05$). All resultant means fall between '-1' and ‘1’. Therefore, for a better visualization, the scale of the figure’s axis has been limited (Rates based on 7-point Likert scales). Figure’s source, [20].

The results of this study revealed that the participants liked the chocolate significantly more after than before tasting it (see Table 1). They reported being willing to pay an average of 0.59 before trying the chocolate (average of the four conditions). The average price – again, of the four conditions – after having had the multisensory experience was 0.65 euros, and in condition C it was 0.71 euros. The price difference across conditions was significant (see Table 2). The perceived taste of the chocolate (assessed by means of sweetness, bitterness, sourness, and saltiness scales) did not vary as a function of condition. Moreover, the participants that experienced Condition C gave the highest liking ratings after tasting. In this same condition, the differences between the ratings prior to and after tasting were also the highest (Mean before = 4, SD =1.5; Mean after= 5.4, SD = 1.3). Summarizing, the participants in Condition C, that is, those participants who had been told that the song was used as the source of inspiration by the chef, where the ones that liked the chocolate the most after eating it, and were also the ones who were willing to pay the most for the multisensory experience.

Based on the results of this study, it is possible to say that people may be willing to pay more for a gustatory experience that comes with its own soundscape. Therefore, those companies that may be willing to pay for the development of technological multisensory dining experiences should be aware that there might already a public that is willing to pay for this.

3. Assessing the influence of music in multisensory tasting experiences

The first part of this study evaluated the way in which participants matched three different songs with three different chocolate samples (pre-test) - one sweet (SC), one bitter (BC), and another in between (MC) (see [20], for complete report). In the second part, we analyzed whether listening to each of these songs would modulate the perceived taste of the aforementioned three types of chocolates. The chocolates were also tasted in silence, and the effect of the soundscapes was compared with this data as well.

The soundscape (sound stimuli) used here were produced to be congruent with each of the three available chocolate samples (a sweet soundscape 'SS', a bitter soundscape 'BS', and a medium[2] soundscape 'MS'). For their production, [10] acted as baseline, followed by the music samples produced for [3][3].

A control group rated, as expected, the SS as the sweetest, the BS the most bitter, and the MS falling in-between the other two. As taste stimuli, the participants in [20] tasted the three types of chocolate. These samples were prepared under the supervision of Dominique Persoone (**www.thechocolateline.be**). During the study, the participants could not see the shape and color of these chocolates.

These results revealed that most of them (approximately 83%) matched the bitter chocolate with the BS. However, most participants matched either the SS or MS with the sweet and medium chocolates. The participants also rated how good they thought the combinations they chose felt. Only 4% of these combinations were rated as "bad".

The main experiment (test) assessed whether these soundscapes would modulate the perceived taste of the chocolates. It was anticipated that the soundscapes would make the chocolates taste more or less bitter/sweet as a function of the soundscape played in the background. The results obtained were consistent with what was expected, especially for the bitter chocolate (see Figure 1 for details). When comparing the data organized considering the individual matches versus the group averages[4], we were able to document one case in which the modulation effects of the soundscapes on taste went in opposite directions. In particular, an increase in sweetness was observed when considering the group average (MS/BC, Figure 1, panel B), whereas a trend toward increased bitterness was noted when considering the individually-matched one (SMS/BC, Figure 1, panel D).

The analyses revealed significant differences between music conditions only for the bitter chocolate sample (see asterisks in Figure 1). Figure 1 shows that the chocolate was perceived as significantly sweeter under the influence of SSS versus tasted in silence (Panel D, asterisk top right). Furthermore, there was a significant difference in the perceived taste of the bitter chocolate when tasted while listening to the SSS versus the SMS and SBS (Panel D, asterisks on the left). Finally, we observed a significant difference between the taste ratings of the MS versus the BS (Panel B). The reason for more conclusive results regarding the bitter chocolate may be related with the fact that the participants were not able to distinguish clearly between the sweet and medium chocolates[5] (as the results of the pre-test showed).

In conclusion, soundscapes can have an enhancing effect on the perceived taste of a chocolate sample. Ambient sound can influence taste judgments, and potentially provide useful insights concerning the design of multisensory tasting experiences. Such effects may be even more salient if each participant is allowed to individually customize its own sound-taste experience. When thinking about technological applications, sound-taste matching algorithms might be developed, for example, in music playlist customization. Consider being able to choose, from your own musical preferences, which songs would be better to be heard while drinking, for instance, red wine versus white wine, cocktails, whisky, beer, etc.

4. Using music to modulate the perceived creaminess, and taste attributes of chocolate

As showed above, a spate of recent studies has been asking whether sound can enhance basic taste attributes (i.e., sweetness, bitterness, sourness, etc.). Moving forward, now there is a growing interest on determining if sound can influence other flavor attributes as well, such as those which relate to oral somatosensation. Whereas it is known that the sounds that derive from mastication can be modified to augment and/or reduce specific food-related textures (e.g., [42]), less research has been conducted on the influence of non-mastication sounds on food texture perception. For example, would the presentation of sounds (that are not necessarily related to eating/drinking) nevertheless still make food/drinks be perceived as more/less crispy, crunchy, creamy, or carbonated? Research suggests that it may be the case [32].

In this study, we hypothesized that soundscapes can have a perceptual effect on the perceived creaminess of chocolate (see [28]). The participants tasted and rated the same chocolate twice, each time under the influence of one of two soundscapes. One soundscape was designed to enhance the perceived creaminess, and the other to have an opposite effect. The production of these soundscapes was based on previous literature. For instance, we considered the results of a study by [4] as potentially providing some musical guidance. They addressed musical parameters, such as pitch, loudness, timbre, and how their interactions affect auditory–tactile metaphorical mappings. For example, they found that a flute's timbre, was rated as smoother than the violin's timbre, which, when compared to the flute, it has a more complex sound in terms of harmonics.

As baseline for the sound production, we considered that soft/smooth sounds are usually correlated to long-consonant-legato notes. In contrast, hard/rough sounds are most likely represented by short-dissonant-staccato notes[6]. As a result, the first soundscape (produced to be congruent with creaminess, namely the 'Creamy soundscape') is a loop-ascending scale of consonant-long flute notes, mixed with large hall reverberation. The second soundscape (namely the 'Rough soundscape', intended to have an opposite effect when compared to the Creamy soundscape) is a loop-ascending scale of three blended dissonant-dry pizzicato short violin lines. The results of a control test

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[2] By medium, we mean a stimulus somewhere in between the most bitter and the sweeter stimuli.

[3] Some guidelines concerning taste/sound associations emerged as follows: high-pitched "bubbling" sounds for sweetness; low resonance filters for bitterness; and a narrowed frequency bandwidth for the medium song. In a control test, the participants' evaluation of the musical selections went as anticipated with the results of the preliminary study (Link to the songs http://sonictaste.weebly.com/blog/music-can-influence-tasting-experiences; retrieved on March, 2016).

[4] By individual matches, we refer to the data that considers the song-chocolate pairs that the participants made in the pre-test (namely, SSS, SMS, and SBS). By group average, we are referring to the data organized considering the bitter, sweet, and medium songs as always the same (the ones that were produced, following the theory, to be congruent with bitterness, and so on; namely SS, MS, and BS).

[5] Note that, due to this fact, it was decided to collapse the SC and MC into a single category next to the BC, namely sweet chocolate^{+} (SC^{+})(see Figure 1).

[6] For example, in [4], higher – and louder – pitches/notes were rated as rougher/harder. Moreover, violin sound was rated as rougher/harder and drier as compared to flute.

revealed that the participants were able to classify both soundscapes as expected.

Two bitter chocolate formulas were prepared for this study (basic ingredients: cocoa mass, sugar, cocoa butter and natural vanilla flavor). One formula had 71% cocoa content and the other 80%. Furthermore, each formula was presented in two different molds (one with round features and the other with angular/asymmetrical features). Therefore, in total, four different chocolate samples were available, one for each of the four groups of participants. Note that all of the chocolate samples had the same dark brown color, and similar volume (approximately 2.5 cm^3).

The participants tasted and rated two identical chocolates (unfamiliar to them) in two trials, each time listening to one of the two soundscapes (all rates based on 7-point scales). The independent variables for each experiment were sound condition, chocolate shape, and cocoa content. The dependent variables were the ratings that the participants made for each trial. The soundscapes were presented in a counterbalanced order.

The results revealed that the soundscapes had the predicted effect on the perceived creaminess of the chocolates. In particular, the creamy soundscape significantly elevated ratings on creaminess and sweetness, when compared to the rough soundscape which had an opposite effect on creaminess, and enhanced the perceived bitterness (see Figure 2). The participants also reported having liked the creamy soundscape significantly more than the rough soundscape, from which we might presume that the greater enjoyment of the creamy soundscape could have enhanced both the perceived sweetness and creaminess of the chocolate (see [2], on the notion of sensation transference).

The fact that people liked one soundscape more than the other did not affect their overall enjoyment of the chocolates. So far, similar studies have reported that soundscapes tend to have an enhancing effect in terms of the hedonic and sensory ratings of food and beverages (cf. with [24], that worked with chocolate pralines; and with [9], that worked with ice cream). One possible explanation here is that the chocolates used in our experiment were pure chocolate formulas. Thus, people are very familiar with such chocolates and probably have a firm idea on how much they like or dislike them. So, in this case, the enjoinment of the chocolate could be less susceptible towards the effects of music.

These results demonstrate that sounds can, in some cases at least, influence the perception of the food without altering its hedonic experience, regardless of their preference for the sonic stimuli. Here, it is also important to consider that the robustness of these results allow us to conclude that the soundscapes that were produced for this study can be considered as baseline for future similar assessments.

Nevertheless, one limitation of this study deserves to be assessed as future work. Principally, it is difficult to conclude whether there is only one, or perhaps several mechanisms underlying sound-chocolate associations. It would appear that there are a number of explicit crossmodal sound-flavor correspondences, driven mainly by the salient musical attributes of each soundscape. However, some may argue that the present results hinge on some form of sensation transference effect rather than reflecting a 'true' crossmodal correspondence effect (see [2] for an overview on sensation transference; see [10], for an overview on crossmodal correspondences). Still, most of the musical attributes used in this study were chosen on the basis of contrast (think of consonant versus dissonant harmonies, reverberant versus dry ambiances, and so on). For that reason, a plausible assumption would be that most people (especially the ones without musical training) would prefer to listen to consonant harmonies over dissonant ones. Therefore, assessments such as this one will most likely be constantly conditioned by the individual preferences of each participant.

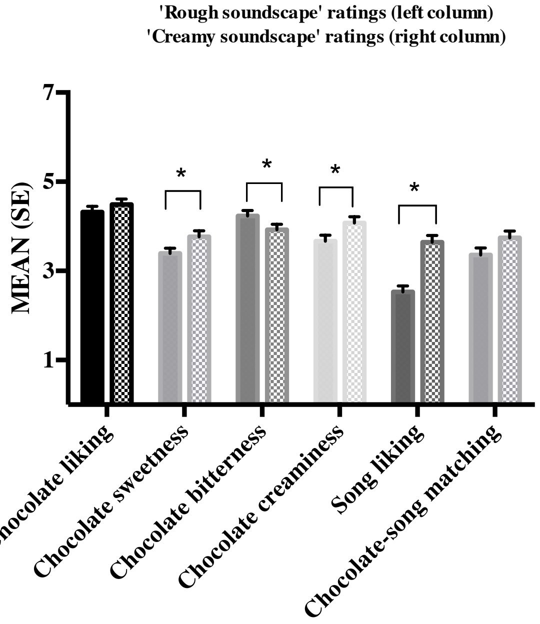

Figure 2. Participants' mean ratings (based on 7-point scale). For each attribute, the left column corresponds to Rough soundscape ratings, and the right column to Creamy soundscape ratings. Error bars indicate standard error. Asterisks '*' indicates a significant difference - at p = .010 -, between Rough soundscape and Creamy soundscape ratings.

The different studies summarized here have clear applications in our daily lives. Consequently, we believe that these insights could blend with state-of-the-art technology (i.e. algorithms, gadgets, sensors, etc.). An extensive analysis (including potential examples) on foreseen applications that may derive from the knowledge exposed in the previous sections are further discussed in Section 5.

5. Future work - Blending sound-taste experiences with state-of-the-art technology

We will now focus on the role of new technologies as means for multisensory food and drink experience design, in particular, when they relate to sound. Potential applications are discussed below.

5.1 Sound-taste algorithms

The experiments summarized above tells us much about the potential of sounds while developing multisensory tasting experiences (a practice that is also commonly referred as gastrophysics[7]). So far, we have been able to show systematically that it is possible to produce music that modulates the perception of taste attributes in foods and drinks [3,20,23]. Furthermore, a few reports have suggested that it may also be feasible to characterize existent songs - that were not produced with gastrophysics in mind - in order to predict its potential modulatory effects on tastes and flavors, by analyzing their spectral, musical, and psychoacoustic features [21,24].

Now, what if we could use the aforementioned ability to characterize songs, while thinking about their potential modulatory effect on taste and flavor perception? We could, for instance, think of developing technologies that effectively classify existent music playlists associated with specific tastes and flavors? Imagine that, one day in the near future, you will buy a sandwich and, with it, there may be a Quick Response code (QR code) that will give you access to the 'ideal' song to be listened while eating the sandwich. On the one hand, it would be possible to offer such solutions to the food industry. Here, food designers could easily access songs/music to 'season' their eating and drinking experiences, perhaps with the aim of enhancing a specific taste attribute on simply making the experience more enjoyable.

Moreover, the same type of classification can be directly implemented for user experience purposes (i.e. as a plugin available as part of online streaming services, such as Spotify or Apple Music[8]; both offer developer kits). Personal playlists could be classified as a function of tastes/flavors. Customers could be aware, from their own musical preferences, which songs are more suitable while drinking, for instance, red wine versus white wine, cocktails, whisky, beer, etc. Given the wide range of musical and food preferences, it seems reasonable to explore means for customization.

Finally, the same classification system, which involves music and foods/drinks, could be offered to musicians who are producing music to be used in experiences based on Gastrophysics. They could know, potentially in real-time, that the songs that are being produced may have specific enhancing effects on taste and flavor attributes. Given that music has a direct influence on the emotional state of listeners (see [2], for an overview on sensation transference), we can presume that the usage of a song that is part of a person's favorite playlist could have more salient multisensory perceptual effects, when compared to another song that is, perhaps, unfamiliar to the same listener.

It is worth mentioning that people already create playlists for their food experiences. For example, when you search for the word "chocolate" in sound streaming music apps (e.g., Soundcloud, Spotify), you will most likely find multiple playlists that people have created for eating situations that involve chocolate. This may also be extended to foods and other beverages, such as barbecue (BBQ), pizzas, wine, beer, etc. These music streaming services offer researchers the opportunity to computationally analyze the way in which songs are classified as a function of food. Perhaps, as a first exploratory assessment, one could start by assessing which songs come up more often when searching for specific foods or drinks, and then conduct some machine learning (or similar) analysis for sonic parameters, and so on. For instance, if we search for 'white chocolate' in Apple Music, what would appear more often? Why would this be the case?

5.2 Sound-taste mixed/virtual reality

Sonic and visual stimuli are the most common sensory inputs that the available virtual reality environments rely on (or, at least, these two are the ones that are being most extensively studied and developed). Nevertheless, there is research that intends to work with taste as well. Some time ago, an 'electronic tongue', an instrument that is able to measure and compare tastes, has been developed [41]. Most recently, similar technologies are being studied with the intention of reproducing taste attributes directly into the brain, by means of electrical signals applied into the tongue [17]. What this means is that, eventually, taste could become part of virtual environments and, hence, sound-taste correspondences may also be exploited as an attractive added value inside mixed/virtual reality solutions. Furthermore, food/beverage companies (such as Coca-Cola and McDonalds), are already offering virtual reality solutions based on packaging[9,10] (packages that turn into cardboard-like virtual reality headsets), from which we could deduce that these companies may already have a strong interest on the potential development of the type of application that we are discussing here. We believe that one potential direction that companies will be taking in the years to come concerns the design of specific multisensory experiences in virtual reality to accompany food and drink products.

Moreover, Reinoso Carvalho et al. [24] reported an online study, where participants had to associate different sounds with food types. The results showed that, most of the times, the participants were able to consistently match one favorite food type with a given sonic stimulus. These preliminary results could be used as source of inspiration for the development of experiences where different background soundscapes may be used in order to potentially influence decision-making while ordering food in restaurants and catering facilities. For instance, people may feel commonly tempted to eat unhealthy food. What if a beach soundscape could gently lead customers to rethink their choices, while selecting from several food/beverage options? Now, think of this type of experiences in, for example, mixed/virtual environments, where people could purchase food virtually, while stimulated by immersive soundscaping techniques.

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[7] Gastrophysics is an emerging scientific discipline that employs a wide range of the theoretical, simulational and experimental biophysical techniques to study the empirical world of cooking and gastronomy [12].

[8] https://developer.spotify.com/ (retrieved on February/2016); http://www.apple.com/music/ (retrieved on February/2016)

[9] Retrieved from http://mashable.com/2016/03/02/coca-cola-vr-cardboard/#TW65473RjSqE (May, 2016)

[10] Retrieved from http://mashable.com/2016/02/29/vr-headset-happy-meals/#8OtR.JH5jiqT (May, 2016).

5.3 Sensors as part of multisensory tasting experiences

Two previous studies [19,25] presented acoustic-wireless sensor networks (AWSN), as a breakthrough technology for audio/acoustic applications, such as sound design. AWSN are, in practice, spatially distributed devices that uses sensor to, for example, monitor physical or environmental conditions. These networks could provide opportunities to sum real-time audio information into sound production techniques, and such usage could go even further. It could, for example, help on-field audiovisual producers to identify ideal locations and time frames for future high-quality on-location sound recordings. Part of the studies that have been reported in this manuscript require the production of customized soundscapes, which are able to blend, for example, music with real restaurant soundscapes, such as the sounds of people while eating and/or the sounds of cooking [21,24,32]. Although these methods do not specify the necessity of real-time audio streaming, with a AWSN implementation, eating/cooking sounds could be used as part of customized soundscapes. With such real-time techniques, one could work with different soundscapes in the same place (think of a lab equipped with Ambisonics or Wave field synthesis set-ups). This, in turn, would allow the implementation of, lets say, cross-cultural assessments, in which it would be possible to rely on natural soundscapes (potentially streamed in real-time) coming from the most different parts of the world.

Another interesting application relates to the role of sensors in the context of calories intake control. A recent study presented [1] a wearable system to monitor and recognize food intakes. An embedded hardware prototype collects food intake sensor data, which is captured by a microphone worn on the person's neck, in order to precisely record acoustic signals while eating. These acoustic data is preprocessed, and then sent to a smartphone via Bluetooth, where food types are immediately recognized. Now, imagine such system interacting with the aforementioned algorithms (see Section 5.1), in order to consistently align personal music playlists with, again, experiences designed based on Gastrophysics. Such playlists could potentially interact with its user, producing the foreseen sound-taste interaction effects on the food that is being eaten, in real-time.

6. Final remarks

Based on the studies reviewed, it is clear that soundscapes/music can influence the perception of taste/flavor. As such, we suggest that sound can be used to enhance multisensory food and drink experiences. This, and also the fact that consumers are willing to pay significantly more for food accompanied by customized soundscapes, open up new doors for the scientific inquiry of auditory-gustatory interactions and for rethinking the way in which we consume food along with music.

How can we explain the fact that sonic cues influence the way we perceive tastes and flavors? When thinking about how sound can modulate the perceived taste, it is not so easy to point to a single mechanism [36]. For example, crossmodal correspondences may influence taste and flavor perception via psychoacoustic features that match or mismatch tasting attributes, by drawing people's attention towards such attributes [10]. However, soundscapes (or music) that we enjoy may trigger emotional effects that could be transferred to the experience of eating/drinking. Therefore, specific tasting cues may be particularly emphasized by our emotions ([23,28]; see [2], for a review on sensation transference). What is more, it has also been argued that a people's mood can influence their olfactory detection abilities (e.g. [16]) and the perception over their experience of a gustatory stimuli [6,7]. In addition, any emotion that might be induced by music can have an attentional effect on the way people perceive taste. For instance, [9] recently reported that sweetness can be perceived as more dominant when people enjoy the music that they are listening to, while tasting an ice cream. On the other hand, higher levels in perceived bitterness seem to be triggered by music that people dislike. What is more, a bitter chocolate accompanied by high-pitched sounds may be perceived as less bitter, making its consumption more pleasant - and potentially with less added sugar - for those who prefer sweeter tastes [23,29].

Finally, it is important to note that our studies so far involved ecological set ups, in order to make our results widely applicable. As future work, we believe that such insights could blend with novel technological solutions (i.e. algorithms, gadgets, sensors, etc.) in order to potentially bring this knowledge into our daily lives. This way, chefs, the food/beverage industry, and people from the general public in general, could further rely on sound-taste correspondences in order to customize and enhance their own individual (or group) eating/drinking experiences.

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7. References

[1] Bi, Y., Lv, M., Song, C., Xu, W., Guan, N., & Yi, W. (2016) AutoDietary: A Wearable Acoustic Sensor System for Food Intake Recognition in Daily Life. *Sensors, 16*(3).

[2] Cheskin, L. (1972). *Marketing success: How to achieve it*. Boston, MA: Cahners Books.

[3] Crisinel, A.-S., Cosser, S., King, S., Jones, R., Petrie, J., & Spence, C. (2012). A bittersweet symphony: Systematically modulating the taste of food by changing the sonic properties of the soundtrack playing in the background. *Food Quality and Preference, 24*(1), 201-204.

[4] Eitan, Z., & Rothschild, I. (2010). How music touches: Musical parameters and listeners' audiotactile metaphorical mappings. *Psychology of Music*, *39*(4), 449-467.

[5] Ferber, C., & Cabanac, M. (1987). Influence of noise on gustatory affective ratings and preference for sweet or salt. *Appetite*, *8*(3), 229-235.

[6] Frandsen, L. W., Dijksterhuis, G. B., Brockhoff, P. B., Nielsen, J. H., & Martens, M. (2007). Feelings as a basis for discrimination:

Comparison of a modified authenticity test with the same–different test for slightly different types of milk. *Food Quality and Preference*, *18*(1), 97-105.

[7] Heath, T. P., Melichar, J. K., Nutt, D. J., & Donaldson, L. F. (2006). Human taste thresholds are modulated by serotonin and noradrenaline. *The Journal of neuroscience*, *26*(49), 12664-12671.

[8] Heylighen, A., Rychtáriková, M., & Vermeir, G. (2009). Designing spaces for every listener. *Universal Access in the Information Society*, *9(3)*, 283-292.

[9] Kantono, K., Hamid, N., Shepherd, D., Yoo, M. J., Grazioli, G., & Carr, B. T. (2016). Listening to music can influence hedonic and sensory perceptions of gelati. *Appetite, 100*, 244-255.

[10] Knoeferle, K., & Spence, C. (2012). Crossmodal correspondences between sounds and tastes. *Psychonomic Bulletin Review, 19*, 992-1006.

[11] Koizumi, N., Tanaka, H., Uema, Y., & Inami, M. (2011, November). Chewing jockey: augmented food texture by using sound based on the cross-modal effect. In *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology*, 21. ACM.

[12] Mouritsen, O. G. (2012). The emerging science of gastrophysics and its application to the algal cuisine. *Flavour*, *1*(1), 6.

[13] Nijholt, A., Velasco, C., Huisman, G., & Karunanayaka, K. (in press). A multi-sensorial approach to human-food interaction. Workshop at *CHI* 2016.

[14] Obrist, M., Velasco, C., Vi, C. T., Ranasingue, N., Israr, A., Cheok, A. D., Spence, C., & Gopalakrishnakone, P. (in press). Touch, taste, & smell interfaces: The future of multisensory HCI. Workshop at *CHI* 2016.

[15] Petit, O., Cheok, A. D., Spence, C., Velasco, C., & Karunanayaka, K. T. (in press) Sensory marketing in light of new technologies. In Proceedings of the *12th International Conference on Advances in Computer Entertainment Technology*. ACE.

[16] Pollatos, O., Kopietz, R., Linn, J., Albrecht, J., Sakar, V., Anzinger, A., ... & Wiesmann, M. (2007). Emotional stimulation alters olfactory sensitivity and odor judgment. *Chemical senses*, *32*(6), 583-589.

[17] Putic, G. (2015) Smartphones about to make leap, carry basic senses. *Voice of America News, Science & Technology.* Retrieved from http://www.voanews.com/content/smartphones-to-carry-basic-sense-of-smell-taste-and-touch/2617420.html (February, 2016).

[18] Reinoso Carvalho, F., Van Ee, R., & Touhafi, A. (2013). T.A.S.T.E. Testing Auditory Solutions Towards the improvement of the Tasting Experience. In *Proceedings of 10th International Symposium on Computer Music Multidisciplinary Research*, 795-805. Publications of L.M.A., Marseille.

[19] Reinoso Carvalho, F., Tiete, J., Touhafi, A., & Steenhaut, K. (2014). ABox: New method for evaluating wireless acoustic-sensor networks. *Applied Acoustics*,*79*, 81-91.

[20] Reinoso Carvalho, F., Van Ee, R., Rychtarikova, M., Touhafi A., Steenhaut, K., Persoone, D., Spence, C. & Leman, M. (2015). Does music influence de Multisensory tasting experience? *Journal of Sensory Studies, 30*(5), 404-412.

[21] Reinoso Carvalho, F., Van Ee, R., Rychtarikova, M., Touhafi, A., Steenhaut, K., Persoone, D., & Spence, C. (2015). Using sound-taste correspondences to enhance the subjective value of tasting experiences. *Frontiers in Psychology*, *6*:1309.

[22] Reinoso Carvalho, F., Van Ee, R., Touhafi, A., Steenhaut, K., Leman, M. & Rychtarikova, M., (2015). Assessing multisensory tasting experiences by means of customized sonic cues. In *Proceedings of Euronoise 2015, 352*, 1-6. Maastricht.

[23] Reinoso Carvalho, F., Wang, Q. (J.), Van Ee, R., & Spence, C. (2016). The influence of soundscapes in the perception and evaluation of beers. *Food Quality and Preference*, *52*, 32-41.

[24] Reinoso Carvalho, F., Van Ee, R. & Rychtarikova, M., (2016). Matching soundscapes and music with food types. In *Proceedings of Euroregio 2016, June 13th -15th, Porto, Portugal.*

[25] Reinoso Carvalho, F., Touhafi, A. & Steenhaut, K. (2016). Wireless Sensor Networks for sound design: A summary of possibilities and challenges. In *Proceedings of 140th AES Convention*, *June 4th-7th 2016*, Paris.

[26] Reinoso Carvalho, F., Velasco, C., Van Ee, R., Leboeuf, Y., & Spence (2016). Music influences hedonic and taste ratings in beer. *Frontiers in Psychology, 7.*

[27] Reinoso Carvalho, F., van Ee, R., Touhafi, A., Steenhaut, K., & Velasco, C. (2016). Using sound to enhance taste experiences: An overview. In *Proceedings of 12th International Symposium on Computer Music Multidisciplinary Research, São Paulo, Brazil.*

[28] Reinoso Carvalho, F., Wang, Q. (J.), Van Ee, R., Persoone, D., & Spence, C. (submitted). Smooth Operator: Music modulates the perceived creaminess, sweetness and bitterness of chocolate. *Appetite.*

[29] Reinoso Carvalho, F., Wang, Q. (J.), Steenhaut, K., Van Ee, R., & Spence, C. (submitted). Tune that beer! Finding the pitch corresponding to the Taste of Belgian Bitter Beers. *Beverages.*

[30] Spence, C. (2012). Auditory contributions to flavour perception and feeding behaviour. *Physiology & Behavior*, *107(4)*, 505-515.

[31] Spence, C. (2014). Noise and its impact on the perception of food and drink. *Flavour*, *3:*9.

[32] Spence, C. (2015). Eating with our ears: Assessing the importance of the sounds of consumption to our perception and enjoyment of multisensory flavour experiences. *Flavour, 4:*3.

[33] Spence, C., Michel, C., & Smith, B. (2014). Airplane noise and the taste of umami. *Flavour*, *3:*2.

[34] Spence, C., & Shankar, M. U. (2010). The influence of auditory cues on the perception of, and responses to, food and drink. *Journal of Sensory Studies*, *25,* 406-430.

[35] Spence, C., Shankar, M. U., & Blumenthal, H. (2011). 'Sound bites': Auditory contributions to the perception and consumption of food and drink. In *Art and the Senses.* (Eds. F. Bacci & D. Melcher), 207-238. Oxford University Press, Oxford, UK.

[36] Spence, C., & Wang, Q. J. (2015). Wine and music (II): can you taste the music? Modulating the experience of wine through music and sound. *Flavour*, *4*(1), 1-14.

[37] Stafford, L. D., Fernandes, M., & Agobiani, E. (2012). Effects of noise and distraction on alcohol perception. *Food Quality and Preference*, *24(1),* 218-224.

[38] Velasco, C., Michel, C., Youssef, J., Gomez, X., Cheok, A. D., & Spence, C. (in press). Colour-taste correspondences: Design food experiences to meet expectations or surprise. *International Journal of Food Design.*

[39] Velasco, C., Obrist, M., Petit, O., Karunanayaka, K., Cheok, A. D., & Spence, C. (in press). Crossmodal correspondences in the context of digital taste and flavor communications. Workshop at *CHI 2016.*

[40] Winquist, F., Wide, P., & Lundström, I. (1997). An electronic tongue based on voltammetry. *Analytica chimica acta*, *357*(1), 21-31.

[41] Woods, A. T., Poliakoff, E., Lloyd, D. M., Kuenzel, J., Hodson, R., Gonda, H., Batchelor, J., Dijksterhuis, A., & Thomas, A. (2011). Effect of background noise on food perception. *Food Quality and Preference, 22(1),* 42-47.

[42] Zampini, M., & Spence, C. (2004). The role of auditory cues in modulating the perceived crispness and staleness of potato chips. *Journal of sensory studies*, *19*(5), 347-363.

The Unity and Complexity of Flavour Perception: Multisensory Phenomenology and Processing in Human-Food Interactions

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ABSTRACT

This paper discusses two main features of flavour perception, namely its unity and complexity occurring at different levels of our cognitive system – multimodal phenomenal experience and underlying information processing. Exploring these issues is important for providing a holistic account of tasting flavours that is both empirically and phenomenologically sensitive. In addition, it yields significant clues to multimodal nature of perception and consciousness in general.

CCS Concepts

• **Human-centered computing~HCI theory, concepts and models** • *Applied computing~Psychology*

Keywords

flavour perception; perceptual phenomenology; perceptual processing; multimodality of perception; multisensory integration; unity; complexity; science and philosophy of perception; conscious experience of tasting

1. INTRODUCTION

Different things may be meant by ”perception”. In order to avoid misunderstandings it is useful to differentiate two main ways of approaching perception. The view of perception as perceptual processing deals with different stages of information processing from sensory stimulation to perceptually based beliefs or actions (no matter if perceptual information is used at the personal or unconscious sub-personal level).

In contrast, perception as perceptual phenomenology concentrates on conscious perception, i.e., perceptual experience, its various features and epistemological implications (Nanay 2016).

The two approaches often come apart, but to understand the complex phenomenon that is perception, especially what kind of perceptual processing leads to what kind of perceptual experience, we should try to bring these views together.

It seems that what may help the reconciliation between the two approaches to perception is to narrow down the research focus and work on one specific kind of perception and its characteristics, rather than to look for some common, universal features of perception. For instance, working on the specificities of flavour perception requires going beyond the introspection of conscious perceptual experience of tasting and considering empirical evidence of how sensory information relevant to flavour gets processed.

2. THE MULTIMODALITY OF TASTING FOOD

One of the recent interests in the science and philosophy of perception is the study of the multimodal nature of perception exhibited by intricate and heterogeneous interactions between sensory modalities, which can start at early stages of perceptual processing (Spence and Driver 2004; Watkins et al. 2006; O'Callaghan 2008; Mroczko-Wąsowicz 2016).

Human-food interaction, in particular flavour perception is an example of multimodal perception par excellence, both at the level of phenomenology and processing. Food, as many other multisensory perceptual objects, can be perceived with more than one sense modality. Additionally, our experience of tasting food tells us that sensory attributes related to taste, smell, tactile texture, temperature, color, and sound often co-occur and influence each other.

In the act of tasting something we experience a blend of sensory features, we experience flavours. Although we ordinarily call it ‘taste' assuming a unisensory basis of this experience, this is a complex interaction effect of gustatory, olfactory, tactile, and trigeminal inputs which are conjointly perceived and combined into an integrated flavour percept, a unified flavour experience (Auvrey and Spence 2008; Yeomans et al. 2008; Spence, Auvray, and Smith 2015; Smith 2015).

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3. THE UNITY OF FLAVOUR PERCEPTION

The unity associated with a flavour experience arises without any special cognitive efforts of reflecting on different sensory parts of the experience. This is due to their (multisensory) integration at a lower sub-personal level of processing (Bult et al. 2007; Spence 2012; Smith 2015).

While instances of successful multisensory integration facilitated by spatio-temporal, semantic, or sensory congruence are not always accompanied by unified multimodal experiences, flavour binding gets clearly manifested in multisensory conscious episodes (Deroy 2014; Deroy et al. 2016; Smith 2015).

There are two main conceptions of multisensory integration. Accordingly, cross-modal cases can be interpreted in two ways, causally or constitutively. The causal thesis claims that input in one modality has a causal impact on experiences in another modality. The multisensory nature of sensory integration is then limited to processing the relevant perceptual input. It is multisensory only in this minimal sense because the resulting perceptual representations are just conjunctions decomposable into consciously independent, unisensory components. In contrast, the constitutive thesis states that the multisensory nature of sensory integration extends beyond perceptual processing to perceptual representations that are intrinsically multimodal and fundamentally unified states, i.e., they cannot be fully decomposed into independent unisensory elements (Bayne 2014).

In flavour perception, the relationship of olfactory input to gustatory experience seems to be constitutive not merely causal. Since flavours consist in olfaction, we cannot enjoy tasting food's flavours when having impaired smell during a severe cold. On the contrary, the contribution of auditory input to gustatory experience may be just a matter of causal influence, e.g., when hearing the sound of crunching makes potato chips taste crispier and apples fresher (Zampini and Spence 2004, 2010). It seems it is merely a causal relationship because a lack of auditory input would not stop us from tasting the food's flavours. Generally, not everything that affects our flavour experience is a constitutive part of flavour, e.g., environmental lighting and sound, the perceived weight of the food, as well as hedonic values we assign to the food we like or dislike (Smith 2013b). Although these are testable predictions, still more work is needed to confirm the assumptions. Certainly, it is important to distinguish the overall phenomenology of eating, including evaluative, cognitive, and sensory aspects from the pure flavour phenomenology.

The outcome of multisensory processing in the case of flavour perception is not a mere sum of co-occurring independent unisensory contents, but rather an inherently multimodal unified whole that cannot be parceled out into modality specific components. Experiences of flavour are genuine cases of unified multisensory consciousness since the emerging new quality of flavour could not be experienced just by a conjunction of unisensory contents. The single unified experience of a flavour comes into existence through the multimodal integration of chemical senses and touch; it is a joint result of their interaction. As its sensory elements combine outside of consciousness, we experience flavour holistically without a mereological part-whole structure. This can shed some light on the characterization of the basic units of conscious perceptual experience, of the building blocks that feature in multisensory perception as perceptual phenomenology (Bayne 2014).

4. THE COMPLEXITY OF FLAVOUR PERCEPTION

The above discussed unity of flavour experience is likely responsible for our failing to recognize the high complexity in the acts of tasting food.

As Barry Smith states, "Taste has been unjustly neglected in the philosophy of perception, largely as the result of the failure to recognize the complexity of tasting experiences. This complexity has been brought to light through research by sensory scientists, which offers philosophers the opportunity to reexamine traditional thinking." (Smith 2013a: 731)

Usually we are not able to separate particular components of a flavour experience. This inability to phenomenologically decompose a flavour into its constitutive elements – especially to separate gustation and retronasal smell - leaves us with a single, unified percept of a flavour (Smith 2013b).

The reason why the complex nature of flavour perception is neglected, is that one of the main components of this aggregate – retronasal olfaction – goes missing and cannot be consciously acknowledged in the phenomenology of tasting. This is related to the phenomenon of oral referral. It contributes to the everyday confusion between taste and smell so that people are not sure which of their senses have actually been stimulated and which sense really provides the information that is bound together in flavour percepts and localized together to the mouth. The phenomenon can also be characterized as an inability to voluntarily attend to olfactory component once it gets integrated into a flavour object/Gestalt due to attentional capture by salient gustatory stimuli (Lim and Johnson 2011, 2012; Stevenson et al. 2011a, 2011b; Spence 2016). As a result, people find it very difficult to attend selectively to food-related olfactory stimuli following their oral referral to the oral cavity (Ashkenazi and Marks 2004).

Also, in many cases we do not notice the temporal dimension of tasting flavours. We fail to recognize that flavour perception is a compound and unfolding process, i.e., a series of stages with a dynamic time course influencing the phenomenal quality of flavour (Piggott 1994; Smith 2013a). This means that different flavours are perceived at different places in the mouth across the time of food consuming. This sequence of events shapes our assessment of things we eat and drink, whether we like them or not as well as which details we detect in different phases of tasting.

Finally, there are some other extra factors able to modify our experience of tasting food. Though they do not belong to the necessary and sufficient constitutive elements of flavour, they still have a significant causal impact on the overall phenomenology of human-food interaction. These are the features of cognitive phenomenology and embrace cognitive, evaluative, and affective aspects that accompany the hedonistic side of this specific interaction (cf. Bayne and Montague 2011).

5. IMPLICATIONS FOR UNDERSTANDING THE EXPERIENCE OF TASTING FLAVOURS

Since flavour perception exhibits two main features, viz. unity and complexity, one may wonder what the ultimate nature of flavour perception actually is and how to understand flavour experiences. This question can be further complicated by asking whether flavours are mainly psychological constructs, subjective sensations produced by our brains when we eat or drink (Prescott 1999; Shepherd 2012; Small 2012), or rather experiences of certain objective properties of substances such as foods and liquids (Smith 2013b). On the subjectivist view, tasting flavours is not one of the higher distal perceptual senses like vision or audition, which deliver knowledge about the external world and its properties. It is one of the lower inner senses giving us information about ourselves and our individual responses to the items we consume. On the objectivist view of tasting flavours, flavours are properties that foods or liquids possess and we are able to perceive these properties by tasting. This way we can gain knowledge of external objects, i.e., of things we eat and drink (Smith 2015).

None of these conceptions seems fully capable to accommodate the main features of flavours and flavour experiences. A combination of them might provide key insights into the nature of flavour perception. Applying the traditional distinctions common in philosophy of perception between high and low senses, informing us about the properties of the outside world or about our bodily sensations, is not really useful. The same is the case for distinguishing between flavour perceptions and flavours per se. What is important for a comprehensive view of the holistic nature of flavour perception is to understand flavours as inseparable from our experience of flavours and to recognize that in flavour perception we deal with physical properties of something in the environment, features of different sensory systems involved in flavour binding, and phenomenal qualities of the arising multimodal experiences.

Exploring these issues is crucial in order to provide an interdisciplinary account of flavour that is both empirically and phenomenologically sensitive. Combining both perspectives reveals that distinct components interacting together give rise to experiences of tasting a single but not simple flavour – an integrated flavour percept, or a unitary flavour object (Lim and Johnson 2012; Stevenson 2014). Such an intersensory Gestalt is an emergent multisensory property, that cannot be located in either of the component sense modalities but only as a result of their combination (Spence 2016; Spence and Bayne 2015; Spence, Sanabria, and Soto-Faraco 2007). Accordingly, flavour may be understood as a mereologically complex yet unified, constitutively multimodal sensory individual (cf. Nanay 2016; O'Callaghan 2016).

This also means that we are not able to direct our endogenous attention selectively to each particular sensory modality contributing to this multimodal sensory individual, e.g., retronasal olfaction remains beyond our awareness (Spence 2014; Smith 2013a). If so then in the case of flavour perception we cannot expect to be able to switch our attention between various co-occurring unisensory components, which is generally supposed by the unisensory view of the structure of perceptual consciousness. In contrast, the multisensory view endorsing that consciousness contains experiences associated with distinct sensory modalities simultaneously can account for the conscious experience of flavour more adequately (see Spence and Bayne 2015 for the debate between the unisensory and multisensory views).

Another consequence of the intricate concoction of flavour experiences is that they challenge philosophical theories that assume our senses transparently inform us about the character of our experience, theories that suppose we have a direct privileged access to our perceptual experiences and accurate first-person knowledge of their nature (Alston 1971; Shoemaker 1990; Gertler 2003). Flavour experiences demonstrate that we may overlook some aspects of our perceptual episodes and even though they are conscious experiences almost immediately known to the subject, we can have neither phenomenal consciousness nor access consciousness of each of their components (cf. Block 1995). For these reasons, taking the multimodality of flavour perception seriously constraints what can be said about conscious perceptual experience.

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7. REFERENCES

[1] Alston, W. 1971. Varieties of privileged access. *American Philosophical Quarterly* 8, 223-241.

[2] Ashkenazi, A., and Marks, L. E. 2004. Effect of endogenous attention on detection of weak gustatory and olfactory flavors. *Perception & Psychophysics* 66, 596–608.

[3] Auvray, M., and Spence, C. 2008. The multisensory perception of flavor. *Consciousness and Cognition* 17(3), 1016-31.

[4] Bayne, T. 2014. The multisensory nature of perceptual consciousness. In *Sensory integration and the unity of consciousness*, D. Bennett, and C. Hill, Eds. MIT Press, Cambridge, MA, USA, 15-36.

[5] Bayne, T. and Montague, M., Eds. 2011. *Cognitive phenomenology*. Oxford University Press, Oxford, UK.

[6] Block, N. 1995. On a confusion about the function of consciousness. *Behavioral and Brain Sciences* 18, 227–47.

[7] Bult, J., Wijk, R., and Hummel, T. 2007. Investigations on multimodal sensory integration: Texture, taste, and ortho- and retronasal olfactory stimuli in concert, *Neuroscience Letters* 411 (1), 6-10.

[8] Deroy, O. 2014. The unity assumption and the many unities of consciousness. In *Sensory integration and the unity of consciousness*, D. Bennett, and C. Hill, Eds. MIT Press, Cambridge, MA, USA, 105–124.

[9] Deroy, O., Faivre, N., Lunghi, C., Spence, C., Aller, M., and Noppeney, U. 2016. The complex interplay between multisensory integration and perceptual awareness. *Multisensory Research* 29(6/7), 585-606. <10.1163/22134808-00002529>

[10] Gertler, B. 2003. *Privileged access: Philosophical accounts of self-knowledge*. Ashgate Publishing, Aldershot, UK.

[11] Lim, J., and Johnson, M.B. 2011. Potential mechanisms of retronasal odor referral to the mouth. *Chemical Senses* 36, 283–289.

[12] Lim, J., and Johnson, M. 2012. The role of congruency in retronasal odor referral to the mouth. *Chemical Senses* 37, 515–521.

[13] Mroczko-Wasowicz, A. 2016. Perception-cognition interface and cross-modal experiences: Insights into unified consciousness. *Front. Psychol.* 7:1593. doi: 10.3389/fpsyg.2016.01593

[14] Nanay, B. 2016. *Current controversies in philosophy of perception*. Routledge, New York, USA.

[15] O'Callaghan, C. 2008. Seeing what you hear: Cross-modal illusions and perception. *Philosophical Issues* 18(1), 316–338.

[16] O'Callaghan, C. 2016. Enhancement through coordination. In *Current controversies in philosophy of perception*, B. Nanay, Ed. Routledge, New York, USA, 109-120.

[17] Piggott, J. 1994. Understanding flavour quality: Difficult or impossible? *Food Quality and Preference* 5, 157–171.

[18] Prescott, J. 1999. Flavour as a psychological construct: implications for perceiving and measuring the sensory qualities of foods. *Food Quality and Preference* 10, 349-356.

[19] Shepherd, G. M. 2012. *Neurogastronomy: How the brain creates flavor and why it matters*. Columbia University Press, New York, USA.

[20] Shoemaker, S. 1990. First person access. In *Philosophical perspectives 4: Action theory and philosophy of mind*, J. Tomerlin, Ed. Ridgeview Publishing Company, Atascadero, CA, USA .

[21] Small, D. M. 2012. Flavor is in the brain. *Physiology & Behavior* 107 (4), 540-552.

[22] Smith, B. 2013a. Taste, philosophical perspectives. In *Encyclopaedia of mind*, H. Pashler Ed. University of California, San Diego, CA, USA, 731–734.

[23] Smith, B. 2013b. The nature of sensory experience: The case of taste and tasting. *Phenomenology and Mind* 4, 293-313.

[24] Smith, B. 2015. The chemical senses. In *The Oxford handbook to philosophy of perception*, M. Matthen, Ed. Oxford University Press, Oxford, UK, 314-352.

[25] Spence, C. 2012. Multi-sensory integration & the psychophysics of flavour perception**.** In *Food oral processing—Fundamentals of eating and sensory perception,* J. Chen, and L. Engelen, Ed. Blackwell, Oxford, UK, 203–219.

[26] Spence, C. 2014. Orienting attention: A crossmodal perspective. In *The Oxford handbook of attention,* A.C. Nobre, and S. Kastner Eds. Oxford University Press, Oxford, UK, 446–471.

[27] Spence, C. 2016. Oral referral: On the mislocalization of odours to the mouth. *Food Quality & Preference* 50, 117-128.

[28] Spence, C. and Bayne, T. 2015. Is consciousness multisensory? In *Perception and its modalities*, D. Stokes, M. Matthen, and S. Biggs, Eds. Oxford University Press, Oxford, UK, 95–132.

[29] Spence, C., and Driver, J. Eds. 2004. *Crossmodal space and crossmodal attention*. Oxford University Press, Oxford, UK.

[30] Spence, C., Auvray, M. and Smith, B. 2015. Confusing tastes and flavours. In *Perception and its modalities*, D. Stokes, M. Matthen, and S. Biggs, Eds), pp. 247–274. Oxford University Press, Oxford, UK.

[31] Spence, C., Sanabria, D., and Soto-Faraco, S. 2007. Intersensory Gestalten and crossmodal scene perception. In *Psychology of beauty and Kansei: New horizons of Gestalt perception,* K. Noguchi, Ed. Fuzanbo International, Tokyo, 519–579.

[32] Stevenson, R. J. 2014. Flavor binding: Its nature and cause. *Psychological Bulletin*, 140, 487–510.

[33] Stevenson, R. J., Oaten, M. J., and Mahmut, M. K. 2011a. The role of attention in the localization of odors to the mouth. *Attention, Perception, & Psychophysics* 73, 247–258.

[34] Stevenson, R. J., Oaten, M. J., and Mahmut, M. K. 2011b. The role of taste and oral somatosensation in olfactory localization. *Quarterly Journal of Experimental Psychology* 64, 224–240.

[35] Watkins, S., L. Shams, S. Tanaka, J.-D. Haynes, and Rees, G. 2006. Sound alters activity in human V1 in association with illusory visual perception. *NeuroImage* 31, 1247–1256.

[36] Yeomans, M. Chambers, L., Blumenthal, H., and Blake, A. 2008. The role of expectancy in sensory and hedonic evaluation: The case of smoked salmon icecream. *Food Quality and Preference* 19, 565–573.

[37] Zampini, M., and Spence, C. 2004. The role of auditory cues in modulating the perceived crispness and staleness of potato chips. *J Sens Sci* 19, 347–363. 10.1111/j.1745-459x.2004.080403.x

[38] Zampini, M., and Spence, C. 2010. Assessing the role of sound in the perception of food and drink. *Chemosens Percept* 3, 57–67. 10.1007/s12078-010-9064-2

A Multisensory Approach for the Design of Food and Drink Enhancing Sonic Systems

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ABSTRACT

Everyday eating and drinking experiences involve multiple, interrelated, sensory inputs. However, when it comes to human-food interaction design (HFI) research, certain senses have received more attention than others have. Here, we focus on audition, a sense that has received limited attention in such context. In particular, we highlight the role of food/drink-related eating sounds, as a potential input for human-food interaction design. We review some of the few systems that have built on such sounds within food and drink contexts. We also present a multisensory design framework and discuss how the systematic connections that exist between the senses may provide some guidelines for the integration of eating sounds in HFI design. Finally, we present some key prospects that we foresee for research in technology design in HFI.

CCS Concepts

• **Applied computing→ Law, social and behavioral sciences → Psychology**

Keywords

Food; drink; sound; multisensory; eating

1. INTRODUCTION

It has been suggested that eating and drinking are some of the most multisensory experiences of our everyday lives [1,2]. Just think of your average snack or meal. The visual and olfactory characteristics of the food provide you with an initial idea of what you are about to experience. Then, you may use either specific tableware or perhaps your hands to eat it. The act of eating will take place in an environment characterized by specific visual (e.g., light or decoration) and sonic atmospheres (e.g., music or noise). Next, when you put the food into your mouth, you experience a complex psychological construct, namely, flavor. Flavor is generally defined as the combination of, at least, taste (e.g., sweet, sour, salty, bitter, and umami), which arises from the stimulation of the receptors of tongue, and retronasal smell inputs (smells processed orally), and perhaps other elements such as the texture and temperature [3]. In fact, whether or not the flavor construct in itself involves other sensory inputs is still an open question, though it is largely acknowledged that the other senses (e.g., vision, hearing) can, at the very least, influence the expectations associated with - and the experience of - foods and drinks [4]. That said, not all senses have received the same attention in this context. In the present article, we focus on one of such senses, namely, audition, and the potential that auditory inputs associated with eating offer in the world of HFI.

The aim of this article is to highlight the potential role of eating-related sounds in multisensory human-food interaction design. We argue that in order to successfully articulate these sounds in HFI, designers should focus on the different multisensory inputs present in a given experience, and should therefore build from the existing knowledge on multisensory perception. We start by describing the role of sound in eating and drinking. After that, we present some of the few technologies that have been designed to date that capitalize on eating-related sounds for HFI design. We then present a design framework based on earlier suggestions on synaesthetic design (e.g., [5,6]), that could be used as a guideline to exploit sound, combined with other sensory cues, in the context of multisensory HFI design. The idea here is that, in design contexts, the senses should not be approached separately or independently, but rather in combination whilst contemplating their systematic connections. As Haverkamp [7] puts it, the ultimate goal consists of "…*achieving the optimal figuration of objects based upon the systematic connections between the senses*" (p. 15). Following that, we present what we believe are

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some key opportunities for research in technology design that take advantage of sound for the design of meaningful HFI.

2. THE ROLE OF SOUND IN EATING AND DRINKING

Many people seem to believe that audition is the least important sense when it comes to flavor perception [8]. However, research has started to demonstrate that sound is critical to both our eating and drinking experiences, as well as to the flavors that arise from them [9]. As we will see later, the sounds associated with a food or a drink item before we purchase them (e.g., TV ad, vending machine, cooking), the sounds derived from our interaction with such items (e.g., crunching, gulping, or smacking), but also the environmental noise or music that might be playing when we eat or drink, can impact our expectations and experiences of such items (see Figure 1, for some examples).

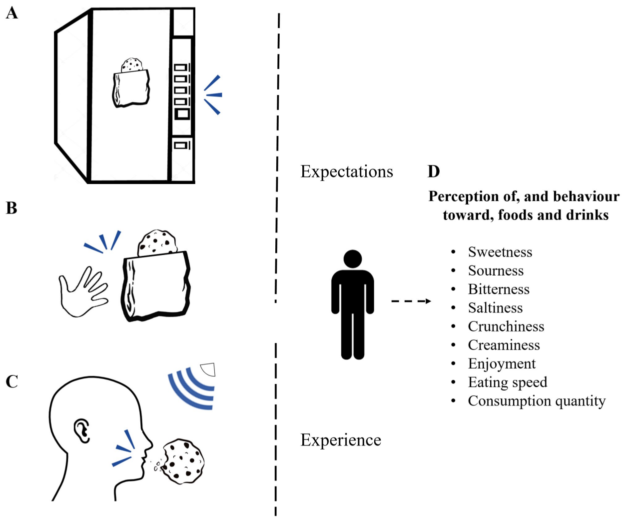

Figure 1. Sounds are ever-present in HFIs, from the moment when we acquire and process the food (A), through our interaction with its presentation format, (B), to the moment when we eat it (C). The sounds that accompany such process can influence the expectations and perception of the food, but also our behavior towards it (D).

A pleasant sonic atmosphere can make a meal more or less enjoyable [10], while the sound derived from chewing a carrot or potato chip can make a big difference in terms of how crunchy (and fresh) we may perceive it [11,12]. Even before we eat, the sonic cues that originate from the foods and drinks that we consume can already prime specific notions about their sensory and hedonic attributes. For instance, research has demonstrated that, on the sole basis of the sound that can be heard when a liquid is poured into a receptacle, people can tell whether the liquid is hot or cold. Such percept can also be modified by artificially changing the sonic properties of the pouring liquid [13]. What is more, research has begun to show that other sonic cues - such as the level of background noise - can modulate the perception of specific taste attributes (e.g., how sweet the food is). For instance, Yan and Dando [14] showed that noise can reduce the perception of sweetness and enhance the perception of umami. Perhaps unsurprisingly, many modernist chefs are now experimenting with sound as a new 'ingredient' in their experience recipe [12,13].

Whilst our understanding of the role of audition in the perception and experience of foods and drinks is still at an early stage, there has been a growing number of studies on the topic in the last decade or so (see [15], for a review). This has opened up a number of opportunities for technology design in the context of HFI. Nevertheless, research and development of design that capitalize on sounds linked with eating and drinking (e.g., masticating, ingurgitating, crunching, gulping, or smacking), in order to invent new, or re-designing already existing, food and drink experiences, has been rather limited. Eating-related sounds are critical to any eating or drinking experience as they can influence the perception of attributes such as crunchiness, creaminess, and carbonation, and influence the enjoyment of the food [8].

3. FOOD AND DRINK ENHANCING EATING-RELATED SOUND-BASED SYSTEMS

Whereas the notions of multisensory human-computer interaction (HCI), as well as multisensory HFI, have gained momentum in the last decade (see [18]), the usage/adaptation of sounds associated with eating, in combination with other sensory inputs, in HFI, has been somewhat limited [12]. Nonetheless, a few researchers have worked in augmenting food and drink properties by means of enhancing the auditory feedback associated with eating and drinking.

For example, Hashimoto et al. [19] introduced one of the early systems design to augment drinking experiences based on the multisensory cues associated with drinking. "Straw-like User Interface (SUI)" (see Figure 2) allows people to virtually experience the process of drinking a beverage by reproducing the pressure, vibration, and sound that accompany the act of drinking (see also [20]). A system such as SUI may be an important step towards virtual food and drink experiences (see also [21]).

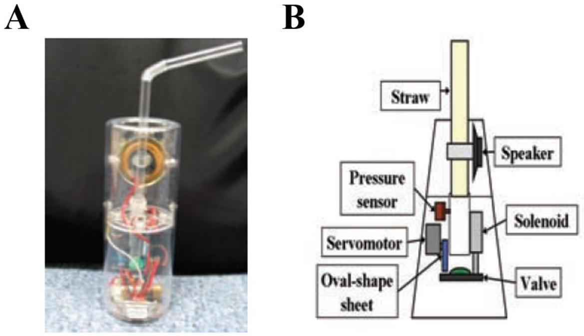

Figure 2. A real (A) and a schematic (B) representations of "Straw-like User Interface (SUI)" [19]. Figure reprinted from "Straw-like user interface: virtual experience of the sensation of drinking using a straw," ACE' 2006-Hollywood, California, USA, © 2006 ACM, Inc. http://doi.acm.org/10.1145/1178823.1178873.

Koizumi et al. [22] developed one of the first systems to capitalize on mastication sounds in order to enhance the perception of food textures, as well as the overall enjoyment of the food. The "Chewing Jockey" (see Figure 3), utilizes a bone-conduction speaker, a microphone, a sensor to track the jaw's movement, and a computer to control the sound that matches the process of mastication. These researchers designed two applications. In the first, a chewing game, participants would chew sweets and hear screaming sounds as they did so. Here, the idea was to make them feel that the gummies were living creatures in a horror movie-type experience. The second application was aimed at augmenting texture perception, and was based on previous research suggesting that the perception of crispiness of potato chips can be modulated by the sounds derived from mastication [9]. The authors concluded that the system was a promising tool for HFI, not only for the general public, but also for people with, for example, dental or oral-somatosensory dysfunctions.

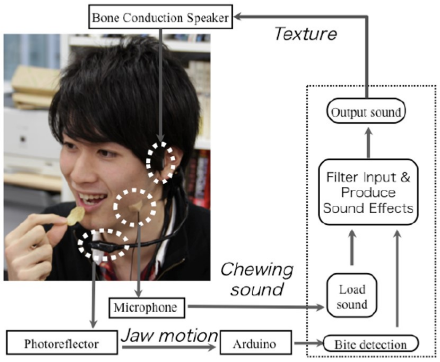

Figure 3. A schematic representation of the "chewing jockey" [22]. Figure reprinted from "Chewing Jockey: Augmented Food Texture by using sound based on the cross-modal effect," ACE' 2011-Lisbon, Portugal, © 2011 ACM, Inc. http://doi.acm.org/10.1145/2071423.2071449.

In another investigation, Kadomura et al. [23] introduced 'EducaTableware', a computer-based system designed to augment eating and drinking experiences via some of the utensils that we use to eat and drink. 'EducaTableware' involves two devices, namely a fork (or EaTheremin, see Figure 4A) and a cup (or TeaTheremin, see Figure 4B). Both devices use resistance values (e.g., resistance value of the food, biting time) to map/emit sounds during the process of eating and drinking. The aim of using such system consisted of encouraging better eating habits, in particular, among children.

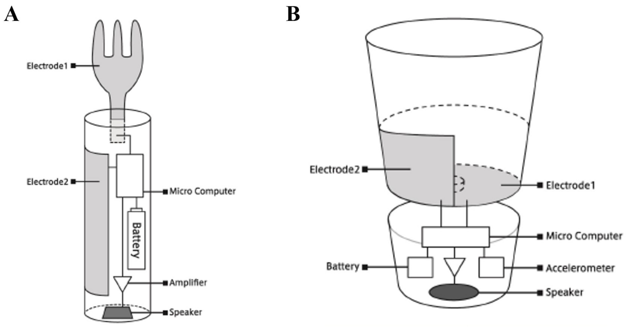

Figure 4. "EducaTableware's" EaTheremin (A) and "TeaTheremin" [23]. Figure reprinted from "EducaTableware: computer-augmented tableware to enhance the eating experiences," CHI EA '13-Paris, France. http://doi.acm.org/10.1145/2468356.2479613.

4. MULTISENSORY DESIGN OF TECHNOLOGIES TO ENHANCE FOOD AND DRINK EXPERIENCES

A common feature to the systems reviewed above is the fact that the sonic cues are never the only sensory input in their HFIs. In contrast, and as it is often common in eating/drinking environments, sound is just one of the many different sensory inputs involved in the experience. For that purpose, any system that design HFIs should consider the way in which different sensory inputs are combined, and/or influence one another, in order to evoke a specific percept or behavior.

4.1 Factors that Influence the Correspondence between Sensory Features

Indeed, one of the differences between a design approach in which each sense is considered independently or in multisensory fashion, lies on the kinds of questions that designers ask. For example, in the first approach one may ask "what is the optimal sound for a given food product?" whereas in the latter one may enquire "how does the food's sound could enhance a given taste note?" (e.g., [24]). With this in mind, it is critical to take into account the different factors that have been shown to influence how our brain relates information from the different senses. Note that this section does not aim to provide a comprehensive review of such factors, but rather discuss some of them as they may guide the process of multisensory design.

Figure 5 presents some of the elements that govern multisensory processing [17,25-27]. Elements such as the temporal (e.g., whether two signals happen at the same time) and spatial (e.g., whether two signals come from the same location) aspects of multisensory information are perhaps some of the most basic features that influence the correspondence between the senses [28]. In addition, it has been shown that sensory information that shares the same identity or meaning tend to correspond (namely semantic correspondence, e.g., [29]). This applies not only to individual objects (e.g., the sound of an apple bite and the image of an apple) but also for the contexts in which they are presented (e.g., perhaps the sound of Chopin does not correspond with the food of a fast food restaurant, whereas it may correspond well with a tea house, [30]).

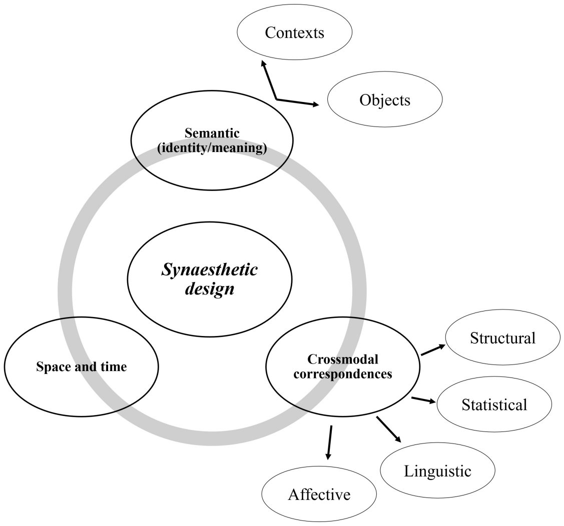

Figure 5. Levels of analyses for the design of multisensory experiences (e.g., [17,32])

Importantly, we also related information based on the compatibility of different cross-sensory features, or crossmodal correspondences. The concept of crossmodal (or synaesthetic) correspondences refer to the association that exist between features across the senses [31, 32]. In such associations, in contrast with semantic correspondences, when two features correspond (e.g., pitch and brightness), they often provide non-redundant, complementary, information about objects in the environment. For example, it is known that people associate basic tastes with specific pitches, but also with complex sounds [33].

Some researchers have suggested that there are four different kinds of crossmodal correspondences: (1) structural, (2) statistical, (2) linguistic, and (2) affective [27,34]. The first seems to arise from a basic common coding of stimulus features (e.g., intensity, see [35]) and the second as a function of the interiorization of the statistical constancies of the environment (such as pitch and spatial elevation, see [36]). Linguistic correspondences are related to metaphor; that is, in language we use terms from one sensory modality to describe attributes in another modality (e.g., describing odors in terms of musical parameters, see [37]). Finally, affective correspondences appear to result from a common 'feeling' evoked by the corresponding stimuli (e.g., as in music and colors, see [38]). These different kinds of crossmodal correspondences are not mutually exclusive; rather, they seem complement each other ([39]).

Note that the different factors described above may not act independently, but rather, in conjunction during perception [39]. In that sense, whilst, for example, people may hear the sound of coffee being poured into a receptacle (via a vender machine), the sound derived from grinding the coffee beans might guide people to expect the taste of coffee (semantic correspondence). Moreover, the sonic parameters of the liquid being poured into the receptacle may guide people's expectations about the creaminess or bitterness of the coffee (crossmodal correspondences). With these ideas in mind, although the focus of the present article is on the correspondence between eating sounds and the other senses, this design approach may well guide the creation of other multisensory experiences.

4.2 Congruence or Incongruence?

Whether different sensory cues may be used congruently or not (i.e., in terms of space/time, semantics, or correspondences) is not necessarily fixed and should be looked at the different moments of a given experience [40, 41, 42]. Figure 6 presents a schematic example. For instance, congruence between the senses can be approached before eating a cookie (Figure 6A), where people may be exposed to the visual, tactile, and sonic parameters associated with the cookie and its package. Such parameters can create specific expectations about the experience of consuming the cookie. But then the experience of eating, which comprises another moment of congruence (Figure 6C), may involve the taste, smell, and sound derived from mastication, or perhaps the ambient soundscape (which could, for example, mask the mastication sound). Additionally, one may also think about the congruence between the overall multisensory inputs during expectations and the overall multisensory inputs during the actual experience of the cookie (Figure 6B).

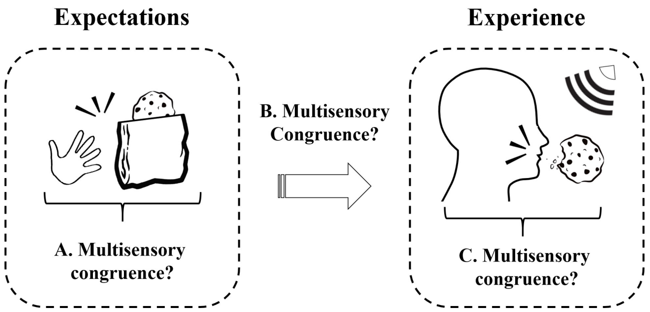

Figure 6. Examples of different moments of congruence. A) Are the different sensory features associated with the food/drink expectations congruent between themselves (before eating)? B) Are the sensory features and the expectations that they elicit congruent with the experience? C) Are the sensory features associated with the experience of the food/drink congruent between themselves?

It is worth mentioning that congruence can also be considered as relevant before we approach a food or a drink (e.g., when it is presented, for example, via TV commercials) and/or after the experience of eating or drinking (e.g., whether there are some leftovers). Undoubtedly, thinking of each 'congruence moment', and the congruence between these moments, increases the complexity of the design process. However, one may be able to achieve remarkable experiences, which are based on the systematic connections between the senses.

As mentioned before, one of the key questions when it comes to multisensory design is whether the aim should always be to design congruent experiences and therefore focus on the alignment of sensory inputs in terms of the different levels of analysis presented in Figure 5 (e.g., [34]). The answer to this question largely depends on the aim that the designer has, as well as the context in which the experience takes place. For example, using the 'Chewing Jockey' in an experimental restaurant to map the process of chewing a broccoli salad with the sound of a violin (temporally congruent although, perhaps, semantically incongruent) may be an enjoyable experience for the diner [cf. 41-42]. Nevertheless, this may not have the same effect in a large and massive cafeteria where workers eat the meal of the day, on a daily basis.

One of the suggestions that was forwarded in the 1980s by Mandler [43] is that neither perfect congruence, nor complete incongruence, are ideal in consumer contexts. Rather, a small degree of incongruence, whilst at the same time providing the consumer with the tools to solve such incongruence, may be ideal. However, once again, congruency should be based on the aim and context associated with an experience. If the aim is to create a humorous situation [40] for children, the Chewing Jockey may be used to map the sound of a super crunchy apple with the process of chewing a cherry. In contrary, if the aim is to enhance the perception of sweetness of a given food or drink (whilst having low levels of sugar), one may align the different multisensory cues during the experience of the item in terms of their correspondence with such taste attribute. Critically, the different levels of analysis presented before (in Figure 5), and the careful consideration of the different 'congruence moments' associated with a specific food or drink experience, can provide a map with which to navigate and design routes to reach a specific behavior or percept.

5. CONCLUSIONS AND FUTURE APPLICATIONS

Clearly, there are a number of design opportunities for sound-based systems in HFI, for both the general public and specific groups of people, such as those who attend experimental dining events or food museums.

We believe that in the years to come, as electronics become smaller, and technology develops, an increasing number of systems will be introduced. Perhaps, as a reminiscence of the Italian Futurists [44,45], a number of different sensors will be ubiquitous to the utensils that we use to eat in order to generate specific sounds while eating/drinking. This may result in some kind of 'cutlery orchestra', which could impact of our eating and drinking experiences and habits in a number of ways.

What is more, the rapid growth of face processing software will allow the mapping of offline eating experiences with the virtual world (e.g., [46]) in which, for example, mastication movements and/or any other movements during eating could be mapped on to specific sonic parameters. This may also have implications for those systems that are aiming at digitizing taste and flavor experiences. For instance, any electric taste system may be combined with sounds that are mapped onto mouth movements in order to create more realistic taste/flavor experiences in the virtual world (see also [47]).

We also believe that the technological advances that have been made in recent years, and that will be introduced in the upcoming ones, will allow the reinvention of old technologies. Think, for example, of a product's packaging. Although there are a number of technical developments still to be made for the conservation of the different foods and beverages, nowadays food and drinking packaging design can also focus on consumer marketing and experience design. Indeed, research has already suggested that the sounds of a product's packaging can influence the sensory and hedonic expectations associated with the products [48]. Food packaging may progressively involve more salient sonic technologies.

The aforesaid systems are and will likely be used for a number of purposes, which could involve: experimental dining/art experiences, playful eating, nutritious/healthy eating, and perhaps food and drinking 'sonic' seasoning. For example, a fun application may involve the mapping of incongruent slurping sounds (e.g., the sound of an accelerating Harley Davison) with the act of drinking a given beverage (e.g., apple juice). Health applications may build on these systems to enhance specific taste qualities or textures in people with taste/smell and/or haptic dysfunctions [49-51]. Finally, as suggested by Kadomura et al. [23], people may just use sounds to create playful food education at school.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] Auvray, M. and Spence, C. 2008. The multisensory perception of flavor. *Conscious. Cogn.* 17(3), 1016-1031. http://dx.doi.org/10.1016/j.concog.2007.06.005

[2] Spence, C. 2015. Multisensory flavor perception. *Cell* 161(1), 24-35. http://dx.doi.org/10.1016/j.cell.2015.03.007

[3] Prescott, J. 1999. Flavour as a psychological construct: implications for perceiving and measuring the sensory qualities of foods. *Food Qual. Prefer.* 10(4), 349-356. http://dx.doi.org/10.1016/S0950-3293(98)00048-2

[4] Prescott, J. 2015. Multisensory processes in flavour perception and their influence on food choice. *Curr. Opin. Food Sci.* 3, 47-52. http://dx.doi.org/10.1016/j.cofs.2015.02.007

[5] Haverkamp, M. 2009. Synesthetic design–building multi-sensory arrangements. In Kai Bronner & Rainer Hirt (eds.), *Audio Branding: Brands, Sound and Communication* (pp. 164-181). Nomos, Berlin, Germany.

[6] Haverkamp, M. 2010. Synesthetic approach for evaluation of the cross-sensory quality of multi-media applications. *In Quality of Multimedia Experience* (QoMEX) (Trondheim, Norway, June 21–23, 2010). QoMEX. IEEE, 136-141. DOI= http://dx.doi.org/10.1109/QOMEX.2010.5516107

[7] Haverkamp, M. 2013. Synesthetic design: Handbook for a multi-sensory approach. Birkhäuser Verlag, Basel.

[8] Spence, C. 2015. Eating with our ears: assessing the importance of the sounds of consumption on our perception and enjoyment of multisensory flavour experiences. *Flavour* 4:3. http://dx.doi.org/10.1186/2044-7248-4-3

[9] Zampini, M. and Spence, C. 2010. Assessing the role of sound in the perception of food and drink. *Chemosen. Perception*, 3(1), 57-67. http://dx.doi.org/10.1007/s12078-010-9064-2

[10] Reinoso Carvalho, F., Velasco, C., van Ee, R., Leboeuf, Y. and Spence, C. 2016. Music influences hedonic and taste ratings in beer. *Front. Psychol.* 7: 636. http://dx.doi.org/10.3389/fpsyg.2016.00636

[11] Vickers, Z. and Bourne, M. C. 1976. Crispness in foods: A review. *J. Food Sci.* 41(5), 1153-1157. http://dx.doi.org/10.1111/j.1365-2621.1976.tb14406.x

[12] Zampini, M. and Spence, C. 2004. The role of auditory cues in modulating the perceived crispness and staleness of potato chips. *J. Sense. Stud.* 19(5), 347-363. h http://dx.doi.org/10.1111/j.1745-459x.2004.080403.x

[13] Velasco, C., Jones, R., King, S. and Spence, C. 2013. The sound of temperature: What information do pouring sounds convey concerning the temperature of a beverage. *J. Sense. Stud.* 28(5), 335-345. http://dx.doi.org/10.1111/joss.12052

[14] Yan, K. S. and Dando, R. 2015. A crossmodal role for audition in taste perception. *J. Exp. Psychol. Hum. Percept.* 41(3), 590-596. http://dx.doi.org/10.1037/xhp0000044

[15] Spence, C. and Piqueras-Fiszman, B. 2013. Technology at the dining table. *Flavour* 2:16. http://dx.doi.org/10.1186/2044-7248-2-16

[16] Spence, C. and Piqueras-Fiszman, B. 2014. *The perfect meal: the multisensory science of food and dining*. Wiley-Blackwell, Oxford, UK.

[17] Spence, C. 2012. Auditory contributions to flavour perception and feeding behaviour. *Physiol. Behav. 107*(4), 505-515. http://dx.doi.org/10.1016/j.physbeh.2012.04.022

[18] Obrist, M., Velasco, C., Vi, C. T., Ranasinghe, N., Israr, A., Cheok, A. D., Spence, C. and Gopalakrishnakone, P. 2016. Touch, taste, & smell user interfaces: The future of

multisensory HCI. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (CHI EA '16). ACM, New York, NY, USA, 3285-3292. DOI= http://dx.doi.org/10.1145/2851581.2856462

[19] Hashimoto, Y., Nagaya, N., Kojima, M., Miyajima, S., Ohtaki, J., Yamamoto, A., Mitani, T. and Inami, M. 2006. Straw-like user interface: virtual experience of the sensation of drinking using a straw. In *Proceedings of the 2006 ACM SIGCHI international conference on Advances in computer entertainment technology* (ACE '06). ACM, New York, NY, USA, Article 42. DOI= http://dx.doi.org/10.1145/1178823.1178873

[20] Hashimoto, Y., Inami, M. and Kajimoto. H. 2008. Straw-Like User Interface (II): A New Method of Presenting Auditory Sensations for a More Natural Experience. In *Proceedings of the 6th international conference on Haptics: Perception, Devices and Scenarios* (EuroHaptics '08), Manuel Ferre (Ed.). Springer-Verlag, Berlin, Heidelberg, 484-493. DOI= http://dx.doi.org/10.1007/978-3-540-69057-3_62

[21] Petit, O., Cheok, A. D., Spence, C., Velasco, C. and Karunanayaka, K. T. 2015. Sensory marketing in light of new technologies. In *Proceedings of the 12th International Conference on Advances in Computer Entertainment Technology* (ACE '15). ACM, New York, NY, USA, Article 53, 4 pages. DOI= http://dx.doi.org/10.1145/2832932.2837006

[22] Koizumi, N., Tanaka, H., Uema, Y. and Inami, M. 2011. Chewing jockey: augmented food texture by using sound based on the cross-modal effect. In *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology* (ACE '11). ACM, New York, NY, USA, Article 2, 4 pages. DOI= http://dx.doi.org/10.1145/2071423.2071449

[23] Kadomura, A., Tsukada, K. and Siio. I. 2013. EducaTableware: computer-augmented tableware to enhance the eating experiences. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems* (CHI EA '13). ACM, New York, NY, USA, 3071-3074. http://dx.doi.org/10.1145/2468356.2479613

[24] Haverkamp, M. 2015. Can synesthetic perception help to define attractive product design? In *5th International Congress of Synaesthesia, Science & Arts*. Alcalá la Real, Jaén, Spain.

[25] Calvert, G., Spence, C. and Stein, B. E. 2004. The handbook of multisensory processes. MIT press, Cambridge, MA.

[26] Velasco, C., Obrist, M., Petit, O., Karunanayaka, K., Cheok, A. D. and Spence, C. (2016). Cross-modal correspondences in the context of digital taste and flavor interfaces. Presented at CHI Conference on Human Factors in Computing Systems, San Jose, CA, USA.

[27] Spence, C. 2011. Crossmodal correspondences: A tutorial review. *Atten. Percept. Psychophys. 73*(4), 971-995. http://dx.doi.org/10.3758/s13414-010-0073-7

[28] Chen, L. and Vroomen, J. (2013). Intersensory binding across space and time: a tutorial review. *Atten. Percept. Psychophys.*, *75*(5), 790-811. http://dx.doi.org/10.3758/s13414-013-0475-4.

[29] Iordanescu, L., Grabowecky, M. and Suzuki, S. 2011. Object-based auditory facilitation of visual search for pictures and words with frequent and rare targets. *Acta Psychol. 137*(2), 252-259. http://dx.doi.org/10.1016/j.actpsy.2010.07.017

[30] Milliman, R. E. 1986. The influence of background music on the behavior of restaurant patrons. *J. Cons. Res. 13*(2), 286-289. http://dx.doi.org/10.1086/209068

[31] Marks, L. E. 1978. The unity of the senses: Interrelations among the modalities. Academic Press, New York, NY.

[32] Martino, G. and Marks, L. E. 2001. Synesthesia: Strong and weak. *Curr. Dir. Psychol. Sci.* 10(2), 61-65. http://dx.doi.org/10.1111/1467-8721.00116

[33] Reinoso Carvalho, F., Van Ee, R., Rychtarikova, M., Touhafi, A., Steenhaut, K., Persoone, D., Spence, C. and Leman, M. 2015. Does music influence the multisensory tasting experience?. *J. Sense. Stud. 30*(5), 404-412. http://dx.doi.org/10.1111/joss.12168

[34] Velasco, C., Woods, A. T., Petit, O., Cheok, A. D. and Spence, C. 2016. Crossmodal correspondences between taste and shape, and their implications for product packaging: A review. *Food Qual. Prefer.*, *52*, 17-26. http://dx.doi.org/10.1016/j.foodqual.2016.03.005

[35] Bahrick, L. E., Lickliter, R. and Flom, R. 2004. Intersensory redundancy guides infants' selective attention, perceptual and cognitive development. *Curr. Dir. Psychol. Sci. 13*(99), 102. http://dx.doi.org/10.1111/j.1467-7687.2006.00539.x

[36] Parise, C. V., Knorre, K. and Ernst, M. O. 2014. Natural auditory scene statistics shapes human spatial hearing. *Proc. Natl. Acad. Sci. U.S.A.*, *111*(16), 6104-6108. http://dx.doi.org/10.1073/pnas.1322705111

[37] Deroy, O., Crisinel, A. S. and Spence, C. 2013. Crossmodal correspondences between odors and contingent features: odors, musical notes, and geometrical shapes. *Psychon. Bull. Rev.*, *20*(5), 878-896. http://dx.doi.org/10.3758/s13423-013-0397-0

[38] Palmer, S. E., Langlois, T. A. and Schloss, K. B. 2016. Music-to-color associations of single-line piano melodies in non-synesthetes. *Multis. Res. 29*(1-3), 157-193. http://dx.doi.org/10.1163/22134808-00002486

[39] Parise, C. and Spence, C. 2013. Audiovisual cross-modal correspondences in the general population. In J. Simner & E. Hubbard (Eds.), *The Oxford handbook of synaesthesia* (pp. 790-815). Oxford University Press, Oxford, UK.

[40] Ludden, G. D., Kudrowitz, B. M., Schifferstein, H. N. and Hekkert, P. 2012. Surprise and humor in product design. *Humor 25*(3), 285-309. http://dx.doi.org/10.1515/humor-2012-0015

[41] Ludden, G. D. and Schifferstein, H. N. 2007. Effects of visual-auditory incongruity on product expression and surprise. *Int. J. Des. 1*(3), 29-39.

[42] Ludden, G. D., Schifferstein, H. N. and Hekkert, P. 2008. Surprise as a design strategy. *Des. Issues* 24(2), 28-38. http://dx.doi.org/10.1162/desi.2008.24.2.28

[43] Mandler, G. P. 1982. The structure of value: Accounting for taste. In M. S. Clark & S. T. Fiske (Eds.), *Affect and*

cognition. The 17th Annual Carnegie Symposium on Cognition (pp. 3-36). Lawrence Erlbaum, Hillsdale, NJ.

[44] Marinetti, F. T. 1909. The founding and manifesto of futurism. Retrieved from http://web.itu.edu.tr/~inceogl4/thresholds/futuristmanifesto.doc

[45] Howells, T. 2014. Experimental eating. Black Dog Publishing, London, UK.

[46] Fox, J., Bailenson, J. and Binney, J. 2009. Virtual experiences, physical behaviors: The effect of presence on imitation of an eating avatar. *Presence-Teleop. Virt.*, 18(4), 294-303. http://dx.doi.org/10.1162/pres.18.4.294

[47] Project Nourishing, retrieved from http://www.projectnourished.com/

[48] Spence, C. and Wang, Q. J. 2015. Sensory expectations elicited by the sounds of opening the packaging and pouring a beverage. *Flavour* 4:35. http://dx.doi.org/10.1186/s13411-015-0044-y

[49] Stroebele, N., & de Castro, J. M. 2006. Listening to music while eating is related to increases in people's food intake and meal duration. *Appetite* 47(3), 285-289. http://dx.doi.org/10.1016/j.appet.2006.04.001

[50] Guéguen, N., Jacob, C., Le Guellec, H., Morineau, T., & Lourel, M. 2008. Sound level of environmental music and drinking behavior: A field experiment with beer drinkers. *Alcohol Clin. Exp. Res.* 32(10), 1795-1798. http://dx.doi.org/10.1111/j.1530-0277.2008.00764.x

[51] Elder, R. S., & Mohr, G. S. 2016. The crunch effect: Food sound salience as a consumption monitoring cue. *Food Qual. Prefer. 51*, 39-46. http://dx.doi.org/10.1016/j.foodqual.2016.02.015