

REVIEW

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A touch of gastronomy

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Abstract

The last few years have seen a rapid growth of research interest in the study of the role of touch and oral-somatosensation in the experience of eating and drinking. The various ways in which the sense of touch can be used to enhance the diner's/consumer's experience in both everyday eating and drinking, as well as in the context of experiential dining, is also gaining ever more attention from professionals in a variety of disciplines. In this review, we highlight the importance that everything that we perceive via the sense of touch, from the weight of the menu to the feel of the tablecloth, tableware, cutlery, and even the food itself, has on our eating experience and food and beverage-related behaviors. Everything we feel, be it the weight, the temperature, or the texture of whatever we happen to come across while eating appears to matter. In addition, we also highlight the relevance of oral-somatosensory cues to our sensory and hedonic perception of foods. A number of examples are given to demonstrate some of the many ways in which chefs, designers, and artists are now exploiting these findings in order to change and, hopefully, to enhance the diner's eating experience in innovative ways.

Keywords: Touch, Food, Texture, Multisensory perception, Experiential dining

Introduction

With his tactile dinner parties, the famous Italian Futurist Filippo Tommaso Marinetti was perhaps the first to think creatively about the importance of touch and tactile stimulation to the act of eating, not to mention its enjoyment by diners. His suggestion was that in order to maximally stimulate the senses while dining, people should wear pajamas made of (or covered by) differently textured materials, such as cork, sponge, sandpaper, and/or felt and eat without the aid of knives and forks to enhance the tactile sensations (see [1], p. 61; [2], pp. 1–2). The movement that Marinetti founded back in 1909 with the publication of *The Futurist Manifesto* [3] was, in many ways, well ahead of its time. That said, the last few years have seen something of a revolution in terms of our growing understanding of the role of touch in the experience of eating and drinking and, perhaps more importantly, its exploitation in both everyday eating and drinking, as well as in the context of experiential dining.

In this article, we take a closer look at a number of the ways in which touch (including oral-somatosensation) can

influence the experience of eating and drinking, and how the latest scientific insights are now starting to make their way into an increasing number of our everyday food experiences. The focus of the first part of this article will be on touch as it influences the experience of a diner in a restaurant setting. Later, we will provide an overview of the oral-somatosensory contributions to the experience of the taste/flavor of foods and beverages. These in-mouth tactile sensations affect our food and beverage experiences regardless of what it is that we happen to be eating or drinking. Furthermore, they affect us whether we realize it or not (and typically we do not). As Brillat-Savarin [4], the famous French gastronôme put it, the pleasures associated with eating and drinking constitute some of life's most enjoyable experiences. This, he thought, was especially likely to be true for the growing aging population (even more of a problem now than when he was writing). Given the importance of touch and oral-somatosensation to the experience of tasting and flavor perception (as discussed below), it is surprising that none of the many books that have been published over the years on the topic of tactile perception (for example, [5-9]) has ever mentioned the significant role that this sense plays in our experience of food and drink. Perhaps even more surprisingly, those professionals working in the fields of food science and

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gastronomy do not appear to have given this topic the thought that it most surely deserves either.

On the feel of the restaurant

The information that we receive by means of the sense of touch (not to mention the related haptic, proprioceptive, and kinesthetic cues) plays a subtle but nonetheless important role in many aspects of our eating and dining experiences (see [4,10] [11; Chapter 17]). Taking inspiration from Marinetti, there would certainly seem to be grounds for thinking that simply by enhancing the tactile stimulation delivered by the chair on which a person is sitting at a restaurant, it might actually be possible to enhance (or, at the very least, to alter) a diner's experience. Indeed, in her new book, Barb Stuckey [12] reports on a California chef who deliberately chooses throws for the back of the diners' chairs with the stated aim of delivering a richer tactile experience.

Presumably the pleasant feelings associated with dining from a table covered with a starched tablecloth (as compared to an uncovered plastic tabletop, say) might serve much the same purpose (of stimulating the diner's sense of touch). Although, of course, in the former case, or even when thinking about the role that linen napkins might play in influencing the experience of the diner, it becomes much harder to separate out any positive effects associated with the sensory properties (for example, the sight or feel) of the material of the tablecloth (or napkins) from any cultural associations that we may have with such table coverings and fine dining experiences, more generally (see [13] compare with [14]). At the restaurant Nerua, in Bilbao, Spain [15], when the service starts, the diners find themselves seated at an empty table: no cutlery, no glasses, and no plates. The waiter then brings each diner a warm napkin, as a way of transmitting tenderness and care (as its founder and chef Josean Alija states). Next, the cutlery is 'served', and depending on its temperature, the diner can infer if the plate which is going to be served next will be warm or cold.

Regarding the environment and interior décor, many top restaurants are increasingly collaborating with well-known architects and interior designers in order to create unique dining atmospheres (see [16]) that stimulate, as much as possible, their diners' sense of touch. As Crawford [17] put it: 'surfaces made from natural materials are often preferable, as irregularity is far more sensual than clinically perfect surfaces.' However, certain restaurants or bars, involve the diners' sense of touch in a wholly different way: they incorporate new socializing interactive technologies in their counters, table-tops, or walls (such as i-Bar or i-Wall; <http://www.i-bar.ch/> accessed on 25 October 2012) that produce sounds or light up as the diner touches them. In one

way or another, then, it seems as though more and more importance is now being given to the experiences being delivered through the sense of touch (no matter how it is done) in the contemporary gastronomic context.

A number of bars and restaurants, such as The Ice Bar in London, also play with the environmental temperature. Such changes, as well as creating a means of differentiation from the competition in the marketplace, may also exert a subtle influence on how much people consume [18]. Elsewhere, in Paco Roncero's experimental workshop/dining space in Madrid, Spain, both the temperature and the humidity can be controlled throughout the course of the meal [19]. Furthermore, the ceramic table that people eat from is heated and can also vibrate.

On the weight of the (wine) menu

Ackerman *et al.* [20] reported a series of experiments in which they convincingly demonstrated that our judgments of other people (specifically, the qualities/characteristics of job candidates whose CVs we happen to be assessing) can be influenced by something as seemingly irrelevant as the weight of the clipboard on which those CVs happen to be placed. Reading about such results could certainly make one wonder whether the weight of the menu (for example, in a restaurant setting) might not also influence a diner's (or for that matter, drinker's) choice behavior, not to mention their overall impression of the feel of a restaurant or bar. Might there be, for example, a correlation between the weight of the menu and the likely price of the food/wine that a restaurant happens to offer? And, if there were to be, have consumers/diners internalized that correlation (see [21]). One concrete question to address here in future research would, therefore, be to see whether it is possible to increase the average spend in a restaurant simply by increasing the weight of the menu.

Thus far, the tactile attributes/features of the dining experience that have been evaluated have been pretty far removed from the food and drink itself. Note that such contextual effects are likely to set up a particular expectation in the mind of the consumer that colors their experience of whatever food or drink they consumer subsequently.

On the feel of the glassware

Many consumers believe that drinks taste better when served from a heavier cup/glass than from a lighter one. Our guess is that in many cases it would be perceived by a drinker as being of higher quality as well. However, this claim is not always going to be true. The quality of bone china tea cups, for instance, is judged primarily in terms of the translucency of the china (and hence, in this case, lighter presumably equals better). While wine sometimes appears to taste better from a heavy glass, on other

occasions, the most expensive glassware (such as the popular Riedel range of wine glasses), which can actually be surprisingly light, purportedly delivers the best taste (although see [22], for a review of the physical versus psychological effects of a wine glass on our perception of the contents). Why, one might ask should heavy glasses work under some conditions but light glasses under others? Our suggestion here would be that it is the perceived quality of the glassware that matters. In the absence of any other cue, consumers presumably use weight as a proxy for quality. However, there are occasions when the perceived quality of the glassware does not rely on the weight because the quality is otherwise apparent.

However, it is usually not only the weight of the glass that transmits that sense of quality to the contents (in the mind of the drinker), it is also the general feel of the material (that is, its quality). Krishna and Morrin [23] reported on a study in which water samples (that the participants got to taste) were perceived as significantly higher in quality when the participants were not able to touch or hold the flimsy plastic cup in which they were served than when they were. Note that in all these cases, the participants drank with the aid of a straw (so that their lips never came into contact with the container). Results such as these suggest that changes in the haptic qualities of the glass, cup, or any type of container in/on which a food is served, might have important effects on a consumer's appraisal of the quality of the product within, not to mention on their global experience. Meanwhile, in another study, Schifferstein [24] had participants evaluate either empty cups made from different materials, or the experience of drinking hot tea or a chilled soft drink from these cups. For many of the attributes that the participants were asked to assess, the results revealed that the drinking experience was related to the participants' experience of the cups. It was as if, without realizing it, the participants transferred some of their experience related to the cups themselves to their judgments of the drinks contained within.

Designers might be well advised to try to capitalize on such findings. One designer who already seems to be doing this is Ingrid Rügemer with her Frooty sensual smoothie cups. These fine bone china cups have the shape of different fruits that have apparently been designed to 'provide a new, tactile drinking experience that stimulates your senses' [25].

Another means of consuming a drink is by means of a straw (often one does this without touching the glass or cup, as for the participants in Krishna and Morrin's study just mentioned, for example [23]). After having incorporated long straws with which to drink into her experiential dinners, the conceptual culinary artist Caroline Hobkinson (see <http://www.stirringwithknives.com/> accessed 27 September 2012) observed that diners

tend to drink (alcoholic beverages) more rapidly when compared to drinking directly from the glass.

On the weight of the wine bottle

The increasing weight of certain wine bottles that one nowadays finds in the wine store, think of those wines that come under the header of Super-Tuscans, for example, is something that is increasingly being commented on by consumers and wine writers alike (for example, see [26]). We would argue that such manipulation in the marketplace is primarily designed to convince the undecided supermarket shopper about which bottles represent better value for money (or quality). However, that said, the weight of the wine bottle will still likely have an effect in those restaurants in which the diners have to pour the wine for themselves. (Although in this case, of course, the weight of the wine bottle is only experienced after the purchasing decision has been made.) Research from Faraday Packaging Partnership and Glass Technology Services [27] suggests that people's preference for drinks served from heavier bottles extends well beyond the world of wine: they observed that consumers also preferred vodka when it was served from a heavier bottle.

Recent research has demonstrated the significant correlation that exists between the weight of the bottle and the price that you are likely to pay for a wine. When Piqueras-Fizman and Spence [28] recently measured the weight of all the wine bottles in a wine store in Oxford (UK), they found that for every UK pound more on the ticketed price, the weight of the wine bottle increased by an average of 8 g (see Figure 1). The lightest bottles weighed 340 g, as compared to 1,180 g for the heaviest bottle (both empty) – that is, the heaviest bottle weighed more than three times as much as the lightest bottle, all for the same 750 ml of wine.^a However, there are even heavier bottles in the

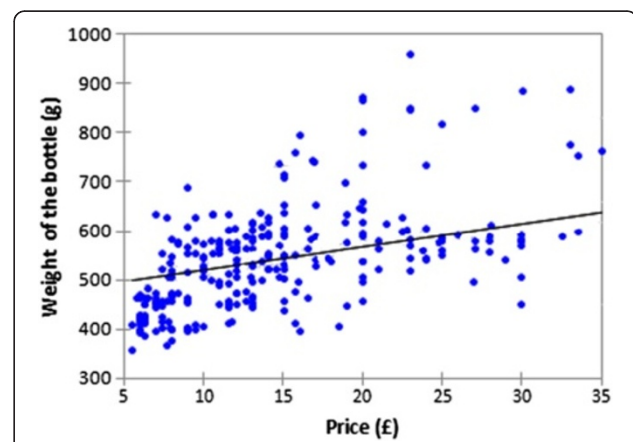


Figure 1 Wine bottle weight – price correlation as reported in Piqueras-Fizman and Spence ([28], Figure 1). Each point represents a bottle of wine. [Figure reprinted with permission].

marketplace, some weighing as much as 1,500 g empty, connoting who knows what quality in the mind of the consumer! And while it is certainly true that one can make a rough guess about the weight of a bottle from its visual size alone, it is nevertheless important to note that variations in the thickness of the glass, and the depth of the punt (at the bottom of the bottle), attributes that cannot necessarily be assessed visually, can result in some bottles being surprisingly heavy when first picked up.

On the feel of the plateware

As the 'Fur-Covered Cup' [29] by Meret Oppenheim (see Figure 2) illustrates, the feel (either real or expected) of plateware against our skin (especially against sensitive regions of the body, such as the lips; [30]) can generate unpleasant sensations. Over the last couple of years, researchers have been investigating just what effect varying the weight and texture of the plateware has on people's perceptions of the food served from it.

While the visual pun of Oppenheim's work was very much about something that people would likely not want to put their lips to, psychologists, together with modernist chefs and a growing number of food and beverage producers, are currently trying to make plateware and/or packaging that, by more effectively stimulating the sense of touch, manages to enhance the diner's (or consumer's) experience of food and drink. An example of plateware that may successfully achieve this goal is Nao Tamura's silicone leaf plates, whose texture resembles that of a leaf, possibly making the eating experience more natural [31] (Figure 3).

Piqueras-Fizman *et al.* [32] published what is perhaps the first study to demonstrate that eating off of heavier plateware, at least when that plateware is held by the



person doing the eating, also impacts on the perceived quality of the food (in particular, on both their sensory and hedonic evaluations). Piqueras-Fizman and her colleagues had participants rate a spoonful of yogurt served from visually-identical bowls that varied only in terms of their weight (375 g, 675 g, and 975 g, respectively). The participants in this particular study sequentially held each one of the three bowls in one hand (with the order of presentation of the bowls counterbalanced across participants) while taking a spoonful of the plain yogurt from each bowl with their other hand. The participants rated each of the yogurts using a series of pencil and paper labeled line scales. The results revealed that the participants liked the yogurt served from the heavier bowl significantly more than when exactly the same yogurt was served from either of the other two lighter bowls. The participants also rated the yogurt as significantly more expensive and as significantly denser (see Figure 4).

In their subsequent research, Piqueras-Fizman and Spence [33] have gone on to demonstrate similar effects on people's ratings of yogurt when served from either light (20 g) or heavy (95 g) plastic bowls (see also [34]). This time, the absolute variation in the weight of the plateware was much subtler, and yet the yogurt tasted from the heavier pot was still estimated as likely to be more satiating (prior to consumption), denser (once again), and as likely to be more filling, after it had been tasted (see [35,36]).^b

Now, it is not only the weight of the plateware that matters, but also its texture (especially when held in the hand, and hence felt by the diner). Suggestive evidence in this regard comes from a recent study published by Piqueras-Fizman and Spence [37]. They reported that people rated pieces of digestive biscuit (either stale or fresh) served from a small plastic yogurt pot as tasting both crunchier and harder when the container had been coated with a rough sandpaper finish, as compared to when exactly the same food was served from a container



Figure 2 Meret Oppenheim's [26] *Fur Covered Cup* (1936). Most people find the idea of putting their lips to such a textured cup rather off-putting. Just one extreme example, then, of how the texture of the plateware may affect us. (Picture downloaded from http://www.moma.org/collection/browse_results.php?object_id=80997 on 27 September 2012).

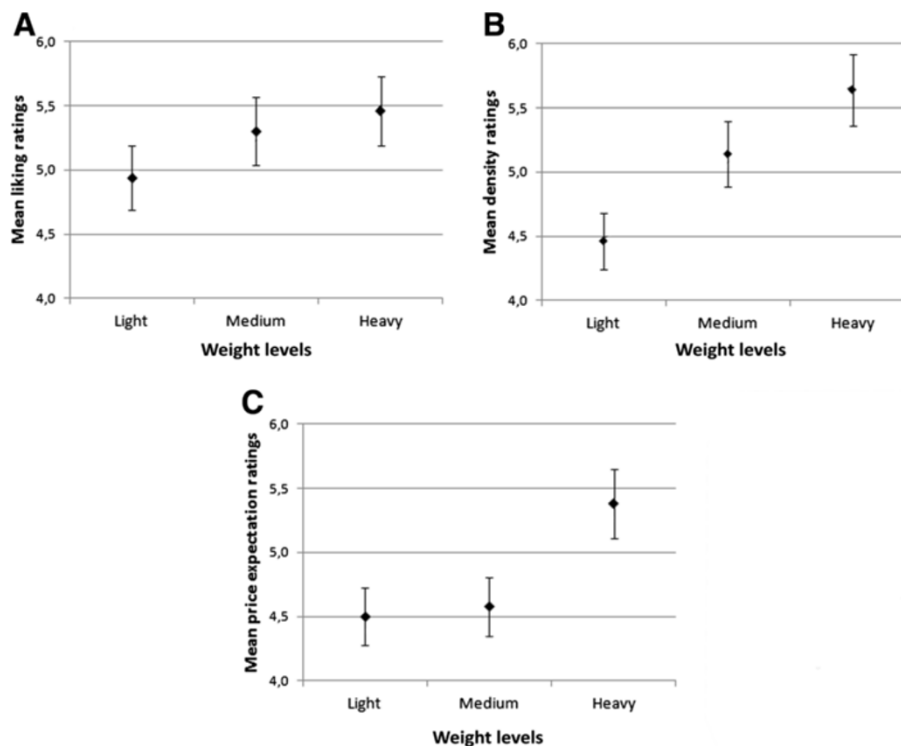


Figure 4 Results of Piqueras-Fiszman *et al.*'s [32] study showing how the weight of the plateware, at least when that plateware (a bowl in this study), is held in a person's hands, can enhance their perception of yogurt. [Picture redrawn from Piqueras-Fiszman *et al.* (2011), Figure one.]

with the usual smooth plastic feel of a yogurt pot (see Figure 5).^c

Interim summary

Thus, to summarize the findings reported in this section, the weight ([28,32,34]), the texture ([37]), and possibly even the temperature (see [38], discussed below) of the plateware and glassware can all be modified in order to enhance (or, at the very least, to alter) a diner's multisensory experience of food and drink items. In contrast to the results reviewed in the previous section, the plateware and glassware are obviously much more closely related to the experience. As such, it should perhaps be less surprising that these factors have an impact on the experience of eating and drinking. While the initial results (of the feel of the restaurant, of the wine menu and so on) were accounted for in terms of touch cues setting up a particular context that colored a diner's subsequent impressions, results of the plateware on perception likely result, at least in part, from 'sensation transference' [39], by which our perception of certain sensory attributes related to the plateware may be transferred to (or come to influence) our perception/rating of the food served from that plateware. What is also worth noting here, though, is that not everyone is necessarily likely to be similarly affected by the feel of the tableware. Results originally reported by

Peck and Childers ([40,41]), and followed-up more recently by a number of other researchers (for example, [23,42,43]), suggest that there are stable and significant individual differences in terms of people's need for touch. Those individuals who score higher on the 'Need for touch' scale developed by Peck and Childers seem to prefer a greater degree of tactile contact than those who score lower. Particularly relevant in the context of the present chapter are findings reported by Krishna and Morrin [23]. They found that those who score higher on Peck and Childers' questionnaire tend to be influenced more by the feel of a flimsy water container than those who score lower on the scale, as mentioned above. That said, the question of why it is that some people should exhibit a much higher score on the 'Need for touch' scale than others has yet to be addressed/resolved.

On the weight and feel of the cutlery

Investigators have recently started to turn their attention to the area of cutlery design (for example, [14,34,44-46]) and, as we will see below, a number of insights from this novel area of research are already starting to appear in the context of experiential dining. In one such study, for example, Piqueras-Fiszman and Spence had participants sample vanilla yogurt using either a light or a heavy spoon (4.9 g versus 19.2 g, respectively). The participants



Figure 5 The rough and smooth food containers used in Piqueras-Fizman and Spence's [34] study of texture transfer effects. Pieces of biscuit (stale and fresh) were rated as tasting significantly crunchier and harder when sampled from the rougher container shown on the left, than when tasted from the smoother container shown on the right. Interestingly, however, participants' freshness and liking ratings were not affected by the variation in the pot's surface texture, but only by the texture of the food itself. That is, the fresh food samples were, unsurprisingly, perceived as being fresher and more liked than the stale biscuits, regardless of the container in which they were presented. [Picture from [34], Figure one; Reprinted with permission].

liked the yogurt sampled with the aid of the heavier spoon more than when exactly the same food was tasted using the lighter spoon. Additionally, the yogurt was rated as being of significantly higher quality (when tasted with the aid of the heavier spoon), even if the weight of the spoon itself did not affect the rated intensity of the vanilla flavor. Harrar and Spence [44] have subsequently reported similar results in a study in which they independently varied both the weight and size of the spoons that they were testing.

Elsewhere, researchers have investigated how the material properties of the cutlery affect the taste of food. For example, Piqueras-Fizman *et al.* [46] recently demonstrated that eating with the aid of different spoons (coated with silver, gold, copper, stainless steel and so on) made food (in this case, cream samples to which salt, sugar, citric acid, or caffeine had been added) taste different. However, these results are unlikely to have had anything to do with touch *per se*, since the participants in this study were blindfolded prior to being presented with each of the spoons, and there was no discernible difference in the feel of the spoons in the hand when participants were blindfolded. Hence, in this case, it was solely the spoons' material properties (as experienced intra-orally) that affected the taste. (Perhaps if the participants had their eyes open in this study, then the impact of the different spoons on the participants' experience might have been even larger.)

Many practitioners are currently using the insights of such laboratory-based research in a real dining context.

Hobkinson (see <http://www.stirringwithknives.com/> accessed on 27 September 2012) has, over the last couple of years, been hosting culinary events in which she has been experimenting by providing diners with a variety of unusual eating utensils to work with. In one such dish, for example, diners were invited to use hand-carved tree branches in order to 'spear' the foraged Chanterelles and the wild venison from the table (see Figure 6). These utensils were specifically designed to enhance the feeling of wild unaltered nature, of eating wild, gamey food.

When the House of Wolf opened in London (see <http://houseofwolf.co.uk/> accessed 27 September 2012), the inaugural chef (the chef rotates every month or so), Caroline Hobkinson, created a series of courses designed to sequentially stimulate each of the diner's senses (see Figure 7 for the opening menu from the restaurant). Of particular relevance here, are the dishes on the menu that were specifically designed to engage the diner's sense of touch. These included the use of small whittled tree branches as cutlery, while another of the dishes (again designed to stimulate the diner's sense of touch more effectively) was a 'Hendrick's gin infused cucumber Granita'. This dish was to be eaten with spoons that had been treated with rose water crystals and Maldon sea salt to give them a distinctive and unusually gritty texture (see Figure 8).

The tactile experience of eating

Eating with one's hands might seem uncultured, or uncivilized in today's day and age, especially in those



Figure 6 Diners enjoying traditional Scottish venison with a somewhat unusual choice of cutlery (see <http://www.stirringwithknives.com/> figure downloaded on 27 September 2012, with permission of the chef).

contexts where cutlery is available/provided. However, it is important to note that eating behaviors have changed over the years and now high-end meals have evolved to enable this format of eating (often referred to as 'finger food' [47], Chapter 3). Indeed, for many eastern cultures, the practice of eating with the fingers definitely constitutes a very multisensory approach to eating, which offers a sensual, tactile experience (see [48]). As Jo Bryant, etiquette advisor at Debrett's has been quoted as saying [49], 'The influence of other cultures and new foods, such as calzone, means eating with our hands is a growing trend'. In fact, the latest version of the classic Debrett's etiquette guide has, for the first time, suggested that eating with one's hands (as suggested by the title of Zachary Pellacio's most recent cookbook [50]), now constitutes an acceptable practice, at least for

certain foods, such as pizza and calzone, as long as the diners remember not to lick their fingers afterward. As fine dining becomes ever more adventurous and playful, a growing number of chefs seem to be considering course-specific alternatives to the knife and fork – that is, moving away from traditional cutlery. Some chefs, such as the Chicago-based Grant Achatz, certainly seems to invest enormous amounts of thought and planning in customizing serving vessels for each micro-course of his degustation menu ([51]). Indeed, one of Achatz's most famous dishes is a shrimp tempura skewered on a vanilla pod. Diners are instructed to tilt their heads back and take the shrimp into their mouths in one sweep.

Leaving such extravagant creations aside for a moment, the fundamental truth is that many people simply

LOOK. LISTEN. SMELL. TOUCH. EAT!

A fully immersive sensory dining experience by Caroline Hobkinson
In collaboration with Experimental Psychologist Professor Charles Spence

AMUSE BOUCHE

Insert your earplugs
Devour the freshly baked Bread roll without the use of your hands
Neuroscience has revealed a deep 'cross modal' connection, sounds can actually change how we perceive food experiences.
Can you hear the taste?

SIGHT

Blindfold yourself
Your waiter will describe the dish to you
A Cracker bread is placed in front of you
The Smell of Roast Peppers and Fresh Rosemary is distributed
Remove your blindfold
Can you see the taste?

SMELL

Salmon Sashimi accompanied by a Syringe filled with Ardbeg Ten Years Old.
Revered as the peatiest and smokiest Single Malt.
Inject the Salmon with the Whisky and eat it
Reconstruct the taste of Smoked Salmon with the Smokey Scent
Taste sensations are picked up chemically by our tongue.
The sensation of flavour is a combination of taste and smell. Most of flavour is smell.
Can you smell the taste?

TOUCH

Palate cleanser
HENDRICK'S Gin infused Cucumber Granita
Slurp with texture treated spoons with
Rose Water Crystals and Maldon Sea Salt

TOUCH

Main
Saddle of Venison with foraged Prunes, Chanterelles and Wild Cherries
Grab the hand carved long tree branch and spear it
Can you feel the taste?

SOUND

In collaboration with Condiment Junkie
Sonic cake pop
Please take your phone
Dial 0845 680 2419
Research at Oxford University proved that by changing a sound alone we can change a taste from Bitter to Sweet.
A low note brings out the Bitter, a high pitched sound brings out the Sweet flavour.
Can you dial a taste?

Figure 7 Opening menu from the House of Wolf restaurant, London. (see <http://houseofwolf.co.uk/> figure downloaded on 27 September 2012, with permission of the chef). Menu developed by Caroline Hobkinson. Note how different dishes are designed to stimulate each of the diner's senses.



Figure 8 The textured spoons presented to diners for one of the touch courses at House of Wolf (see <http://www.stirringwithknives.com/> figure downloaded on 27 September 2012, with permission of the chef).

find it more enjoyable to eat certain foods with the hands instead of using the cutlery, when provided, a hamburger being the perfect example of one of those meals (or Fish and Chips from a newspaper wrapping for The Brits [47]). In fact, it is interesting to note that a number of restaurants have recently started to appear where no cutlery is provided to the diner (for example, 'Il Giambellino' in Milan, Italy; [52]). That is, the diners are forced to eat with their hands. Some marketers have recently started to capitalize on such observations: One example comes from Kraft in Italy who used the slogan 'Se non ti lecchi le dita godi solo a metà' (If you don't lick your fingers you only half enjoy it; where in Italian 'godi' is also related to sexual enjoyment) to advertise their 'Fonzies' crisps. Similarly, consumers often use the expression 'finger-licking good' to describe a food that they think is delicious (this was KFC's slogan, one of the best recognized, until they ditched it in 2011; <http://www.dailymail.co.uk/news/article-1358784/KFC-ditches-finger-lickin-good-healthier-slogan.html>, accessed on 26 October 2012).

Apart from the enjoyment that handling the food with our hands may provide to the eating experience, it is important to note that people can also evaluate a food's texture (that is, they can gain useful information) using nothing more than haptic information. In one study, for example, Michael Barnett-Cowan [53] had blindfolded participants rate the freshness/staleness and the crispness/softness of a series of pretzels while biting into either the fresh or stale end of a pretzel. Barnett-Cowan manipulated the congruency between the tactile/haptic information provided to the participants' hand and that provided to their mouth. In half of the trials, the participants were given a half fresh-half stale pretzel (incongruent conditions); whereas in the remainder of the trials, they were given either a whole fresh or stale pretzel (the congruent condition). The results revealed that in the incongruent conditions, the stale part of the pretzel was rated as being significantly fresher and crispier in-mouth because the hands held what felt like a fresh pretzel, and vice versa when holding the stale end. Such results suggest that the perceived texture of food in-mouth can be altered simply by changing the haptic information provided to the consumer's hands (no matter whether those textural cues are delivered by the food being held in the hand or by the cutlery or plateware if that is held instead).

Note how, in the preceding sections, we have steadily moved from looking at the impact of the more peripheral aspects of touch (for example, the weight of the wine menu, the feel of the table cloth) through to the feel of those items that are more closely associated with the act of eating and drinking itself (for example, the feel of the plateware, glassware, and cutlery). In the next section, we will take a look at the more perceptual multisensory interactions taking place in mouth.

Mouth-feel and the oral-somatosensory aspects of food and drink

It turns out that oral-somatosensation plays a crucial role in many aspects of our multisensory perception of food/flavor. The tactile stimulation we receive in-mouth informs us about everything from the temperature of a food through to its texture (for example, [54-58]). Bourne ([59], p. 259) has defined food texture as: 'the response of the tactile senses to physical stimuli that result from contact between some part of the body and the food'. More recently, other researchers have been tempted to include a contribution from the other senses, such as vision, hearing, olfaction, and kinesthesia in their definitions (for example, [54] see also [53]). In terms of typical descriptions of oral texture, one might think of whether a foodstuff feels sticky, slippery, gritty and so on in the mouth.

When it comes to the tactile experiences associated with the consumption of food and drink, they are obviously

important, although they typically fall behind taste and smell in people's ratings (especially if the opinions of those working in the food industry are anything to go by). That said, according to the results of a survey of 140 people working in various capacities in the area of food/chemical senses, temperature and texture came out ahead of color, appearance, and sound in terms of people's rankings of the importance of various sensory cues to the perception of flavor ([60]). While oral-somatosensory cues do not obviously fall under official definitions of flavor,^d they are nevertheless increasingly coming to be recognized for the integral role that they play in our experience of food and drink. Indeed, some talk of touch as the forgotten flavor sense.

The multisensory aspects of texture

It is, however, not always so easy to ascertain exactly which sense is actually doing the work in terms of giving rise to specific aspects of our multisensory experience of food and drink (see [61]). For example, take attributes such as carbonation, fattiness, and astringency. While intuitively many people assume that the experience of carbonation in mouth is attributable to the feel of the bubbles bursting in the oral cavity, it turns out that carbonation is as much a result of the stimulation of the sour taste receptors on the tongue [62]. Meanwhile, most of us would say that the perception of fattiness in a food or drink is an oral-somatosensory textural attribute. However, it turns out that our experience of this food attribute does not come just from the oral-somatosensory texture/consistency of a foodstuff in the mouth: olfactory and gustatory cues are also important (for example, [63]). Indeed, a number of researchers have recently started to suggest that one of the basic tastes, that is, along with sweet, sour, salty, bitter, and umami, may be the taste of certain fatty acids (for example, [64]). Astringency too, as in an overstewed cup of tea or in a tannic young red wine (that has been fermenting in, for example, new oak barrels), is actually a tactile sensation, although many think of it as part of the taste/flavor of a beverage ([65]).

The oral-somatosensory attributes of food also give rise to what food science researchers often refer to as 'mouthfeel' (for example, [66-71]). This is the term used to describe the feeling that we have in our mouths on, and after, eating a certain food or drink. Olive oil, for example, may give rise to an oily mouth-coating, while foods containing menthol may well give rise to a cool mouthfeel. Jowitt ([72] p. 356) has defined mouthfeel as: 'those textural attributes of a food or beverage responsible for producing characteristic tactile sensations on the surfaces of the oral cavity.' Typical mouthfeel characteristics, then, include sticky, astringent, stinging, oily and so on.

The oral texture (in particular, the viscosity) of food and drink turns out to exert a significant influence on

our multisensory perception of flavor (for example, [63,73,74]). While the results of early studies in this area (for example, [75]) often led to the suggestion that increased viscosity in a foodstuff impaired the perception of taste, it has, for many years, been difficult to disentangle whether such effects had a physicochemical, as opposed to a neurophysiological, origin (since increased viscosity is likely to reduce volatility at the food-air interface; see [76]). However, the technological advances that have been seen in the field of food science research over the last 5 to 10 years or so now mean that it is possible to isolate (and thus to demonstrate) the genuinely psychological nature (of at least a part) of this crossmodal effect (for example, [63,77]).

In one study, for example, Bult *et al.* [63] presented participants with a creamy odor using a computer-controlled olfactometer. The olfactory stimulus was either presented orthonasally or retronasally. At the same time, milk-like foods with different viscosities were delivered to the participant's mouth. The participants had to rate the thickness and creaminess of the resulting experience as well as the intensity of the overall flavor. Crucially, the participants' ratings of the intensity of the flavor decreased as the viscosity of the liquid increased, regardless of how the odor was presented (that is, orthonasally or retronasally). Given the independent control of texture and odor delivery in this study, these results therefore highlight the importance of texture (mouthfeel) to multisensory flavor perception in humans. Finally, Bult *et al.*'s results also suggest that the presence of a retronasal odor can alter the perceived thickness of a foodstuff in the mouth (see also [78,79]).

The tactile stimulation of the oral cavity is also very important for another reason: it turns out that where we localize a tastant follows the location of a tactile stimulus drawn across the tongue and not the point where the taste stimulus itself happens to have been transduced on the receptor surface ([80-82]; although see also [83]). The same may also be true for olfactants [84]. This phenomenon can be thought of as a kind of flavor-based ventriloquism illusion (for example, [85]). Thus, the fact that people localize the flavor of food to their mouth, despite the fact that the majority of the information concerning the flavor comes from their nose (that is, from olfaction) is likely attributable in large part to the tactile stimulation that they experience in their oral cavity while eating [81,86,87].

Another kind of crossmodal interaction involving oral-somatosensation occurs between temperature and taste. Roughly a third to a half of the population experience what is known as the 'thermal-taste' illusion [88,89]. This term refers to an effect that was first documented by Barry Green and his colleagues. They found that

simply by raising or lowering the temperature at various points on a person's tongue, they were able to elicit sensations of sweet, sour, salty and bitter – that is, the four main basic tastes [89].

In terms of the underlying neuroscience, oral-somatosensory information regarding the food or liquid in the mouth is transferred to the brain by means of the trigeminal nerve, which projects directly to the primary somatic sensory cortex [90]. This projection carries information concerning touch, texture (mouthfeel), temperature, and proprioception (not to mention nociception or oral pain, and chemical irritation) from the relevant receptors in the mouth. The results of neuroimaging studies suggest that the oral texture of a foodstuff appears to be represented in the orbitofrontal cortex as well as in several other brain areas [91,92]. The texture of fatty foods also appears to light up the cingulate cortex (see [93]). Indeed, it may have been important, evolutionarily-speaking, for our ancestors to have detected the textures of fatty foods, since they would normally have constituted a dense source of energy.

The hedonics of oral texture

It is worth noting how many of our food likes and dislikes are also dependent on the oral-somatosensory texture of particular foodstuffs (for example, [94]; see also [95]). As John Prescott ([94], pp. 25–26) points out: 'Other less obvious tactile sensations are also important in food acceptability. In particular, problems with texture are a common reason for rejecting foods'. He continues: 'The oyster is a pre-eminent example of the role that texture often plays as a reason for rejection of a food'. That said, it should be noted that a food's textural properties can also constitute a key part of what we find so pleasing (addictive) about certain other foods. Indeed, advertisements for mass-marketed red wines often make reference to mouthfeel: Take a recent print ad for Blossom Hill Winemaker's Reserve Merlot 'velvety, soft and has impeccable taste'. A number of researchers have argued that is part of the appeal of chocolate, one of the few foods to melt at mouth temperature (see [12]). Texture, then, plays a crucial role in determining our perception of a food's quality, its acceptability, and eventually our food and beverage preferences (for example, [96,97]). In addition, many chefs consider texture as a major element in their creations, searching for the diners' expression of surprise (for instance, by giving a mousse the appearance of a rock, or by giving a crunchy texture format to a food that is often consumed soft, and so on). Texture contrast is also something that many chefs work with (for example, [12] pp. 93–95), and that consumers are known to value in a food/dish [98].

One dramatic way in which to make a diner focus on the texture of the food is by removing any color cues from the dish, letting the diner discover the flavor of the foods via their texture, perceived through their hands and mouth (one might also consider that dining in dark restaurants achieves a similar goal by a slightly different means; see [99]). Relevant in this regard are the 'White funeral' meals organized by chef-artist Marije Vogelzang. They consist entirely of white food and specially designed white crockery [100], which enable one to focus on the visual, tactile, and oral texture of the foods served (see Figure 9).

The sound of texture

Our perception of a food's texture can also be perceived and modulated by the sounds that the food makes during the breakdown of its structure. Several experiments have demonstrated that food-eating sounds can make a significant contribution to our perception of crispness and freshness in foods such as crisps (potato chips), biscuits, breakfast cereals, and vegetables [101–103]. For example, the participants in one study by Zampini and Spence had to bite into a large number of potato chips (around 180 in total) and rate each one on its perceived crispness and freshness. The crisp-biting sounds were picked up by a microphone, modified, and then immediately played back over headphones. Importantly, the crisps were rated as tasting significantly crisper (and fresher) if the overall sound level was increased, or if just the high frequency components of the crisp biting sounds were boosted. Furthermore, subsequent research has now shown that people's perceptions of the crispness of potato chips can also be modified, albeit more subtly, by changing the sound of the packaging that people hold – potato chips are rated as tasting slightly, but significantly, crisper



Figure 9 Detail of Marije Vogelzang's White funeral meal (see [100]; figure downloaded from www.marijevogelzang.nl on 19 October 2012, with permission of the artist).

if the sound of a noisy crisp packet rattling is played in the background [104]. Meanwhile, elsewhere, researchers have shown that the perception of carbonation in a beverage served in a cup can also be modulated by what a person hears [105]. Thus, such results demonstrate that more of our perception of the oral texture of foods in the mouth actually depends on the sounds that we hear while eating and drinking than many of us probably realize (see [106], for a review).

Social touch in the restaurant: the Midas touch

The social (or interpersonal; [107]) aspects of touch are also important in the context of the restaurant or bar. In what is perhaps the earliest study in this area, Crusco and Wetzel [108] examined the effects of two types of social touch in the setting of a restaurant. The waitresses in this particular study were instructed to touch customers briefly as they were returning their change after they had received the bill. The researchers then compared tipping behavior under three different conditions: when the diner was touched on the hand by the waitress, when they were touched on the shoulder, and when the waitress did not touch the diner at all (the control condition). The results revealed that both male and female customers tipped significantly more after having been touched in both of the touching conditions than in the no touch condition. Subsequently, Stephen and Zweigenhaft [109] replicated this basic phenomenon, showing that touching female diners led to a 4% increase in the tips received, as compared to touching male diners, or not touching anyone at all [see also [110]]. Meanwhile, researchers have also demonstrated that drinkers tend to consume more food if touched by a waitress [111]. In one study, those people drinking in pairs consumed significantly more after having been touched by the waitress; while in another study, diners were more likely to agree to a suggestion made by a waiter or a waitress after tactile contact (around 60% of times they were touched, they ordered the dish that had been suggested to them; [112]).

Of course, here it is worth mentioning that this kind of manipulation might be more acceptable to people in certain countries than others, or to certain age groups more than to others. For instance, the beneficial effects of social touch on dining were nicely demonstrated by Eaton, Mitchell-Bonair, and Friedmann [113]. They found that when the service staff who were caring for elderly people combined their verbal encouragement to eat with tactile contact, they consumed significantly more calories and protein. What is more, these positive effects on eating behavior lasted for up to five days after the tactile contact. However, we believe that how interpersonal touch affects an individual's behavior may well depend on their personal traits too (see also [114]).

On the future of touch at the restaurant

Another trend that is popular currently relates not to the enhancement of specific sensory cues (for example, through the cutlery, as mentioned before) but to their very removal. What about removing the sense of touch? One example of this comes from a most memorable experience when dining at Heston Blumenthal's The Fat Duck restaurant nearly a decade ago. For one of the courses on the tasting menu, the waiter/waitress arrived at the table, and instructed the diner to open his/her mouth and would then proceed to insert a spoonful of the latest molecular gastronomy creation (lime gelee in this case) into the diner's mouth. Restaurants like Madeleines Madteater, in Denmark, in some situations remove the plate instead, serving the food directly into the mouth of the diner with a spoon or a cannula, which are often used as knives and forks [115]. Note that by so doing, many of the tactile/haptic elements normally associated with eating, such as the holding and wielding of cutlery, are removed. Another much more recent example of eating without the aid of cutlery comes from one of the meals organized by Caroline Hobkinson. In one dish/experience, morsels of food were tied to virtually invisible fishing wire and suspended from helium balloons that nestled under the ceiling; what is more, even the bread was also hanging from the ceiling with strings. The diners/guests entered a dark room, one in which the food is only sparingly lit, and hence it appears to be floating in mid-air (see Figure 10). The diners were then encouraged to eat the food using nothing more than their mouths to 'catch' a bite.

While the use of incongruity between the appearance of foods (and beverages) and their flavor or aroma has currently spread out among chefs as a resourceful tool to give rise to deliver surprise (see [116], for a review), it seems likely that more sensory incongruity involving specifically the oral-somatosensory attributes of the food will be found in those cases where the sight of the dish sets up sensory expectations that are incongruent with the experienced oral-somatosensory attributes of the dish. Here, one can think about the 'Hot and iced tea' dish served at The Fat Duck. The dish looks suspiciously like a normal cup of tea (see Figure 11), but actually, half of its content are warm/hot, and the rest, cold.

One technological development that is particularly fascinating in terms of the future of gastronomy involves the Virtual Straw ([117,118]). This device recreates many of the sensations that you would normally expect to be associated with sucking a liquidized food up through a straw. The researchers concerned have managed to do this simply by generating the appropriate sounds and tactile vibrations in the straw whenever a person sucks while the straw is placed over a picture of a particular food. No food is actually delivered, but the illusion is nevertheless still a powerful one. We believe that the future will see far more



Figure 10 Eating without the aid of knives and forks in one of Caroline Hobkinson's culinary installations (see <http://www.stirringwithknives.com/>; figure downloaded on 27 September 2012, with permission of the chef).

examples of the latest in technology being used to enhance (or at the very least to alter) the dining experience. Furthermore, technology also allows the chef to 'break the rules' and bring fun and levity to eating experiences [119,120]. Even nowadays we can start seeing some examples suggested by Philips Design in its latest design probe. Through a new range of plateware concepts, they have explored how the integration of light, conductive printing, selective fragrance diffusion, micro-vibration and the integration of other sensory stimuli might affect the eating experience [121].

Technology may also be used in plateware or the utensils to modify eating behaviors. For instance, in order to remind people to eat more slowly, Toet *et al.* [122]



Figure 11 Heston Blumenthal's 'Hot and iced tea' dish (see <http://www.thefatduck.co.uk/The-Menus/Tasting-Menu/> downloaded on 27 September 2012) as an example of visual-oral-somatosensory incongruity in fine dining. Picture downloaded from <http://thebigfatundertaking.wordpress.com/2010/05/21/28-hot-and-iced-tea-incomplete/> on 27 September 2012).

created 'vibrating cutlery'. This most tactile of cutlery was designed to detect rapid movements of the cutlery by the diner and then to vibrate briefly in order to encourage the diner to slow down. Furthermore, in contrast to molecular gastronomy, where all the new technology tends to be sited in the kitchens/research laboratories, we believe the future will see an increasing move toward technology being present at the front of house when the diner consumes a particular dish [123].

Review and conclusions

While a majority of ordinary consumers may not be especially conscious of the contribution that the sense of touch (nor, for that matter, haptics, proprioception, or kinesthesia) makes when it comes to enjoying a good meal/drink, the research outlined here has hopefully convinced the reader of just how important all of the various tactile/haptic sensations that accompany the consumption of food and drink are (and potentially will be in the future) to our overall enjoyment. While the Italian Futurist, F. T. Marinetti [3] was certainly way ahead of his time, the last few years have seen the emergence of a body of research documenting some of the many ways in which touch contributes to, and, more importantly, can enhance the consumption experience, be it in a restaurant or some other environment. What is particularly exciting for the psychologist/cognitive neuroscientist interested in the sense of touch is that artists, chefs, not to mention cutlery and plateware manufacturers and designers, are now starting to take such scientific insights on board in the offerings they present to their diners. This fact allows great opportunities for collaboration and experimentation, and even for the blurring of the limits between one field and the other. That said, it is worth remembering, in closing, that the various cases in which touch has been

shown to influence the experience of food and drink in this article likely have a number of different explanations: certain of the effects, for example, in the section on oral-somatosensation, are likely perceptual in nature (that is, they likely result from the rules of multisensory integration). Others, meanwhile, likely have a more decisional origin. It will be the job/challenge for future research (especially for the scientists interested in this area), then, to try to ascertain the most appropriate explanation for any given effect of touch at the dinner table.

Endnotes

^aWine bottles constitute an especially interesting class of object to study in this regard since the majority of bottles contain the same amount (and hence weight) of wine. It may, of course, turn out to be for this very reason, that the manipulation of the weight of the packaging is more salient in this sector of the marketplace than elsewhere.

^bSuch results obviously raise some concerns for companies when it comes to thinking about the consequences on product perception of recent moves toward light-weighting (for example, see [34,124]).

^cIt should, however, be noted here that while the feel of the container influences participants' perceptions of a dry food product, it had no effect on people's ratings of yogurt. Further research will, therefore, be needed to understand the limiting conditions on this particular crossmodal effect.

^dThe International Standards Organization (see [125,126]) defines flavor as: 'Complex combination of the olfactory, gustatory and trigeminal sensations perceived during tasting. The flavour may be influenced by tactile, thermal, painful and/or kinaesthetic effects'.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

All authors contributed to the writing of this article, and all read and approved the final manuscript.

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