International Journal of Gastronomy and Food Science 32 (2023) 100695

Contents lists available at ScienceDirect

International Journal of Gastronomy and Food Science

journal homepage: www.elsevier.com/locate/ijgfs

# Digitally enhancing tasting experiences

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ARTICLE INFO

*Keywords:*
Virtual reality
Augmented Reality
Projection Mapping
Sensory Apps

ABSTRACT

Our experience of food and drink depends on more than merely the ingredients that have been combined in a dish or drink and the way in which it has been prepared. There is growing interest in the question of whether digital technologies/solutions can be used to enhance consumers' multisensory tasting experiences. Projection mapping and sonic seasoning have been incorporated onto the menu in a number of world-leading restaurants for several years now. However, there has, as yet, been relatively little uptake of such digital technologies in the home environment. And while a wide (and growing) range of food and beverage brands have come out with sensory apps and sonic seasoning playlists in recent years, they do not tend to be present in the marketplace for very long. In fact, it would appear that the majority of augmented and virtual reality solutions have more relevance to the world of consumer/food science research than necessarily to enhancing the tasting experience for those in the home environment. Looking to the future, the widespread societal uptake of digitally-enhanced tasting experiences will likely only occur when such solutions provide an obvious, and demonstrable, benefit to the intended users.

## 1. Introduction

The last few year have seen a rapid increase of interest in the use of digital technologies to help modify, and hopefully also to enhance, the consumer's experience of food and drink. For instance, there has been a growing fascination in the intersection between virtual/augmented reality (VR/AR; see Liberatore and Wagner, 2021; Van Krevelen and Poelman, 2010) and food and drink experience design (including take-away food packaging, Gu et al., 2023). At the same time, however, one can also consider the use of 'sonic seasoning'[1] (Spence et al., 2019a) to help enhance desirable taste qualities (such as sweet or salty) and/or food experience, more generally. To date, though, digital technologies have primarily been used to modify the visual appearance of food and/or the visual background against which those food and drink products are seen. At the same time, however, unless care is taken, such sensory modifications can all too easily end-up giving rise to sensory incongruency. The latter is typically negatively-valenced, because of its lack of processing fluency.[2] Here, it will be argued that VR and AR currently have more relevance to the world of consumer science/-product development than necessarily to the emerging field of multi-sensory experience design.

In this narrative historical review, the question to be addressed is why, despite the widespread interest in incorporating such a wide range of digital technologies into multisensory tasting experiences (see also Butz and Schmitz, 2005; Choi et al., 2014; Schöning et al., 2012), have there been so few successful (in the sense of long-lasting) commercial applications in the marketplace; That is, outside of the esoteric, exclusive, and expensive world of fine dining? Indeed, it is striking/noticeable how most marketing-led interventions in this space have been short-lived, thus limiting the number of consumers who have access to them. At present, the majority of digital technologies would therefore seem more likely to distract diners from what they are eating (and drinking; e.g., see Anderer, 2019; Braude and Stevenson, 2014; Spence, 2017) rather than enhancing their multisensory dining experience.

## 2. Using digital technology in consumer science/product development

One of the areas where VR/AR has already started to prove useful in relation to food, and thus tasting experiences, is in the area of product innovation, where virtual prototyping (e.g., of food product or packaging) can potentially be used to facilitate product/packaging

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[1] Referring to the deliberate pairing of sound/music with taste/flavour in order to enhance, or modify, the multisensory tasting experience.

[2] Indeed, one of the issues to bear in mind is the importance of congruency to delivering immersive multisensory experiences when only one, or possibly two, senses are altered virtually (Brengman et al., 2022; Chen et al., 2020; Flavián et al., 2021).

https://doi.org/10.1016/j.ijgfs.2023.100695
Received 10 January 2023; Received in revised form 21 February 2023; Accepted 24 February 2023
Available online 2 March 2023
1878-450X/

development (e.g., Branca et al., 2022; Dong et al., 2021). At the same time, however, researchers have also been using immersive technologies to help improve consumer testing by assessing how different virtual environments influence the taste experience (Ammann et al., 2020a; Andersen et al., 2019; Bangcuyo et al., 2015; Delarue et al., 2019; Hartmann and Siegrist, 2019; Hathaway and Simons, 2017; Kong et al., 2020; Liu et al., 2019; Lombart et al., 2019; Low et al., 2021; Oliver and Hollis, 2021; Pennanen et al., 2020; Siegrist et al., 2019; Stelick et al., 2018; Torrico et al., 2020; Ung et al., 2018; Wang, Barbosa Escobar, Alves Da Mota and Velasco, 2021). Relevant here, when researchers have directly compared the behaviour of consumers in VR and real life it often appears to be reasonably similar (Xu et al., 2021; though see also Colla et al., 2022). Such observations suggest that immersive digital environments and AR may provide an effective approach in consumer science research. However, that said, such approaches/uses would seem to have little relevance as far as the delivery of digitally-enhanced tasting experiences in the context of multisensory dining, experiential marketing, or the home environment is concerned.

## 3. Digitally modifying the visual appearance of food

The last few years have seen a number of researchers investigating the question of whether the virtual colour, or appearance, of food and drink has a similar effect as the actual colour of products on consumers' taste expectations and thereafter their taste experiences (e.g., Huang et al., 2019; cf. Huang et al., 2021). For example, a few years ago, Okajima and his colleagues developed an AR "food changer" system that was capable of both identifying and modifying the visual appearance properties of food by means of a sophisticated computer vision algorithm, using either a projector (Nishizawa et al., 2016) or else a head-mounted display (HMD; Okajima and Spence, 2011; Ueda and Okajima, 2019; Ueda et al., 2020; see also Spence et al., 2016). That is, vision science techniques can now be used to segment visual scenes automatically, thus allowing for the food to be tracked directly.[3] Laboratory research using such technical solutions has investigated the effects of changing the colour, saturation, and visual texture of various foods. For example, Nishizawa and colleagues found that there was a correlation between the color saturation and the rated sweetness of cake. Furthermore, these researchers also demonstrated that the mouthfeel, greasiness, and deliciousness of sashimi could be altered by modifying a food's visual texture and colour (Ueda and Okajima, 2019). The moistness and deliciousness of Baumkuchen (a type of German sponge cake), as well as the watery taste in a spoonful of tomato ketchup, has been altered by dynamically modifying the luminance distribution of these foods. However, as is true of many of the studies that have been published to date in the field (of food-related human--computer interaction research), these studies are limited by small sample sizes. For example, only four participants took part in Nisizawa et al.'s cake study, 12 participants in Ueda and Okajima's sashimi study, while a total of 13 participants were involved in the sponge cake and ketchup studies reported recently by Ueda et al. Future research in this area should test larger samples in order to ensure adequate statistical power. While much of this research was conducted with a VR headset, Okajima and his colleagues have, in recent years, successfully extended the approach to work through a smart phone camera and screen instead.[4]

Huang et al. (2019) conducted a series of three studies to investigate the influence of VR drink colour on taste ratings for samples of Chinese green and red tea. The beverage was shown to participants in VR (using a HMD) for 20 s prior to their sampling a tea through a straw (note that the latter was not shown in the VR simulation) while the screen was black.[5] The results of Huang et al.'s first experiment failed to demonstrate any influence of the actual colour of the tea shown in VR on ratings of sourness, sweetness, bitterness, saltiness, or astringency of the green and red teas that were sampled. However, when the virtual colour was made to match the expected colour of the green and red tea then viewing the colour associated with green tea was shown to lead to a small, but significant, change in participants' ratings of the saltiness of the teas (2.14 vs. 1.83 on a 9-point saltiness rating scale). That said, when the virtual tea colour for a new group of participants was yoked to the expected colour of other participants (specifically those from the preceding experiment), there was once again no effect of virtual colour on taste ratings. Taken together, therefore, these results provide only very weak evidence for an influence of virtual drink colour on participants' taste ratings. That said, it should be remembered that tea is a somewhat unusual beverage in that the imagined colour for the drink sometimes differs from the actual colour. So, for example, research has documented how expected tea colour, based on blindfolded tasting, can sometimes differ from the actual colour of the tea that is being sampled (see Huang et al., 2020; Wan et al., 2014).

Ammann et al. (2020b) conducted two VR studies in which the impact of the actual colour, or product-atypical colour, on participants' ability to identify the dominant flavour of several everyday food products was investigated. In their first experiment, 100 participants tasted orange juice, grape juice, and a piece of lemon cake which were either presented in their natural colour or else were miscoloured green, orange, and brown, respectively, in the HMD. As has been shown repeatedly in studies where actual products have been miscoloured (see Spence, 2022b, for a review), Ammann et al.'s participants found it more difficult to correctly identify the flavour of the products when their colour had been modified. In a second study, performance for real and virtual colour was compared directly. This time, orange juice, pineapple juice, and lemon cake were used (and were miscoloured green, red, or brown, respectively), in reality or in VR. Crucially, however, no difference was observed between VR and reality in terms of the accuracy of participants' flavour identification responses.

Wang et al. (2020) conducted another VR study (this time with N = 32 participants) in which 'virtual milk' was added to cold-brew coffee (which appeared either light or dark brown in the HMD).[6] In this case, the results demonstrated a significant impact on rated creaminess, though there was no effect on rated sweetness or liking. Importantly, however, Wang and her colleagues did not compare their results with the addition of whitener to an actual cup of coffee to compare the results between real and virtual colour conditions. What is more, like the majority of the studies that have been conducted in this area to date, the tendency amongst researchers has been to assess the immediate response of consumers to such digital interventions rather than the longer term consequences that may result from repeated use.

Other researchers, meanwhile, have compared the response of consumers to real and virtual chocolate (van der Waal, Janssen, Antheunis, Culleton and van der Laan, 2021), while assessing (psychological) craving and (physiological) salivation. The researchers in this case conducted a study in which a group of 54 participants were either exposed to several types of chocolate or else saw exactly the same range of chocolate samples in HMD VR while they were in either a hungry or

[3] One of the limitations of traditional approaches to augmenting the visual appearance of foods has always been the need to use meta-cookies (Narumi et al., 2010; Narumi et al., 2011) or QR codes (on the food itself) in order to help track its position (see Spence, 2014; Spence and Piqueras-Fiszman, 2013).

[4] That said, one of the limitations with such approaches is that bleeding sometimes occurs at the edges of the augmented food if the food (or camera) moves too rapidly.

[5] This temporal separation, as well as the differences in the content of the VR simulation versus what was actually presented, might well be expected to reduce the participants' conviction that they were actually tasting what they had just seen in VR and thus reduce the impact of virtual colour on taste ratings.

[6] Note that in this case, a tracker was attached to the actual mug of coffee in order to align the virtual with the real movement of cup.

satiated state. The exposure to chocolate led to a stronger craving than exposure to a non-food stimulus, though the effect was more pronounced in the real life setting than in VR. Furthermore, only in real life did exposure to the chocolate lead to an increase in salivation (cf. Spence, 2011). Such results therefore suggest that the VR condition only partially captured the responses elicited by physically encountering chocolate. At the same time, however, it should be noted that the smell of chocolate may play an important role in triggering craving and this cue was presumably only present in the real but not the virtual chocolate condition (see Proserpio et al., 2017; Wolz et al., 2017).

Taken together, the emerging body of laboratory-based research reveals that the virtual colour/appearance of food and drink has much the same effect as actual modifications of colour/appearance of food and beverage products. However, beyond showing that VR/AR can be used to assess the impact of product colour, it is unclear that such findings necessarily have any relevance for those wishing to design multisensory experiential tasting events/experiences. Two other points to note are the small sample sizes tested in many of the studies and the emphasis on the immediate perceptual/hedonic response, rather than on the consequences of longer-term usage of such digital technologies.

## 4. Digitally-modifying the visual background

A separate strand of laboratory-based research has involved augmenting, or replacing the visual environment, to create a different realistic, or else imaginary environment. Here, one might consider both the Provencal Rose Paradox (Spence and Piqueras-Fiszman, 2014),[7] and the fact that the multisensory environment has repeatedly been shown to bias people's ratings of a wide range of food and drink products (e.g., Velasco et al., 2013; and see Spence, 2020a; Stewart, 2017, for a review). If VR could, for example, be used to elicit that Provencal Rose feeling then it might be expected to deliver a positive boost to the user's emotions, and by so doing help to digitally enhance the taste of the food (cf. Colla, 2022; Crofton et al., 2021; Nivedhan et al., 2020; Picket and Dando, 2019; van Bergen et al., 2021). Potentially relevant here, researchers have recently demonstrated that providing virtual terroir in VR can help to enhance the premium coffee experience (Barbosa Escobar, Petit and Velasco, 2021).

Research on multisensory atmospherics has revealed that larger-scale interior architectural features (such as shape and colour) can be associated with taste qualities, and thus may bias people's taste experiences (e.g., Chen et al., 2020; Motoki et al., 2021; Spence, 2020a; Velasco et al., 2013). So, for example, a decade ago, Velasco et al. demonstrated that people's ratings of a glass of whisky were significantly enhanced in terms of perceived sweetness when they rated the drink in a room that was filled with round shapes and coloured in hues that are normally associated with sweetness (e.g., pink, red, purple) than when compared to other multisensory environments that had been designed to bring out the grassiness on the nose or the textured finish of the aftertaste of the whisky instead. Meanwhile, Spence et al. (2014) conducted a multisensory experiential wine tasting in which around 2800 members of the general public were invited to taste a glass of red wine presented in a black tasting glass (to obscure the wine's true colour). The results revealed a significant effect of switching between normal white room lighting and either red or green ambient lighting. Furthermore, adding 'sweet' music to the red lighting condition, or 'sour' music to the green ambient lighting condition, enhanced the ambient environmental effects still further, leading to an overall 15–20% change in people's ratings of the fruitiness vs. freshness of the wine, and their liking of it.

While the results just mentioned were based on the influence of manipulating the actual multisensory environment, researchers have, over the last few years, started to expose people to virtual environments having essentially the same visual features (e.g., colours and shapes based on the crossmodal correspondences that have been documented; Huisman et al., 2016; Spence, 2022b, in press). So, for example, Chen et al. (2020) conducted a VR study in which the shape features of the virtual environment were shown to influence people's taste ratings. In particular, combining round environmental shapes (specifically furniture shape – rounded vs. spiky) with 'sweet' colours (e.g., pink/red/-purple –rather than grey), led to significantly enhanced sweetness ratings (see Fig. 1).

By contrast, though, other researchers have not found there to be much influence of the colour of a virtual environment (when comparing normal ambient white light vs. red or blue) on sweetness ratings (see Cornelio et al., 2022; Nygård and Lie, 2020). Meanwhile, in another VR study, Wu et al. (2022) had 16 participants drink black tea after being exposed to eight different virtual environments each having a different ambient colour. In this case, the pink ambient colour in the HMD VR led to a significant increase in participants' sweetness ratings.[8] That being said, one of the challenges associated with working in this area is that people are rarely aware of the way in which the environment affects them, and their taste judgments, unless the influence is somehow made explicit. As such, while experimental results such as those just reported can clearly highlight the potential impact of attributes of the visual environment on taste ratings, it is not immediately clear that consumers would necessarily see (i.e., be aware of) the benefit of such a digital intervention (cf. Holdack et al., 2020), and hence it might be difficult to get them to pay for such digital dining solutions.

Given that those wearing a VR headset, or else viewing a foodscape through a device such as a smartphone are unlikely to suspend their belief entirely (i.e., they know that what they are looking at is not real), they presumably know that what they are seeing may not be the actual colour of the food or drink that they have been invited to taste. Nevertheless, the results of several recent laboratory studies demonstrate that virtual food colour would appear to operate much like actual product colour in terms of biasing people's taste/flavour expectations, and thereafter their taste experiences (Narumi et al., 2010; Spence, 2022b). In fact, it turns out that ambient colour (i.e., no matter whether it is associated with the food or not) often appears to exert as much influence as actual food colour (see Istiani et al., 2022; Spence et al., 2014; Wu et al., 2022). However, returning to one of the points made earlier, it will be crucial for future research to conduct longer-term studies to investigate whether the consumer response changes in any way with continued exposure: i.e., one might wonder whether visual cues would be down-weighted once the consumer comes to realize that augmented and real colour often do not match?

## 5. Digitally-modifying the sound of food interactions and background soundscapes

Endo et al. (2016, 2017) have conducted a series of studies in which pseudo-chewing sounds were added as people attempted to masticate food. Such research builds on earlier findings demonstrating that the real-time modification of people's actual food chewing sounds can beneficially influence their perception of the crispness/crunchiness of food (e.g., Demattè et al., 2014; Zampini and Spence, 2004). Such digital solutions can presumably be classed as a form of auditory augmentation (or auditory AR; cf. Iijima and Koike, 2013). However, one of the problems/limitations of the approach that has been developed by Endo

[7] This is the name given to the phenomenon where when Northern Europeans holiday in the Mediterranean in the summer, food and drink just seem to taste so much better than when the same food is tasted back at home (Spence and Piqueras-Fiszman, 2014).

[8] It is interesting to consider whether the switching of the ambient lighting colour in VR during the course of an experiment may help to make ambient colour somehow more relevant than it otherwise might be (when it perhaps fades into the background; see Spence, 2020c).

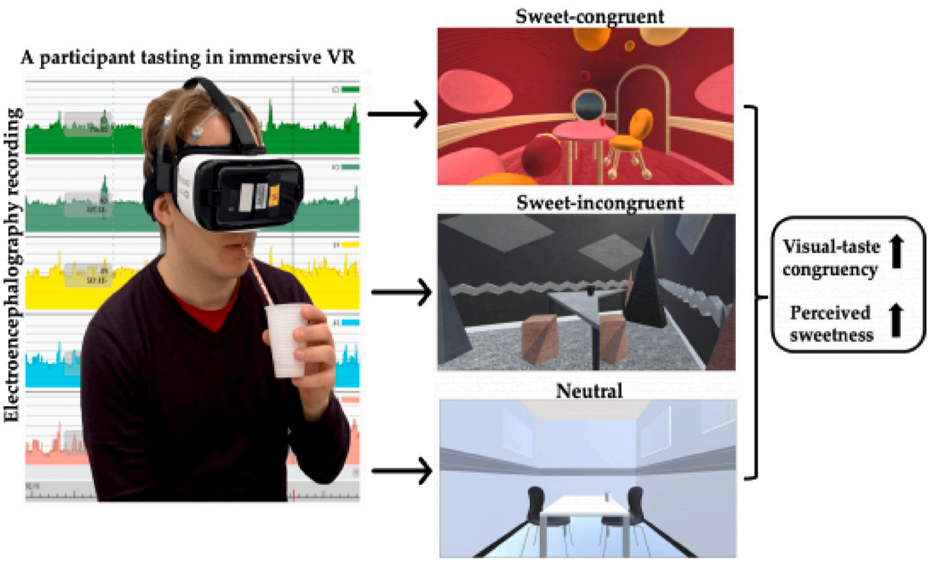


**Fig. 1.** Sweet-congruent, sweet-incongruent (i.e., bitter), and neutral VR environments that were presented to participants in Chen et al.'s (2020) studies. The round shapes and pink-red colours of the sweet environment enhanced sweetness as predicted when compared to sweetness in the bitter environment with black and grey colours and angular shapes. [Reprinted under Creative Commons CC BY 4.0.]. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

and his colleagues is that it requires electrodes to be attached carefully to the user's face in order to be able to measure the user's masticatory muscle movements so as to synchronize the augmented sound (and see Koizumi et al., 2011, for an earlier idea along similar lines; cf. Fellett, 2012; Winter 2012). As an alternative, the EverCrisp App., developed by Kayac Inc., Japan, for mobile devices enhanced the crunch of noisy (e.g., dry) food products simply by changing the sound that people heard as they bit into a particular food (i.e., without the need for electrodes), though sadly was never licensed by Apple (see Spence and Piqueras-Fizsman, 2013).

The first successful example of digital technology being used to enhance the experience of food may well have been with the Sound of the Sea dish that was introduced onto the menu of *The Fat Duck* restaurant in the UK back in 2007 (see Blumenthal, 2008). This dish comes to the table looking like the seashore, with sand, foam, seaweed, and sashimi. The waiter also brings a conch shell in which has been placed an MP3 player. The diners are invited to insert the earbuds dangling from the shell prior to sampling the dish, whereupon they hear the sounds of the waves crashing gently on the beach and seagulls overhead (see Fig. 2). The introduction of the dish was based on research showing that oysters were rated as tasting significantly better, but no more salty, when the participants listened to the sound of the sea rather than to another soundtrack (Spence et al., 2011). This dish can be considered as one the first examples of digital technology being used to enhance the multisensory tasting experience. What was unplanned, though, was the fact that many diners report being brought to tears by the dish (see Spence, 2020b), suggesting that the experience is somehow 'extraordinary'. The dish, representing one of the most successful examples of digital taste enhancement has been a regular feature on the menu at the restaurant for 15 years now.

During the Covid pandemic, we worked with Heineken on a project codenamed 'Air Cheers'. At a time when interpersonal contact was problematic, a small digital disc was developed that could be slotted onto the bottom of one's bottle of beer (a bit like a short stubby holder). Whenever the drinker made the appropriate gesture while holding their beer, the sound of clinking glass bottles would be heard (see "*Air Cheers*' to that: Heineken® unveils world's first self-cheering bottle', 2020), thus providing a digitally-controlled sonic enhancement. Indeed, given how important food (preparation) sounds have been shown to be (e.g., see Spence & Wang, 2017), in the future digitally augmenting, or modifying them is likely to represent a fruitful direction for the digital enhancement of tasting experiences.

A few years ago, I worked with Glenmorangie whisky, Bompas &

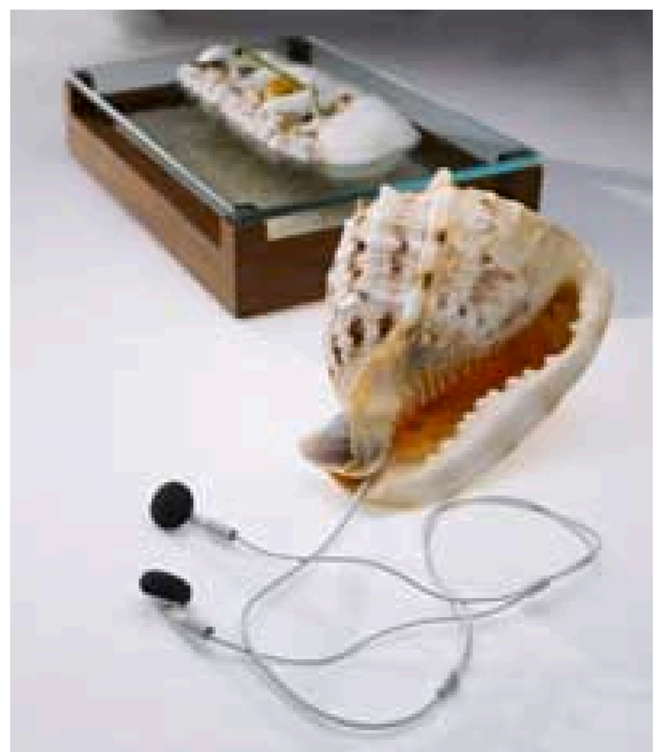

**Fig. 2.** The Sound of the Sea dish, from The Fat Duck restaurant. Possibly one of the most successful examples of digital technology being used to enhance the tasting experience. At the same time, the multisensory experience is one that is restricted to a once in a lifetime experience at one of the world's leading restaurants - The Fat Duck in Bray [Credit Dominic Davies].

Parr (https://bompasandparr.com/), Alter Projects (https://alter-projects.com/projects/curation-glenmorangie/), and a number of video artists in order to create a series of videos designed to elicit the autonomous sensory meridian response (ASMR) in a proportion of those watching (and more importantly listening to) the video while simultaneously sipping the whisky (see Barratt et al., 2017). Intriguingly, this turned out to be one of the company's most successful digital marketing campaigns ever (see also McNeilly, 2019, for more on the intersection of auditory ASMR and food).[9]

If one accepts the suggestion that presenting pre-recorded music or soundscapes also modifies reality, then these can perhaps also be considered as examples of AR (augmented, rather than virtual, as such sounds are typically overlaid over any background sounds that may be present in the environment). Relevant here, a jellyfish dish was introduced onto the menu at Kitchen Theory chef's table in North London (https://kitchen-theory.com/; Youssef et al., 2019). Projection mapping of the water surface was presented visually on the surface of the dining table (cf. Suzuki et al., 2021), while a bespoke soundscape was presented over headphones in which the sounds of crunching were superimposed over a soundscape incorporated the sounds of water (see Fig. 3).[10] Although no formal data was collected, it was striking how many diners reported how much they enjoyed the dish, despite never knowingly having consumed jellyfish before. Here, it is worth noting how several VR restaurants have opened in Japan in recent years, including Tree by Naked (see https://www.timeout.com/tokyo/restaurants/tree-by-naked), that also use projection mapping.

**Fig. 3.** The projection mapped undersea scene that diners see at the Gastrophysics Chef's Table when eating chef Jozef Youssef's jellyfish dish. Notice also the over-ear headphones that the diners are encouraged to put on before starting the dish.

There has also been an explosive growth of interest in the topic of sonic seasoning in recent years (see Wang et al., 2017, 2021). However, given that this topic has been extensively reviewed elsewhere it will not be discussed further here (Spence, 2021b; Spence et al., 2019b, for reviews).

## 6. Digital taste

There has been some interest in the electrical stimulation of the taste buds which under certain conditions, has been shown to elicit a taste sensation. Such taste sensations are clearly virtual (given the absence of any actual tastants). While such technologies have now been commercialized in Japan by Kirin Holdings (see Reuters, 2022), the published scientific research would seem to suggest that only a subset of tastes, primarily salty and sour, can be elicited in (a proportion of) consumers (Nakamura and Miyashita, 2013; see also Bolakhe, 2023).[11] That said, Japanese researchers have reported that anodal electrical stimulation of the tongue can also be used to enhance the perceived piquancy induced by chili peppers and wasabi (Ohno et al., 2016). However, it is unclear whether there was much consumer appeal for early solutions in this space that required the tongue to be sandwiched between two electrodes (e.g., Ranasinghe et al., 2011a; 2011b; 2011c; Ranasinghe et al., 2012), or else for electrodes to be attached to the skin surface using a conducting gel (Ohno et al., 2016), in order to elicit the digital taste sensation. One solution to such practical concerns comes from another U.S. company, TasteBoosters, who also use a microcurrent-based approach to the design of their spoon (https://spoontek.com/).

A somewhat more practical solution has been put forward subsequently by Ranasinghe and colleagues called the Vocktail, in this case it is a glass connected to a source of power with a metallic lip, and LED to change the colour of drinks. The drinking vessel was also capable of emitting an aroma too. It should, however, be noted that the majority of what we think we taste, we actually smell (see Spence, 2015, for a review), hence meaning that digitally stimulating the taste buds may never have as much influence over multisensory flavour perception as the stimulation of the olfactory system. The problem here is that the very different neural coding in olfaction as compared to taste (see Weiss et al., 2016, for a failure to elicit meaningful olfactory sensations by means of electrically stimulating the receptors in the nose), means that it is simply not possible to stimulate discrete olfactory impressions electrically.

## 7. Digitally-stimulating smell and touch

Other researchers, meanwhile, have investigated the possibility of enhancing tasting experiences associated with digitally-controlling (and delivering) thermal/tactile cues, and the release of ambient scent (see Halabi and Saleh, 2021; Harley et al., 2018; Harris, 2013; Hashimoto et al., 2007; Hashimoto et al., 2008; Heller et al., 2019; Iwata et al., 2004; Kerruish, 2019; Nakano et al., 2019; Nijholt et al., 2018; Obrist, Velasco, Vi, Ranasinghe, Israr, Cheok, Spence and Gopalakrishnakone, 2016a, 2016b; Ramic-Brkic and Chalmers, 2010; Robinett, 1992; see also Ranasinghe et al., 2019a; 2019b). Recently, Ranasinghe et al. (2020) have introduced two new drinking vessels that are also capable of introducing thermal sensations (via Peltier elements) as well as electric taste, aroma, and colour. It is, however, important to stress that none of these interventions have, as yet, seen widespread uptake. Jinsoo An of LA-based design think tank Kokiri Lab created something of a stir back in 2015 when, as part of Project Nourished, the Korean designer

[9] Note that while several other food companies have incorporated ASMR triggers into their advertising, this was the first attempt to enhance the tasting experience through the digital presentation of ASMR triggers.

[10] Note that once it has been treated jellyfish has no taste but is pure texture/crunch.

[11] Here, it is worth noting that the functional role salt plays in many foods, e.g., bread, likely means that it will never be possible to replace it entirely (see Spence, 2022c).

claimed that an Oculus Rift headset with scent diffuser could be used to enable people to try 'eating cheesecake on Mars' (visually at least; Victor, 2015).

A decade ago, Philips Design launched a series of design probes to explore a new range of plateware concepts[12] that integrated light, conductive printing, selective fragrance diffusion, micro-vibration, and the integration of other sensory stimuli might affect the eating experience. In the design probe going by the name of 'Multisensorial Gastronomy', researchers explored whether the eating experience can be enhanced or altered by stimulating the senses using the integration of electronics, light, and other stimuli (see Fig. 4). Developed in collaboration with Michelin-starred chef Juan Maria Arzak, the four design concepts of interactive tableware – Lunar Eclipse (bowl), Fama (long plate) and Bocado de Luz (serving plate) and the Eye of the Beholder (platter) – react to food placed on the plates or to liquid poured into the bowl. However, there seems to be little evidence that either of these digital multisensory dining solutions have had a long-term presence in the marketplace. Furthermore, as far as I am aware, this digital plateware series was only to be found being used for a number of the courses in Arzak's restaurant in the Basque country.

One other digital system for the delivery of scent or food aroma goes by the name AromaShooter (see Fig. 5). This smell-delivery device contains six scent cartridges and can be connected to a computer via a USB. (Developed by Aromajoin; Kamps, 2023). Other novel handheld olfactory devices are also becoming available (see Niedenthal et al., 2023). One of the challenges associated with the digital control of smell comes from the observation that unpleasant odours appear to do a much better job of enhancing people's immersion in virtual environments than do neutral or pleasant smells (Baus and Bouchard, 2017; Munyan et al., 2016). It would seem implausible that consumers in the home environment (or anywhere else for that matter) would necessarily wish to be exposed to unpleasant scents in order to make their VR experience more immersive.

**Fig. 4.** Multisensorial Gastronomy: Philips Design and Arzak present a new generation of multi-sensorial tableware. (Copyright Philips.)

A)

B)

**Fig. 5.** A) The Aromashooter developed by Aromajoin; B) Newer digital scent delivery collar from Aromajoin (see Kamps, 2023). This is one of a growing number of digitally-controlled smell delivery devices.

## 8. Using digital technology to entertain

Oftentimes, digital technologies have been introduced at the dining table with the aim of entertaining diners rather than necessarily to enhance the tasting experience directly (Abend, 2019; Stewart, 2017). So, for example, the digital projections over the dining table, accompanied by specifically designed soundscapes, which are a regular feature of many of the dishes served at Kitchen Theory's Chef's Table are often used to help with storytelling around a dish or meal (e.g., Spence and Youssef, 2019; Youssef and Spence, 2021; Youssef and Spence, 2021). That said, while several top chefs have managed to successfully incorporate digital technologies in order to enhance the diner's experience of the food they serve, there have also been a number of seemingly less successful attempts, such as the *Out of the Blue* cocktail bar in London (Ellis, 2017). The latter cocktail tasting experience, which was priced at around £200 for a 1-h experience for four guests, closed shortly after opening.

At the same time, however, a number of designers have, over the years, created VR environments designed to complement the experience of tasting food (e.g., Cascone, 2022; Victor, 2015). For example, at AerobanquetsRMX (https://www.aerobanquets.com/) dining events, the artist Mattia Casalegno (http://www.mattiacasalegno.net/) and chefs (such as Chintan Pandya) team up to present futuristic meals that are eaten while wearing a VR headset (see Fig. 6). Such digital tasting experiences do not come cheap, though, with advertised prices of $58 for five bites of food (in a 30 min experience), through to $200 for ten bites accompanied by matching drinks (in a 1-h experience). As Brinkley (2020) put it: "Virtual reality dining is still a pricey novelty — costing as much as $2000 — but it does have the potential to create a new kind of food experience."[13] Interestingly, however, while VR headsets also

[12] "The FOOD design probe: A far-flung design concept; A provocative and unconventional look at areas that could have a profound effect on the way we eat and source our food 15–20 years from now." (taken from The Philips design website, http://www.design.philips.com/philips/sites/philipsdesign/about/design/designportfolio/design_futures/food.page).

[13] The $2000 in this case referring to a meal at Paco Roncero's Sublimotion in Ibiza's Hard Rock Hotel (see Moore, 2015; Pigott, 2015; cf. Gonzalez, 2013; Kessel, 2013).

**Fig. 6.** A guest dining at Mattia Casalegno's Aerobanquets RMX at Superblue Miami. The 'meal' inspired by the Italian Futurists (see Marinetti, 1932/2014). Note the isolated diner – seemingly missing any aspect of commensality. [Photo courtesy of World Red Eye.]. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

occasionally appear on the websites of top chefs (e.g., see Holmes, 2016; https://uvbypp.cc/), it is much harder to find any chef who actually encourages his/her guests to wear one while dining. Part of the problem here is that dining is a fundamentally social activity, and hence wearing a VR headset will likely interfere with the more social aspects of dining (Higgs and Thomas, 2016).[14]

Le Petit Chef would also appear to have as its purpose primarily entertainment (https://lepetitchef.com/). It has been described as a one-of-a-kind, 3D dining experience inspired by Marco Polo's legendary travels along the Silk Road. The fact that this chain of restaurants has had a presence in the world of dining suggests that it can perhaps be considered as one of the most successful uses of digital technology at the dining table in recent years. Relevant to the latter example, Risso et al. (2022) recently investigated the influence of AR characters situated close to food items on people's ratings and physiological responses to crisps. In terms of digital technology at the dining table, one could also consider the Inamo chain of restaurants (http://www.inamo-restaurant.com/pc/).[15] However, in the latter case, the digital projections are primarily designed to help the customer to visualize the dishes on the menu when ordering, and to order a taxi when leaving (i.e., the digital technology is not really designed to enhance the tasting experience *per se*). Other examples of entertainment that have so far only appeared in the HCI conferences include NetPot which was an application that allowed the user to modify the appearance of the cooking state of food in a Chinese hotpot with remote commensals (Foley-Fisher et al., 2010).

Another potential use of digital technology to enhance the taste of food comes from the suggestion that food could be plated on a tablet. Tablet computers as intelligent 21st Century plateware, in other words. So, for example, Fig. 7A shows one playful (and ironic) attempt in this direction from a Michelin-starred Swiss chef. Elsewhere, we have suggested the possibility of presenting the seashore on a tablet screen and the sounds of the sea over the audio channel (see Fig. 7B). One other potential reason to serve food off a tablet is that it would presumably allow for the optimization of the colour contrast between food and background (see Zhang et al., 2022).[16]

[14] Note that such problems do not really affect consumer science studies where participants are typically tested individually to begin with.

[15] According to the website: *"At the core of Inamo is our interactive ordering system. …. You'll set the mood, discover the local neighbourhood, and even order a taxi home."*

[16] Given that a number of such devices are now waterproof, they could simply be put straight into the dishwasher after use.

A)

B)

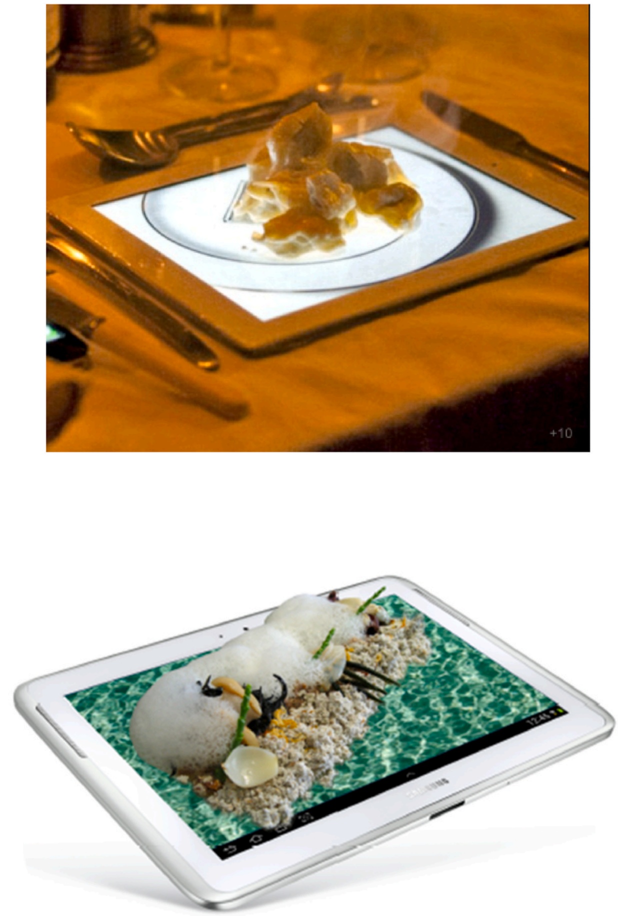

**Fig. 7.** Eating direct from a tablet computer is one of the plateware possibilities of the future that is definitely worth considering. A) Example from a Michelin-starred Swiss restaurant; B) Could the hugely successful 'Sound of the sea' concept be translated from Michelin-starred restaurant to home environment though serving seafood from a tablet at home?.

## 9. Using digital technology to support sensory marketing

There have now been a wide number of examples of sonic seasoning designed to create multisensory tasting experiences that are enhanced as a result of the presentation of matching/synchronized audiovisual content (e.g., Crisinel et al., 2013; Roncero-Menendez, 2015; cf. Deighton, 2015). For instance, a few years ago, I worked with British Airways to pair music with the meal option served to business class diners to help make in-flight food taste better (see Victor, 2014). Various multisensory (audiovisual) virtual reality (VR) installations/experiences have now been created on the basis of the crossmodal correspondences. Take, for example, the pop song and associated music video developed by The Roots in collaboration with Stella Artois beer (e.g., https://www.anheuser-busch.com/newsroom/2016/08/stella-artois-and-the-roots-stimulate-the-senses-with-a-one-of-a-kind-song-you-can-taste/). Teaming up with the experience designers, Bompas and Parr, and myself a special music video was created in 2016 as part of Le Savoir, a multisensory entertainment platform (e.g., Birkner, 2016). The idea was that people at home might enjoy the drink (of Stella Artois beer), and by moving the cursor on their screen while watching the specially composed track and associated music video (called "Sweet to the Bitter End") on their digital device in order to bring out a sweeter (fruitier) or more bitter version of the instrumentation/video backdrop (the bitterness associated with the hops). The suggestion that this personalized version of sonic seasoning could then be used to adjust the drink to taste. Another example is the use of auditory and visual VR to match the taste of three different beers.

This digitally enhanced taste test was introduced in Tesco supermarkets ('Guinness VR Immersive taste sensation MPC Creative', 2017; Glenday, 2017; Hills-Duty, 2017; Kiefer, 2017; Kulal, 2021; Monks, 2015).

A few years later, in 2020, I worked with Pitch and Synch to create bespoke soundscapes to match a series of innovative blends of Black Bottle whisky Alchemy Series (https://whiskymag.com/story/black-bottle-launches-the-alchemy-series-the-first-sonic-seasoning-playlist; alchemyseries.co.uk). My colleagues and I have also worked with Keurig coffee to craft a series of Spotify playlists to create a 'unique sensory experience' for coffee drinkers and matched with the flavour characteristics of different blends (DiPalma, 2021). However, it is striking in hindsight how few of these multisensory marketing campaigns have lasted long in the marketplace.

One of the longest lasting of sensory apps, comes from Krug Champagne. For a number of years, now, they have enabled customers to scan the QR code on the label of one of their Champagnes in order to access a selected playlist. However, in this case, rather than sonic seasoning, the aim is rather to emphasize the parallels between the art of blending wines, and the composition of music (see Anonymous, 2022; https://www.krug.com/playlist/krug-x-music; https://www.reead.com/en/krug-id-champagne-113532022/). Additionally deserving a mention here is the Concerto App from Haagen-Dazs ice cream from a few years ago (https://www.fastcompany.com/1683529/haagen-dazs-presents-a-mini-augmented-reality-concert-atop-your-pint), and the music timer for cooking Barilla pasta (https://www.designboom.com/design/barilla-spotify-playlist-timer-01-20-2021/). In both cases, the musical apps were designed to help pass the time till the product was ready to serve/eat. Another example here is Coca-Cola's virtual reality for Christmas, a campaign developed by the brand in which users are immersed in Coca Cola's animated Christmas world (fantasy), whilst flying in Santa's sleigh (https://www.youtube.com/watch?v=jCdYJfCSqYE). Though note that in this case the VR would appear to exist independent of the drinking experience so isn't relevant to the theme of digitally-enhanced taste experiences. One could say the same about recent food VR (Melnick, 2022). In the years ahead, it will be interesting to see the development of unbranded sensory apps, such as already happened with the release of wine music apps, that allow the users to scan any wine label and get putatively matching music recommendations.

### *9.1. Using digital technology to recreate nature (and the nature effect)*

There is growing interest in the beneficial effects of exposure to nature, this is known as the nature effect (Annerstedt et al., 2013; Spence, 2021a). It is noticeable in hindsight how often chefs have chosen to digitally recreate a natural environment when augmenting their dishes (see Spence, 2022c). One more commercial example of the use of nature sounds comes from Finnair's "Hear the Taste" bisensory experience 'Sound palate' (Silva, 2019). As well as being congruent with the ingredients, digitally simulating aspects of nature, may also inadvertently trigger the nature effect in diners, and so indirectly enhance the experience of the food.

### *9.2. Using digital technology to help encourage healthier eating*

There have been several attempts to consider how digital technologies could be used to nudge people toward healthier eating. For example, the Xin café in Beijing played sweet music so that they could reduce the sugar in their drinks (served in drinks that were digitally connected) while supposedly keeping the taste sensation constant (see Blecken, 2017). However, it is unclear how long this particular marketing-led intervention lasted, perhaps suggesting that the press headlines may have been more important than the long-tern health angle. Relevant here, researchers have now developed musical menus to help enhance the taste of sweetness, saltiness, etc. (e.g., see Guedes et al., 2023; Wang et al., 2021a). Wan et al. (2022) investigated whether colour contrast in VR could be used to help encourage more sustainable food choices (see also Burkert et al., 2022). However, while digital technologies can possibly help consumers make better choices (and/or eat more slowly; see https://www.hapilabs.com/product/hapifork/), one also needs to recognize the dangers of digital enhancement making less healthy foods look more appealing (Petit et al., 2022; Spence et al., 2022).[17] Indeed, marketing researchers are now becoming increasingly interested in the way in which AR can be used to influence food desirability (Fritz et al., 2022).

## 10. Conclusions

In summary, it is clear that the literature on the use of digital technologies to enhance the taste/experience of food and drink can be divided into several distinct categories (or usage scenarios). Looking to the future, it would seem as though those approaches, where digital technologies/solutions are used to help 'nudge' people toward healthier food and drink consumption behaviours, may be more likely to last into the long-term (e.g., Narumi et al., 2012; Pan et al., 2019; Suzuki et al., 2015; Wan et al., 2022). At the same time, however, highly-publicized attempts to introduce such digital solutions to encourage healthier eating (e.g., Blecken, 2017) have thus far seemingly been led by marketing rather than by a genuine desire to use digital technology to encourage healthy eating. That said, there are surprisingly few examples where digital technologies have made their way to the dining table for anything more than a brief interlude. In fact, more often than not, the primary purpose of such digital interventions would appear to be to generate some press/media interest. Once that goal has been achieved, then often the innovations are quietly dropped. While this presumably counts as success from a marketing perspective, the real measure of success as far as digitally enhancing tasting experiences is concerned would surely be when there is mass uptake in the home environment.

While visual projections and sonic seasoning are increasingly common in the context of high-end experiential dining and branded experiential events and installations, as yet there has been little translation of these approaches to the home environment. Nevertheless, looking to the future, there is growing interest in the use of digital technologies to help deliver the benefits of commensal dining (e.g., Pereira-Castro et al., 2022; Si, 2021; Spence et al., 2019; Wang et al., 2021a). It is worth noting here that the majority of situations in which such digital commensal agents are envisioned are outside the context of fine dining. Hence, this may represent one of the most common ways in which digital technology enhances people's mood, and thereby, indirectly, their eating experiences in the years ahead (see Barden et al., 2012; Comber and Barden, 2014; Grimes and Harper, 2008, for early digital solutions to the problem of telematic dining). One might already consider the phenomenal rise of Mukbang in parts of Asia as one of the currently most widespread uses of digital technology while eating (Choe, 2019; James et al., 2022; Kang et al., 2020; Kawai et al., 2021; Kim, 2018; Kircaburun et al., 2021; Pereira et al., 2019). Intriguingly, James et al. conducted a series of experiments showing that Mukbang influenced veiewer's emotions, and by so doing, indirectly influenced their perception of the taste of the food that they had been asked to evaluate. At the same time, however, it should not be forgotten that digital devices can also adversely affect tasting experiences as well. Here, one need only consider how people tend to eat significantly more when distracted by the TV (Braude and Stevenson, 2014; Pope et al., 2015; Spence, 2017). The increasingly ubiquitous presence of smartphones and other digital devices at the dining table has also been shown to increase people's consumption (Gonçalves, Barreto, Monteiro, Zangeronimo, Castelo, van der Bilt, & Pereira, 2019). Indeed, according to

[17] Concerns have also been raised about the dangers associated with incorporating food rewards into the context of online, or digital, gaming (cf. Vi and Obrist, 2018).

the results of one survey, 88% engage in so-called "Zombie eating", where they stare at a screen while consuming food. And while some chefs have attempted to restrict the use of digital devices at table by their diners (e.g., Stapinski, 2013), such attempts rarely last long, in the face of the 'customer always being right' mentality.

Ultimately, one needs to consider how the influence of digital stimulation may be enhanced when synchronized across the senses (Halabi and Saleh, 2021; Nakamura and Miyashita, 2012). Looking to the future, there may also be scope to digitally deliver impossible, or magical, food experiences (Spence et al., 2020; Velasco et al., 2021). It will also be interesting to see how (the use of artificial neural networks can be used to help optimize multisensory dining experiences (see Kantono et al., 2022, on this innovative approach). There are also a number of intriguing questions concerning the future of digital dining in the Metaverse (e.g., see Tonon, 2022). Finally, the growing interest in incorporation of foods into gaming (e.g., Arnold, 2017) means that one day it may be food that is used to enhance people's digital experiences instead/as well. However, given that these topics are likely to develop substantially in the coming years, here is not the place to review them in any detail.

## Authors' contribution

The author wrote all parts of this article, and read and approved the final manuscript.

## Implications for gastronomy

How can digital technologies be used to enhance the tasting experience? Virtual and augmented reality technologies would appear to have a more obvious role in consumer/sensory science than necessarily in the world of gastronomy, in part due to the way such technologies can interfere with the more social aspects of dining. Projection mapping and sonic seasoning have both been used, more or less successfully in the world of fine-dining. However, such digital solutions to enhancing the dining experience have yet to make it into the home environment. At the same time, a growing number of food and drink brands have launched sensory apps to complement the experience of their products. However, such sensory marketing interventions do not tend to last for long in the marketplace. Ultimately, it is argued that the digital enhancement of tasting experiences will only become ubiquitous when such digital solutions offer a demonstrable, and perceptible enhancement to consumers. Furthermore, those digital technologies that help to nudge diners towards more healthy/sustainable food consumption behaviours and/or those that facilitate digital commensality may also have more hope of long-term success than those digital solutions that merely have entertainment value.

## Declaration of competing interest

The author confirms that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. The manuscript has been read and approved by the author and there are no other persons who satisfied the criteria for authorship but are not listed. The author understands that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office).

## Data availability

No data was used for the research described in the article.

## Acknowledgements

None.

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