Music, Mind, and Mouth: Exploring the Interaction Between Music and Flavor Perception

by

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ABSTRACT

This thesis presents a study of how hearing and taste can influence each other, how this interaction can be measured, and how the results can be used to design new, powerful, immersive experiences. The goal of the thesis is to address two questions: does music significantly change flavor perception, and can music change the hedonic experience of a meal? Experimentally, I looked at ways to measure changes in sensory perception. Artistically, I explored how external factors can alter the eating experience. From a cultural perspective, I examined the history of multisensory experiences – in feasts, in everyday cooking, and in community rituals.

I conducted a series of experiments to measure the effect of music on flavor perception, and designed a series of novel eating experiences that make use of congruencies between multiple senses, culminating in a multisensory feast for the Media Lab. From these studies, design patterns and challenges are extracted and analyzed, and new directions are discussed.

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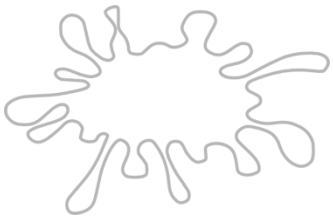


I embarked on this journey for the simple reason that I ate at a very, very good restaurant. A single dinner at Alinea in Chicago changed the course of my studies at the Media Lab. Alinea expanded my mind about what could be possible with food and, perhaps more importantly, with the dining experience. I left the restaurant with my head bursting with ideas about purring cat napkins and soup syringes and flavor enhancing straws.

For the inspiration, I dedicate this thesis to the Alinea team. Thank you.

1 Introduction

"The more I contemplated food phobias, the more I became convinced that people who habitually avoid certifiably delicious food are at least as troubled as people who avoid sex, or take no pleasure from it, except that the latter will probably seek psychiatric help..."

- Jeffrey Steingarten, "The Man Who Ate Eveything"

Everyone eats. It is a fundamental necessity and pleasure rooted in biology, culture, and tradition. The art of cooking and eating is an essential human activity; eating is not just a means for sustenance, but a complex art form designed to delight and satisfy.

More specifically, I emphasize the difference between what we eat and how we eat. What we eat is concerned with what is on the plate, with the physical and chemical transformations behind the cooking process. How we eat, on the other hand, is concerned with the experience of the eater. The total sensory experience of the eater is affected not only by the food in front of them but also by factors such as the setting of the meal, the company, the light and sound in the room, etc.

In recent years, there has been a trend moving food into the laboratory, to better understand the topic of *what* we eat. Molecular gastronomy, first coined by Oxford physicist Nicholas Kurti and French chemist Hervé This (McGee 2008), is used to describe this new science of food where one seeks to understand and manipulate the physical and chemical transformations behind cooking. Foams, gels, and spheres became the new trend; chefs and scientists studied the molecular makeup of food in order to invent a new form of cooking.

Parallel to the molecular gastronomy movement, I propose a study into *how* we eat. More than just eating with the mouth, we also eat with the mind. For example, hearing louder chewing sounds over headphones can make us think that the potato

chips we eat are crispier (Zampani et al. 2004), and the same white wine dyed with red food coloring can suddenly smell like cherries and blackberries (Morrot et al. 2001). In addition, eating phobias, biases, childhood memories, and social pressure all factor into our enjoyment of food.

I aim to explore the artistic and expressive potential of food, as a means of creating memorable experiences that involve multiple senses. Specifically, in the scope of this thesis, I explore connections between music and flavor perception. To bridge science and design, I conducted a series of experiments in addition to designing food-related installations and events. In my analysis, I combine the results of my experimental studies as well as feedback from event participants to take a holistic view on eating experience design.

1.1 Thesis Overview

I start by examining the history of multisensory food experiences, including archeological feasting practices and the Japanese tea ceremony. This provides guidance for my experience design work and anchors them in historical practices. Next, I focus on related works in the field of multisensory perception, which informs my experimental setup, and related works in dining experience design, which inspires my installations and pop-up dinners.

In this thesis, I combine experimental and design work to explore the field of sensory integration from both scientific and artistic angles. I first describe my multisensory design work, starting with installations from 99Fridays parties and moving to a series of pop-up dinners at the Media Lab. Then, I present my music and flavor perception experiments. The culmination of my work was a lab-wide, multisensory feast at the Research@ML event in May, where I also analyzed design patterns for creating an immersive eating experience. In the Discussion and Analysis chapter, I analyze the patterns in music and taste interactions that I find in my work, including challenges and pitfalls in designing real world experiences.

The thesis closes with conclusions and further directions, followed by supporting material and references.

A Portion

Nothing comes without a history.
Pasta, once páste, was a dish
of Ancient Greece: not ambrosia
but barley porridge (more
the foothills of Olympus). Leave it
to the Late Romans to shape
the word into dough, and the French
to cook up their own version:
paste became pâtes and pâtisserie
as across La Manche—The Channel
if you prefer—the English, stuck
on paste, folded in their own sense:
glue, that gooey, glutenous thing.
Well, why shouldn't the word
ripen even as it preserves its past?
Say, the way a family gathering
for the meal simmers tomatoes
in olive oil and minced garlic,
stirs in the fresh basil, grates
the parmesan, then apportions
the noodles. Whatever tensions
have collected in us pass
as we hover above the hot dish,
hungry.

- Jennifer Arin

2 Background

"I look upon it, that he who does not mind his belly will hardly mind anything else."

- Samuel Johnson

This chapter divides the relevant background into three sections. The first, Multisensory Eating Experiences Throughout History, examines the use of feasts, ceremonies, and rituals where the act of eating is designed to evoke all the senses. The second section examines related works in music-flavor interaction in the sciences, notably in consumer behavior studies and the psychology of sensation and perception. The last section looks at current examples of multisensory eating experiences in restaurants and art installations.

2.1 Multisensory Eating Experiences Throughout History

Music has always had a place at the table. As people pursued pleasures, gastronomic and otherwise, it was only natural to combine pleasures of the table with pleasures of the ear. Before recorded music was available, only those with enough resources to hire musicians and entertainers could afford to have music at private dinner parties; for the masses, music and entertainment were provided at public feasts and festivals (Strong 2002).

Archeological accounts show that, during the Aegean Bronze Age, mortuary feasts included not only eating and drinking, but dancing, the consumption of narcotics, and rituals involving the destruction of memories of the deceased (Hamilakis 122). According to an account of a wedding feast given by Hippolochus the Macedonian at around 300 B.C., the sumptuous feast included silver cups and plates, extravagant gifts, and "flute girls", musicians, and "Sambuca players from Rhodes" (Wilkins et al. 43-44). In Heraclides of Cumae's *Account of Persia* (c. 400 B.C.), he writes: "in most cases the king breakfasts and dines alone…And throughout the dinner his concubines sing and play the lyre" (Wilkins et al. 26). For the Greek elites, eating, drinking, story-telling,

philosophy, poetry, singing, and dancing were all part of the Symposium, or drinking party (Wilkins et al. 181). For the less privileged, public banquets and inns offered less refined entertainment in terms of music, dice, dancers, and prostitutes (Wilkins et al. 181).

Figure 1. A female aulos-player entertains men at a symposium. *c.* 420 B.C.

Like the Greeks, the Romans held lavish dinner parties known as convivium where the educated upper class engaged in conversation, and enjoyed multi-course meals with entertainment (Strong 24-26). The imperial banquets of Roman emperors reached new heights of extravagance; at one dinner organized for emperor Nero, the banquet was staged on a cushion-lined raft in the middle of an artificial lake, surrounded by exotic birds and animals, with pleasure pavilions lining the water's edge (Strong 38). In Qing dynasty China, the pleasure-boats of Yangzhou provided eating, drinking, musical, and sexual entertainment for various social classes (Freedman 127-128).

During the Italian renaissance, both the food and the way of presenting it were markers of refinement and elegance amongst the upper circles. An account of Cardinal Ippolito's d'Este's dinner party in 1529 described eighteen courses, each with its own specific music or spectacle, "all perfectly integrated into the serving of the food" (Strong 129-131). Combining religion and feasting, a popular topic for Renaissance painters was the biblical marriage feast at Cana where Jesus turned jugs of water into wine (Freedman 2007). Besides illustrating the miracle, this was an occasion for painters to show contemporary dining practices (Freedman 2007). In the painting by Paolo

Veronese (see Figure 2), the musicians are prominently featured in the middle of the feast, perhaps demonstrating the importance of music at feasts.

Figure 2. Paolo Veronese's The Wedding Feast at Cana, 1563. Note the musicians prominently in the middle of the feast.

Today, multisensory eating experiences can be found in fast food joints and themed restaurants, whether it's the bright colors and upbeat music of MacDonald's, or the medieval-themed dinner-and-jousting entertainment at Medieval Times. Restaurants like Rainforest Cafe, Chuck E. Cheese's, or even Hooters offer entertainment and food in one convenient package, not unlike the feasts of times past.

The practice of multisensory, immersive dinner experiences with a story-telling focus also goes back in time. I would like to mention one specific instance where an "experience" dinner was staged for political control. After his victory over the Dacians, Emperor Domitian (AD 51-96) hosted a banquet for his senators and knights. The theme of the banquet was Hell: diners were placed next to gravestones bearing their name; the dining room, serving ware, and food were all black; and black phantom-like slaves boys

danced and served sacrificial foods. Only the emperor was allowed to speak, and when he did it was on the subject of death. All the guests were in fear of having his throat cut the next moment. (Strong 38-39, Wilkins et al. 181)

Many important life stages – births, initiations, weddings, harvests, deaths – are celebrated in rituals and ceremonies involving food. Before humans had reliable access to food all-year round, any significant event was celebrated with a feast, the essence of plenty, prosperity, and life. I will focus here on instances where feasting was combined with other sensory interventions.

The fishermen of the Norwegian Lofoten islands celebrate the first catch of the codfish in a feast where cod stew is cooked in the bows of old longboats and participants tell stories of the search for cod in verse and song (Luard 44-45). The food, reinforced by storytelling and music, celebrates the origins of the harvest. During the Chinese dragon boat festival, color, sounds, and food combine to honor the memory of a minister who drowned himself in protest of a corrupt emperor. To scare away river dragons that might otherwise eat the sticky rice dumpling offerings, participants wrap dumplings in bright-colored strings and make as much noise as possible. The whole festival takes place amidst beating drums, clashing cymbals, and crackling fire crackers (Luard 47) (see Figure 3). Lastly, many celebrations around the world – especially wedding feasts – end in music and dancing. In Sacred Food, Luard mentions ritual post-feast dancing in Berber and Hungarian weddings (152-157, 158-160); closer to home, modern American weddings often have the couples' first dance before cake cutting!

Figure 3. Dragon Boat festival celebration.

I will now devote my attention to two instances of multisensory eating practices as particular examples of meaningful sensory integration. The first instance is the Japanese tea ceremony, and the second is the combination of music and cooking in Northern India.

The Japanese tea ceremony is an aesthetic and religious practice that embeds meaning and symbolism into the simple act of drinking tea (Anderson 4-8). Fundamentally, the tea ceremony is an expression of hospitality and respect. Each meeting is built around a particular theme, or *toriawase*, that will be symbolically and aesthetically expressed through the ritual (Anderson 137). Everything from the choice of utensils (including their historical significance, origin, and style), flower arrangement, the artwork and calligraphy on the wall, the menu for the kaiseki meal, and even the names of the dishes is chosen to create the desired atmosphere and convey the host's message (Anderson 134-138). Creating the proper *toriawase* is an art form like poetry, where the combination of a few choice symbols can convey a feeling not easily expressed (Anderson 132). For instance, for a spring ceremony, the host might display a plum branch, serve young bamboo shoots and name the tea scoop after an early spring bird (Anderson 132).

Figure 4. Setting for a Japanese tea ceremony.

Figure 5. A course in a kaiseki meal.

Northern India has a history of merging music and food, specifically by way of musical analogies for taste sensations and culinary analogies for specific musical phenomena (McNeil 1993). In "Music and Food in North India", McNeil draws a parallel between a well-cooked dish with proper seasoning and a correctly performed raga with the right balance of melody and ornamentation. In both cases, there is a hierarchy of ingredients/components with a defined structure of preparation, and the term "taste" can be used to define the pleasure one receives from the resulting product. In addition, musicians often draw food and cooking analogies to describe subtleties in melodic expression. McNeil gives an example of a raga with two tetrachords, where the balance

of the tetrachords – which have their own characteristic "flavors" – is similar to the balance between spicy samosas and sweet chutney. McNeil argues that the cognitive processes behind interpreting a raga and preparing a dish are similar; both involve following a prescribed recipe, then adding one's own interpretation and imagination.

2.2 Related Works - Science

The work proposed for this thesis explores how music interacts with flavor perception. This research borrows from a multitude of fields including multisensory integration, consumer behavior, and cognitive psychology. While there is much work done on multisensory integration of smell and taste, there is relatively little work done addressing music and taste perception.

2.2.1 Hypotheses Behind Crossmodal Congruence

I will first examine theories behind the phenomenon of crossmodal congruence before looking at the various manifestations of sound and flavor interaction. Crossmodal congruence is defined as the tendency for people to experience correspondences between features of stimuli from different sensory modalities (Crisinel et al. 2011). One hypothesis to explain why we associate stimuli from different sensory modalities is that these correspondences simplify the flow of sensory information to make us more efficient in dealing with the complex outside world (Crisinel et al. 2010). Evolutionarily speaking, we might have evolved to combine different sensory modalities in a way to best ensure survival. For instance, we might associate a low pitch, such as a growl, with a large animal, so that we could run away before waiting for it to appear (Gallace et al. 2006). This theory could well explain our association of color with smell (Morrot et al. 2001), but other associations, such as bitterness with low pitch (Crisinel et al. 2010), might be hard to justify.

Another theory is the idea of induced expectations. According to Deliza et al. (1995), external cues can generate expectations that change one's sensory perception. More specifically, the authors determined that empirical evidence most supports

assimilation theory, where consumers will unconsciously change their sensory perception to be more in line with their expectations. With the color and smell example, it is possible that red wine induces expectations of blackberry smells such that people will actually detect blackberry scents in the wine.

Martino et al. put forth the proposal that there are two types of synesthesia, strong and weak. Whereas strong synesthesia is uncommon and idiosyncratic, weak synesthesia is widespread and consistent (Martino et al. 2001). It has been shown that, with regards to weak synesthesia, some crossmodal correspondences are inborn, where as others are learned (Martino et al. 2001). Perhaps the inborn correspondences can be attributed to the evolutionary theory, and learned correspondences can be attributed to the induced expectations theory.

2.2.2 Multisensory Integration in the Context of Eating

One of the most widely cited experiments involving multisensory food perception was conducted by Morrot et al. (2001), where the authors investigated the relationship between wine color and flavor. When white wines were artificially colored red, a panel of tasters attributed red wine flavor descriptions to it, discounting flavor information in favor of visual information. In general, several survey papers have been written on the topic of multimodal food perception (Verhagen et al. 2006, Auvray et al. 2008), bringing up topics such as taste and color, taste and viscosity, taste and temperature.

2.2.3 Eating sounds

Eating inherently contains an auditory component from the sounds made during the eating process. Zampini et al. (2004) showed that people's evaluation of crispness and freshness can be modified by changing the level and frequency of the biting sounds. In another experiment, carbonated water was rated as more carbonated when the sound level of carbonation was artificially increased (Zampini et al. 2005).

2.2.4 Auditory cues

Priming occurs when a stimuli, such as music, changes the subject's subsequent thoughts or actions (Kolb et al. 2003) .The priming effect of music can influence both the flavor perception and consumer consumption/purchasing behavior. Wine is a classical subject for music priming experiments, perhaps because the priming effect is stronger when people are asked to judge something they know little about or find difficult to judge (North et al. 2008). For instance, a comparison of classical music versus top 40 music showed that people purchased more expensive wines when classical music was played (Spence 2010). In another study, the sale of French versus German wines rose or fell depending on whether French or German music was played in grocery stores (North et al. 1997). In addition, North showed that the characteristics of music – powerful and heavy, subtle and refined, zingy and refreshing, mellow and soft – can influence people's perception of wine. When music with a similar characteristic was played, subjects increased their association of that characteristic in the wine by up to 60% compared with the no music condition. In addition, the tempo and loudness of the music can influence the rate of eating and quantity of food consumed (Spence et al. 2010). Finally, Spence et al. showed that relevant background sounds can change the perceived flavor of foods; for instance, a 'bacon and egg' ice cream had more perceived bacon flavor when sizzling bacon sounds, as opposed to farmyard chicken sounds, was played in the background (Spence et al. 2010).

2.2.5 Music and Perceived Flavor

Recently, there have been several studies looking at the crossmodal connections between music and taste. One initiative by Mesz et al. looked at the connections between basic tastes (bitter, sweet, sour, salty) and musical characteristics (duration, pitch, loudness, articulation, tempo). They showed that people could identify musical improvisations based on taste descriptors and algorithmically generated music based on taste descriptors with a higher degree of accuracy than that based on chance (Mesz et al. 2011, Mesz et al. 2012). Meanwhile, Crisnel et al. conducted a series of experiments where subjects were given a range of flavored liquids and were asked to pick the pitch

and instrument that they thought matched best to each liquid (Crisinel et al. 2010, Crisinel et al. 2011). Based on these results, Crisnel et al. composed sweet and bitter soundtracks and showed that participants rated bittersweet foods as more sweet when the sweet soundtrack was playing (Crisinel et al. 2012). Finally, Woods et al. showed that the loudness of background noise was inversely correlated with taste sensitivity, but proportional to perceived crunchiness (Woods et al. 2011).

2.2.6 Neurobiological basis of music and food

Neuroimaging studies show that a similar region of the brain responds to manipulations of pleasantness of chocolate by eating to beyond satiety and manipulations of the pleasantness of music by increasing dissonance (Small et al. 2001, Blood et al. 1999). This provides the neurobiological platform on which hedonic interactions between music and mouth may occur.

2.3 Related Works - Design

The exploration of interaction between music and food is not found only in science. Chefs, designers, and artists create multisensory experiences that are tested in the real world.

2.3.1 Restaurants

A focus on the integration of multiple senses can be found in restaurant settings. The *Sound of the Sea* at the Fat Duck restaurant in London is a dish served with headphones playing the sounds of ocean waves (Vettel 2011). On a bigger scale, Ultraviolet in Shanghai is an experimental restaurant designed to deliver a multisensory eating experience through immersive technology such as 360-degree video screen walls, surround sound speakers, and controllable overhead lighting (Bergman 2012).

Figure 6. The Sound of the Sea at The Fat Duck provides an auditory accompaniment to the eating experience.

Figure 7. The dining room at Ultraviolet.

Often multisensory experiences are used to create immersive experiences. From a story-telling perspective, Eleven Madison Park in New York City serves a four-hour tasting menu describing the story of New York, using theatrical aids such as magic tricks and liquid nitrogen (Wells 2012). The restaurant Next in Chicago recently featured a Childhood themed menu where dishes like S'mores and miniature roasted sweet potatoes were designed to evoke memories of childhood (Vettel 2011).

Figure 8. Dish from Next's Childhood menu.

2.3.2 Art

Multisensory eating experiences can also be found in art. For instance, the Italian Futurist movement espoused the idea that meals needed to be subservient to the proper aesthetic experience (Oka et al. 2011). One entry in the Futurist cookbook describes a meal that involved diners fingering each other's pajamas and eating salad by burying their faces in the bowl, with waiters spraying their faces with perfume as they came up to chew (Oka et al. 2011).

More recently, sound artist Ben Houge staged a series of food operas in Boston. His *Food Opera: Four Asparagus Compositions* paired four asparagus dishes with semi-aleatoric music he composed to accompany the feeling of the food (Peralta 2012). Another installation, *Sensing Terroir: A Harvest Food Opera*, provided each diner with individual speakers that played customized music and interviews depending upon the course (Irwin 2013).

Across the ocean, the Roca brothers from the Spanish restaurant El Cellar de Can Rocca debuted their culinary opera El Somni ("The Dream") in May 2013, a banquet in twelve acts exploring major themes during the human lifecycle like awakening, love, war, and death. The opera took place in a multimedia dome, where each course was accompanied by customized music, video, and poetic reflections. The opera was a collaboration between chefs, singers, dancers, composers, musicians, sculptors, poets, engineers, filmmakers, and scientists (El Somni 2013).

In a different twist, Mugaritz, another Spanish restaurant, recently produced the documentary *Mugaritz BSO* showing how famous dishes from Mugaritz were transformed into music by "exploiting the vast range of colours, plasticity and textures common to both worlds, gastronomy and music" (Mugaritz 2012). In addition, the same recipes were "translated" into the language of literature (Mugaritz 2012).

Figure 9. Musicians recording for Mugaritz BSO, with a picture of the dish for inspiration.

Culinary artists Bompas & Parr have been building multisensory experiences around story-telling and technology. The installation, *The Waft that Woos*, was a Sharkespeare-inspired mirror labyrinth where participants were led to the center of the maze by the scent of an aphrodisiac (The Waft that Woos 2012). In another installation, Infinity Pleasure Pod, bio-sensing equipment recorded skin tension, facial expression, swallowing, and heartbeat data from participants as they ate. The sensor data produces generative art that is then projected back into the pod to form a feedback loop (Infinity Pleasure Pod 2012).

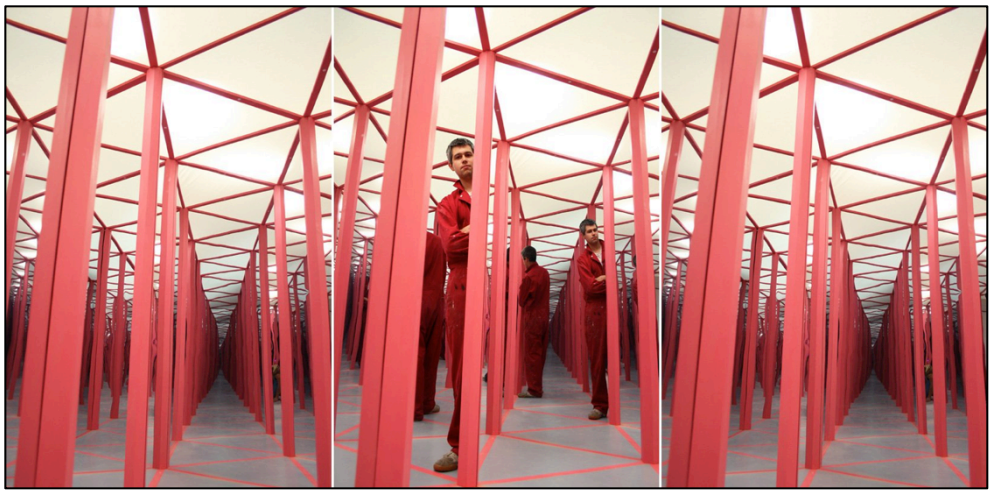


Figure 10. The maze set-up in the Waft that Woos.

Eating is essentially a social, participatory experience, and many artists have combined social elements with food. In his installation "Soup/No Soup" (2012), Rirkrit Tiravanija transformed the main nave of the Grand Palais into a festive banquet composed of a single meal of Tom Ka soup, free for the public to share (Grand Palas 2012). Gordon Matta-Clark served bone dinners in New York City where leftover bones were collected and strung together for guests to wear home (Kennedy 2007). Installation artists Mimi Oka and Doug Fitch created a show called "Good Taste in Art" (1999) where participants where invited to create artworks with colored pasta, then cook and eat their artwork in the gallery (Oka et al. 2011). In Copenhagen, Madeleines Madteater staged interactive dinner performances with active audience involvement For instance, one course involved audience members eating soup with their feet in hot water while watching Indonesian dancers (Sekules 2010).

Figure 11. Examples of artworks from *Good Taste in Art*.

Figure 12. A performance at Madeleine's Madteater.

2.4 Motivation

Why bother with multisensory eating experiences? For those who believe eating can be an art, multisensory experiences give new avenues for chefs to create memorable dishes. For food companies, the fact that taste can be influenced by other senses is of vital importance from an advertising and marketing perspective. For restaurateurs, the existence of commonplace associations between multiple senses is an exciting area of discovery that has yet to be used to its full extent in restaurant design.

Of course, not everyone finds the idea of multisensory eating experiences worthwhile. As one conference reviewer commented, “inserting events [into the eating experience] might destroy the basic meaning of eating food, which is to fulfill our basic desire.” Treated as a basic necessity, food can be seen as a measure of self-discipline

and any measures to increase pleasures from food an unnecessary indulgence. Many religions embrace the idea of fasting and abstinence as a virtue; for example, fasting practices can be seen in Lent, Ramadan, and Yom Kippur (Freedman 2007, Luard 2001). In the Middle Ages, meat and dairy fats were associated with the sins of gluttony and lechery, so it was believed that abstinence from those foods ensured salvation for the soul (Freedman 2007). In the search for a new kind of salvation, modern Americans spend billions each year on diet products, looking for quick ways to lose weight fast (Civitello 2011).

For me, food is the platform for novel experimentation and experiences. The point of my work is not about gluttony, but about expanding the realm of possible experiences, creating new expressive avenues, and most importantly, delighting people. To me, a great multisensory experience is similar to a great magic show – it should leave participants with a sense of wonderment and open-mindedness about what is possible. I want participants to feel that they've learned something new about how their senses operate.

What I found missing from the plethora of design experiences and restaurants was the element of conscious story telling and explicit mapping of multiple senses with the goal of creating a coherent experience. Very often, the accompanying music, visuals, etc, was chosen to match the food on an intuitive level, based on the whim of the chef or other creative force. My ideal multisensory experience is one where crossmodal interactions are designed on a scientific basis, with sensory elements that either match each other or create meaning through explicit dissonance. Furthermore, I envision the experience to have a cohesive theme that develops throughout the meal. The experience would mimic Wagner's ideal of *gesamtkunswerk*, combing multiple artistic mediums for a single coherent message (OED online 2013).

To achieve this goal, I used the design experiments in chapter 3 to test various aspects of an ideal multisensory experience. The elements of story telling, changing flavors with music, emotions, and surprise are incorporated in real dining environments. Chapter 4 probes deeper into the scientific foundations of multisensory integration by

examining the effect of music on taste intensity and duration. Chapter 5 documents my experience staging a multisensory feast where sight, sound, spectacles, creativity, and social interaction are combined to make a story-telling experience around food.

As I mentioned in section 2.1, eating as a cultural artifact has seen thousands of years of history, with an important role in building conviviality, providing entertainment, and strengthening social connection. I believe that the experience of eating is just as important, if not more, than the act of eating itself.

In the Kitchen with Auden

Day frazzled by the usual frustrations
but now I'm heading home, head
full of calves' liver, fried onions,
steamed broccoli (that bright enlivening green)
and small purple-skinned potatoes
roasting in grapeseed oil, all translating
my brain to a moist slavering until
I'm here, it's readying in the kitchen,
the place fragrant with fried onions
while I hang Breughel's Icarus
on the freshly painted wall, bringing
a little touch of Wystan in,
old master who managed to make
even suffering musical. Then it's
kitchen work again: brief clatter-clink
jazz of utensils, silky cool
of fine-sifted flour through fingers,
the cold milk-white of milk
sliding into a yellow bowl, little
blue kitten-tongues of gas
licking the frying pan—all the small
compensatory pleasures of the flesh
aflicker into waiting life, life
called again to attention by what
we take again for granted, tasting it.

-Eamon Grennan

3 Multisensory Experience Design

"He lay back for a little in his bed thinking about the smells of food, of the greasy horror of fried fish and the deeply moving smell that came from it; of the intoxicating breath of bakeries and the dullness of buns… He planned dinners, of enchanting aromatic foods that should be carried under the nose, snuffed and then thrown to the dogs…endless dinners, in which one could alternate flavor with flavor from sunset to dawn without satiety, while one breathed great draughts of the bouquet of old brandy."

- Evelyn Waugh

Given the bimodal, art-science nature of this thesis, I will first describe the design aspects of my work. This chapter is divided into two sections. First, I describe a series of installations I built at the Media Lab that explore multisensory interactions involving food. From the installations, I then proceed to describe a series of design dinners that test different ideas for incorporating multisensory stimuli in food.

3.1 Installations

My first works were a series of installations united under the theme of multisensory experiences. Many of the installations described below are from 99Fridays, a series of homegrown events at the Media Lab aimed at exploring festival technology, interactive arts, and ludic spaces.

3.1.1 Temple of the Beast

Figure 13. Inside the "temple".

Motivation. The temple was my first 99fridays installation. The idea originated from a video I saw of people building an inflatable fort with a box fan. Within the delineated space of the temple, I wanted to construct a powerful, eerie experience that involved food. The Christian communion ceremony, where lines between food, religion, and taboo are poignantly blurred, naturally came to mind.

Implementation. I constructed a 6'x10'x6' "temple" that contained black lights, creepy music, and a table holding a large platter holding a five-pound gummy bear, a knife, and a fork. A piece of paper quoting from John 6:51 was taped in front of the table. "I am the living bread which came down from heaven: if any man eat of this bread, he shall live for ever: and the bread that I will give is my flesh, which I will give for the life of the world."

Figure 14. Participants leaving the "temple".

Experience. Participants were expected to climb into the temple, kneel in front of the beast, and eat a piece of it with the provided utensils.

Feedback. Many participants ended up socializing inside the temple. By the end of the night, the "beast" was half-eaten and decapitated.

3.1.2 Elevator Speakeasy

Figure 15. Elevator speakeasy.

Motivation. I like the idea of building elevator installations because it is an often overlooked space. Elevators are transitory, mobile spaces where anything can happen.

Implementation. For the first speakeasy, I set up a musical wine bar in the Media Lab freight elevator.

Experience. Three to four 99fridays participants were randomly pulled from the party by a masked performer and instructed to go to a specific floor and call the elevator. Once inside, they were given wine with music pairings.

Feedback. A kind of alchemy happened in the elevator that brought people together. The shared surprise of discovery when the elevator door opened served as a good ice-breaker for people who didn't necessarily know each other. By the end of the night, the speakeasy was packed as people spread the word about the hidden wine bar.

3.1.3 Space Elevator

Figure 16. Setting up the space elevator.

Motivation. This was another spin on the elevator idea. I wanted to take the normal use of elevator and turn it on its head – in this case, I constructed a roller coaster ride.

Implementation. We covered the floor of the elevator with moving blankets and suspended red LED lights from the ceiling using clear fishing wire. Speakers were set up to play "spacey" electronic music.

Experience. Participants were given a pack of Pop Rocks before they entered the elevator. Once inside, they were asked to lie down and eat the Pop Rocks as the elevator moved up and down. The elevator was completely dark except for the moving points of red LED lights. After five minutes, the elevator returned to the initial level.

Feedback. Many people stayed in the elevator for multiple sessions. As a testimony to people's pattern-detection tendency, some participants thought the LED lights were synchronized to move with the music. The Pop Rocks provided an unexpected source of sound as they crackled and popped.

3.1.4 Sound-Food Pairings

Figure 17. "Berries in the Forest" installation.

Motivation. For the 2012 fall Media Lab Members Meeting, I built a series of audio-food pairings to explore different aspects of how sound can change flavor perception.

Implementation. There were three pairings: “crunchy cheesecake”, “berries in the forest”, and “heartbreak brownies”. For “crunchy cheesecake”, cubes of soft pound cake were paired with the sounds of eating crunchy potato chips. For “berries in the forest”, raspberries were paired with the sounds of birdsong in a garden. For “heartbreak brownies”, brownie bites were paired with a very sad song (Stars – *Personal*).

Experience. At each station, participants were asked to put on headphones while eating. “Crunchy cheesecake” played with the idea of dissonance between aural feedback and tactile feedback while eating. “Berries in the forest” uses sound to set context for the eating experience. “Heartbreak brownies” uses the relationship between emotion and eating; more specifically, it targeted people’s tendency to eat chocolate desserts when they are feeling sad.

Feedback. Some participants reported synchronizing their chewing with prerecorded chewing sounds in “crunchy cheesecake”. One participant said “berries in the forest” reminded them of being a bird; most others just enjoyed the fresh sensation

of eating fruit in a forest. In general, women understood the idea behind "heartbreak brownies" but men were confused about the connection; some suggested they would rather drink whisky than eat chocolate.

3.1.5 The Dessert Room

Figure 18. View inside the Dessert Room.

Motivation. For the 2013 spring Media Lab Members Meeting, I built an installation in the Media Lab sound studio that explored the importance of food as a source of memory and inspiration for storytelling.

Implementation. The walls of the studio were covered with white curtains. Infrared-controlled LEDs were attached to the curtains and suspended from the ceiling. To create the sensation of fireflies, a Processing program controlled the LEDs so they blinked in sync. Scents of vanilla, baking spices, and citrus were released via a liquid vaporizer. Interviews with the Media Lab community on the subject of their favorite childhood desserts were looped in the background together with a mellow piano track.

Experience. As the participant stepped into the dim room, blinking lights and sweet dessert aromas surrounded them. They were given a piece of caramel at the door to eat inside as they listened to people's stories about their favorite childhood desserts.

Feedback. Interestingly, people did not like the idea of being offered caramels. Some members enjoyed the experience, but most of them moved on rather quickly. This

perhaps highlights the importance of context, i.e., in a Members Meeting with high-octane demos, an experience installation is not what corporate members want to enjoy. Coincidentally, many students and staff members enjoyed staying in the space and listening to the stories. Because they could identify some of the speakers, members of the Media Lab community probably found the stories more interesting and pertinent.

3.2 Design Dinners

In addition to the installations, I also designed a series of pop-up dinners where I tried out different concepts around multisensory eating experiences, with a special focus on music.

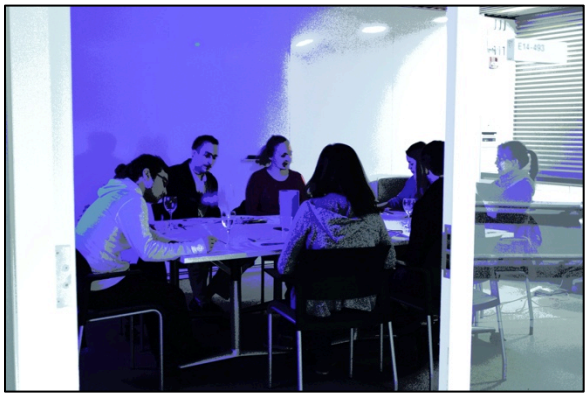


Figure 19. Participants at pop-up dinner.

3.2.1 Dinner 1 - Conceptual Foods

Food can express abstract ideas, too. For the first Media Lab pop-up dinner, I experimented with the idea of using a dish to express a concept, like solace and hope. I constructed the menu with five courses, each with a music pairing and sometimes aroma pairing to reinforce the idea the dish expresses.

First Course

Theme: Ephemeral

Food: Grapefruit Campari sorbet

Music pairing: Boards of Canada - Turquoise Hexagon Sun

Aroma pairing: rosemary vapor

For this dish, I wanted to pair the clean, bitter, fragrant flavors of grapefruit and Campari in a light and refreshing way. The spacey feeling of the music enhanced the light flavors, and the rosemary vapor added an extra refreshing touch. Both the vapor and the sorbet changed form quickly, emphasizing the theme "ephemeral".

Second Course

Theme: Routine

Food: Bread and Cheese

Music pairing: Biosphere - Ballerina

The highly-structured music reminded me of the routine of a 9-5 work day. To pair with the music, I arranged the food to graphically represent something highly regimented. I used bread and cheese, both of which are "commonplace" ingredients.

Figure 20. "Routine" Course.

Third Course

Theme: Spring

Food: Sous-vide asparagus, tahini ginger dressing

Music pairing: Nest - Kyoto

I wanted to highlight the green flavor of the asparagus, and the song Kyoto reminds me of rain on a cold spring day. To me, there is a sense of vitality in the music and the dish.

Fourth Course

Theme: Remembrance

Food: Mushroom lasagna

Music pairing: Max Richter – H in New England

H in New England sounds very nostalgic, like a train ride back in time. I wanted to pair it with something that has associations with childhood and home without calling on specific childhood memories; I settled on the mushroom lasagna, which is comforting

and warm. I put rosemary in the lasagna as a play on rosemary's association with remembrance.

Fifth Course

Theme: Solace

Food: Coffee sabayon

Music pairing: Zoe Keating – Frozen Angels

Smell pairing: Warm snickerdoodle cookies

I wanted the diners to smell the aroma of freshly baked snickerdoodle cookies as they ate the bittersweet coffee foam. The low notes of Zoe Keating's cello complements the bitter notes of the coffee, but the sweetness and richness of the sabayon and cookies brings out warmth against the bitter background.

3.2.1.1 Feedback and Analysis

I gave all eight diners a questionnaire (see Appendix A) where I asked them to guess the theme for each course. I also asked them to match the themes with the courses, given a list of all the themes I used. Routine was the only dish consistently identified correctly.

A big part of the dinner was the effect of music on the overall experience, so each course had its own music pairing. Diners noticed the music at first, but very quickly became accustomed to the music. One person said they stopped noticing the music after the second course. Unlike the music pairing, which quickly became unnoticed, the smell pairing was a big hit, especially with the fresh cookies in the fifth course. This was possibly because smells, especially ones not associated with the food on the table, is an unusual, thus memorable, trigger. In addition, conversation may distract diners from music listening, but smell is uninterrupted by socialization.

Unusual foods or presentation, like the bread and cheese grid, made stronger impressions on the diners.

The dinner also demonstrated that people have very different food associations. For instance, the asparagus dish was homey for some diners and fancy for others.

Cheddar cheese was familiar and "American" for some but exotic for others! In fact, it has been shown that expectations and beliefs are important factors in flavor preference formation (Small 2012). This goes to show how difficult it is to make cultural assumptions about food when planning to use food to convey meaning. I had designed the dishes without any thought to cultural associations, but they came anyway!

3.2.1.2 Personal Critique

I designed the dinner to reflect the abstract nature of food. I imagined the participants would easily understand my intentions behind each course; as it turns out this was not necessarily the case. I had also overlooked the level of socializing the participants would have; by course four the participants were busy talking and eating and not paying attention to the music. On the other hand, I learned that smell was a more salient modality than sound, either because it's a more unusual cue or because it is less disrupted by conversation.

3.2.2 Dinner 2 – Musical Condiments

Music can change the way we perceive flavor. For this Media Lab pop-up lunch, I wanted to play with the idea of musical "condiments" that would highlight certain flavors in a dish.

Constructing Musical Condiments. I constructed the menu with three courses, with two musical condiments per course. I used research from Mesz et al. (2011) to create music that corresponded to basic tastes. Each course was designed to contain both flavors corresponding to the musical condiments.

I started with Bach's French Suite No 5 in G major and modified it using Ableton Live.

1) For sweetness, I lengthened the notes and sped up the tempo from 90 to 120.

2) For sourness, I sped up the tempo to 130 and raised the pitch by an octave.

3) For saltiness, I broke the notes into staccato components.

4) For bitterness, I slowed down the tempo, used a string bass instrument, and changed the tonality to minor.

First Course

Food: Pineapple with orange granules separated by liquid nitrogen.

Musical condiment #1: sour | Musical condiment #2: sweet

Second Course

Thai green curry with roasted squash

Musical condiment #1: salty | Musical condiment #2: sour

Third Course

Food: Coffee panna cotta

Musical condiment #1: Bitter | Musical condiment #2: Sweet

3.2.2.1 Feedback and Analysis

Each of the seven diners received a questionnaire that polled their impressions of the musical condiments while they were eating (see Appendix B). The panna cotta course had the clearest reaction, with six out of the seven participants rating the sweet music condiment as making the food more sweet or pleasant compared to the bitter music condiment. The last participant, interestingly, reported that the bitter music actually made the panna cotta taste sweeter. In the curry dish, participants generally rated the salty music as more sour, spicy, and lively, whereas the sour music was reported to mellow out the flavors and make the food less spicy. In the pineapple and orange course, three participants reported an increased sweetness with the sour music while three other participants reported an increased sweetness with the sweet music. These somewhat contradictory results led me to speculate that there may be two classes of people, one for whom crossmodally congruent music enhances the target flavor, and one for whom crossmodally congruent music suppresses the target flavor (alternatively, it is also possible that these were random responses and music did not have an effect). I will test this theory in Experiment 1 in section 4.2.

Answers from the participants, however, revealed some interesting trends about the pleasantness, intensity, and texture of the foods. Two participants tended to associate pleasantness of food with music, and reported the food to be more enjoyable when the music was more enjoyable. Three participants commented that the food tasted more intense without the music, that music sometimes distracted them too much to focus on the flavors. In addition, three participants commented on the change in texture as a result of the music. Specifically, participants commented that the sweet music made the panna cotta creamier and lighter.

One participant wondered whether the change in taste was a secondary result caused by the change in emotional state created by the music. This is what I explored in the next pop-up dinner.

3.2.2.2 Personal Critique

I had expected participants to have a uniform experience from the musical condiments. What actually happened was very different as I learned that participants had very different reactions to the same musical stimuli. I should have provided more quantitative measurements of taste perception so I could have performed more specific analyses. A vision I have for this experiment is the creation of musical condiment "bottles", where by shaking the bottle over the food, participants could change parameters in the background music to influence the taste of the food.

3.2.3 Dinner 3 – Food and Emotion

For this Media Lab pop-up dinner, I played with the idea of experiencing different emotions while eating. I constructed the menu with four courses. Each course had its own associated emotional state established with lighting and a targeted playlist. The diners ate half of each course with music playing, and half without music.

First Course

Food: Spicy popcorn

Emotion: Anger

Lighting: Red, medium brightness

Music example: Rage Against the Machine – Township Rebellion

Second Course

Food: Roasted eggplant with buttermilk sauce and pomegranates

Emotion: Fear

Lighting: Purple, dim

Music example: Network Music Ensemble - Apocalyptic

Third Course

Food: Herbed couscous salad with feta cheese

Emotion: Happiness

Lighting: Yellow, bright

Music example: The J Street Jumpers – When I Get Low I Get High

Fourth Course

Food: Tapioca pudding with pistachio

Emotion: Melancholy

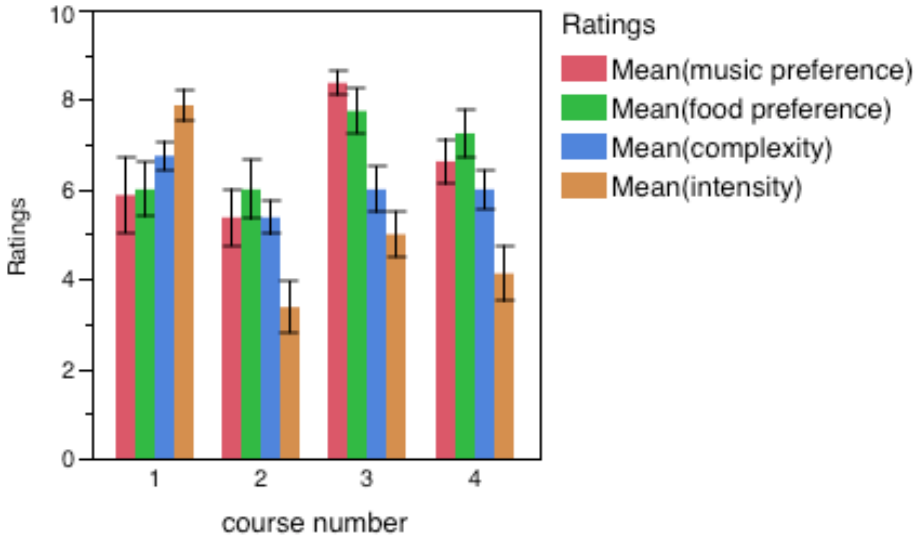
Lighting level: Blue, dim

Music Example: Goldmund – In a Notebook

3.2.3.1 Feedback and Analysis

I was unsatisfied with the questionnaire from the previous pop-up dinner because it only had qualitative questions, so this time I included some quantitative analysis in the questionnaire as well. Each diner received a questionnaire (see Appendix C) which asked them to rate, for each course, how the music made them feel, how they liked the music, how they liked the dish, the intensity of the dish, and the complexity of the dish. The emotion rating was done on a 9-category Geneva Emotion Music Scale (GEMS-9) for emotion analysis (Zentner 2008) (See Appendix D).

Figure 9 shows the mean ratings for each course. On average, the third course (happiness) and fourth course (melancholy) had higher music and food preference ratings than the first (anger) and second (fear) courses. In addition, the intensity rating of the dishes were higher for courses one (anger) and three (happiness) – emotions that are more active – than for courses two (fear) and four (melancholy).



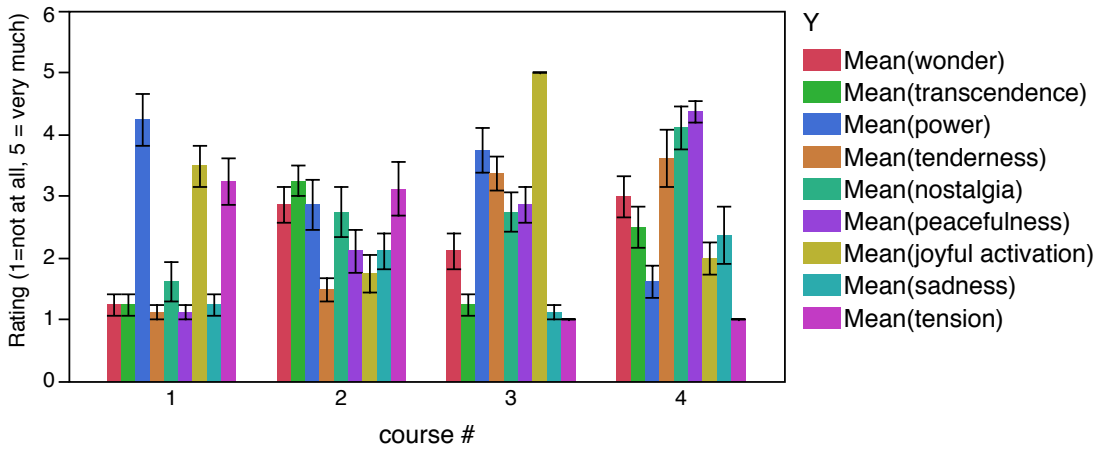
Each error bar is constructed using 1 standard error from the mean.

Figure 21. Mean participant ratings for each course.

A multivariate calculation was performed on the ratings of music preference, food preference, complexity, and intensity ratings over all four courses. In particular, I was curious about the correlation between music and food preference ratings. If music can enhance food preference, then all restaurants had to do was play music people liked to have diners enjoy the food more! The only correlation with statistical significance was between food intensity and complexity ratings, $r=0.494$, $p = 0.004$. On an individual course basis, there was significant correlation between intensity and music preference for the first course ($r=0.788$, $p = 0.020$) and between complexity and music preference for the fourth course ($r = 0.764$, $p = 0.027$).

I also analyzed the emotion ratings from participants to examine how effective my choice of music and lighting was in inducing the desired emotions for each course

(Figure 10). Since the GEMS-9 scale was targeted for musical emotion induction, there is not necessarily an exact match between the intended emotion and the ratings. For instance, for the first course, where the target emotion was anger, there is no precise "anger" category in the GEMS-9 scale, but the three highest emotions felt were power, joyful activation, and tension, which reflects anger. The second course, fear, resulted in a mixture of wonder, transcendence, power, nostalgia, and tension. The third course, happiness, had a clear peak in the joyful activation category. The fourth course was intended to be melancholy, but ended up with higher ratings of peacefulness and nostalgia than sadness. Overall, the music seems fairly accurate in inducing the target emotions, with the exception of course four which was less sad than intended.



Each error bar is constructed using 1 standard error from the mean.

Figure 22. Mean ratings of emotion experienced for each course. The target emotions are course 1 – anger, course 2 – fear, course 3 – happiness, course 4 – melancholy.

The effect of setting on the social behavior of the diners was distinct from course to course. During the first course, the loud heavy rock music was not conducive to talking, although after the music ended some participants were very animated in discussing the seasonings that went into the spicy popcorn dish. The dim atmosphere and horror-movie music in course two made the room silent. Even after the music ended, diners still didn't talk to each other. The happy music in course three promoted much more talking and interaction during the meal. The calming music in course four made for more relaxed conversations at a lower volume.

From the diners' written accounts, several patterns emerged with regard to the effect of music on flavor. First, music had an effect on self-reported eating speed. Three participants reported eating faster during the anger and happiness courses, and four participants reported being more calm and savoring the food more during the melancholy course. Secondly, since the participants ate half of their food with music and half of their food without music, many reported a difference in taste after the music was turned off. However, the differences were not uniform. For course one, with angry music and spicy popcorn, three participants reported the food being less spicy while the music was on because it was distracting, but one participant reported the food seemed more spicy while the music was on. Overall, six participants observed during different parts of the meal that it was easier to "taste the dish as a whole" without music, while with music it was easier to focus on individual flavors. Thirdly, there was an influence of music on texture. Two participants mentioned that the scary music in course two made them focus on the texture of the eggplant dish, and one participant noted that the tapioca pudding in course four tasted smoother with music. This reinforced what I observed in pop-up dinner #2 about music's influence on food texture.

When asked about their favorite and least favorite courses, course three (happiness) had the highest number of votes as the favorite course (four out of eight votes), and course two (scary) had the highest number of votes as the least favorite course (four out of eight votes). Participants liked course three for the enjoyable music and the way flavors combined in the dish. On the other hand, participants did not like course two. The tenseness and undesirability of the music and the sense of uncertainty about what they were eating were main reasons for not liking course two, even though most of the participants reported actually liking the taste of the dish. In other words, even if the food is good, a bad environment can still ruin a meal.

Finally, I was interested in what makes a meal memorable. From the questionnaire, one participant enjoyed the joyful atmosphere of course three, two participants found the musical transition and the experience of changing tastes to be more memorable, and five participants named the popcorn in course one as the most

memorable part of the meal. The popcorn was memorable because it was almost uncomfortably intense in flavor, people had fun reverse-engineering the ingredients, and the spiciness in the popcorn was unexpected. I expanded on this notion of surprise for the next pop-up dinner.

3.2.3.2 Personal Critique

I had envisioned that all the participants would have uniform emotional responses for each course. As it turned out, not everyone had the same perception of the music. For instance, some participants perceived the angry music as positive and energetic, and not everyone thought the sad music was sad. Logistically, since people eat at different rates, it was hard coordinating turning off the music half way during each course so participants could eat half of the food with music and half without. In addition, I should have counterbalanced the order of the music/no-music conditions such that half the participants ate in silence before hearing music, and vice versa.

The clear correlation between musical stimuli and social interactions was not planned but very interesting for future designs.

3.2.4 Dinner 4 – Surprise!

For this Media Lab pop-up dinner, I played with the idea of "unexpectations". Who says dinner has to be predictable?

#1 - Dessert Course

Savory cupcake with herb-infused cream

Music pairing: The Submarines – You, Me, and the Bourgeoisie

For this course, I made a cupcake that looked sweet but was in fact savory. The upbeat music was designed to enhance the feeling of being in a bourgeoise cupcake shop.

#2 - Cheese Course

Cheddar, asiago, white chocolate

Music pairing: Jeswa – Poema Singled

I took advantage of the fact that white chocolate looks similar to cheese to serve cubes of all three on the same plate. The slightly ominous music was a hint that all is not what it appears…

#3 - Cocktail

Tonic Jellies with musical accompaniments

Music 1: Miles Davis – Blue in Green

Music 2: Max Richter - Cathodes

Music 3: Zoe Keating – Legions (War)

I made three gin & tonic jellies, each with a different color and different musical accompaniment, but otherwise identical. Will participants be able to tell?

#4 - Eating Together

Baba ganoush, hummus, muhammara, basil yogurt dip, quinoa salad

Music pairing: Louis Armstrong selections from the 1920s

Each diner was given one dish, with the idea of encouraging social interaction between diners by sharing dishes. The cheerful music was added to help build a friendly atmosphere.

#5 - Eating Alone

Greek yogurt mousse, rosewater strawberries, apricot puree, pisatchios, eye masks, ear plugs.

Music pairing: Air – Alone in Kyoto

The dish was served covered so diners couldn't see what was in the cup. Diners had the option of wearing eye masks and/or ear plugs to eat the dessert with limited sensory information. For those participants who chose to skip the ear plugs, the music is meant to promote an atmosphere of calm and concentration.

#6 – Tea

Rosemary and rose vapor with musical accompaniments

Music pairing: Erik Satie - 3 Gnossiennes

Participants were blindfolded, then led out of the dining room into a pillow-covered lounge to relax and smell the vapor while calming, flowing music played in the background.

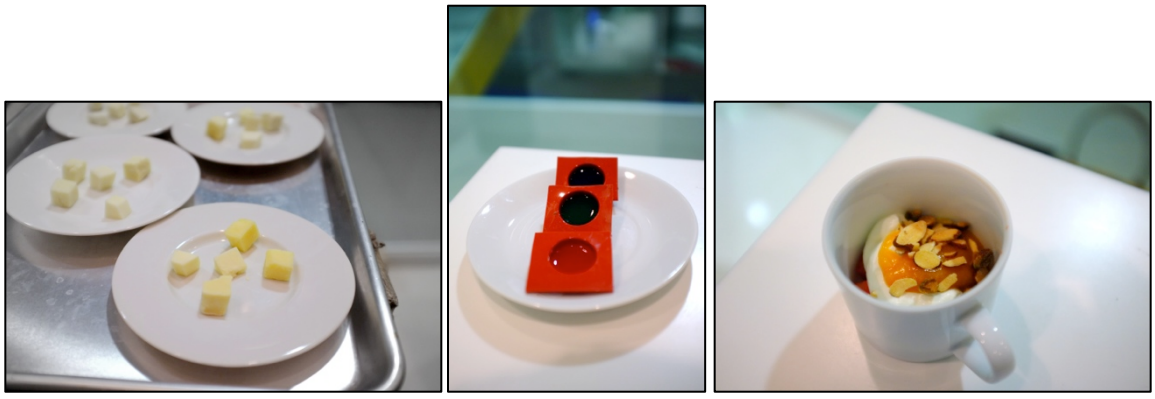


Figure 23. Left to right: Cheese course, Cocktail, Eating Alone (uncovered).

3.2.4.1 Feedback and Analysis

Each participant received a questionnaire after dinner (see Appendix E) asking them to rate how much they liked the food, the presentation, and how memorable the dish was. They were also asked about their favorite course, least favorite course, and most memorable experience.

Figure 12 shows the mean food, presentation, and memorability ratings for each course. On average, the Eating Together course (#4) had the highest food likability rating, the Dessert course (#1) and Eating Alone course (#5) had the highest presentation ratings, and the Cocktail course (#3) and the Eating Alone course (#5) had the highest memorability ratings. Interestingly, there are significant correlations between the participants' presentation rating and food rating ($r = 0.352$, $p = 0.015$) and between presentation rating and memorability rating ($r = 0.426$, $p = 0.003$). This further highlights the importance of vision in our flavor experiences.

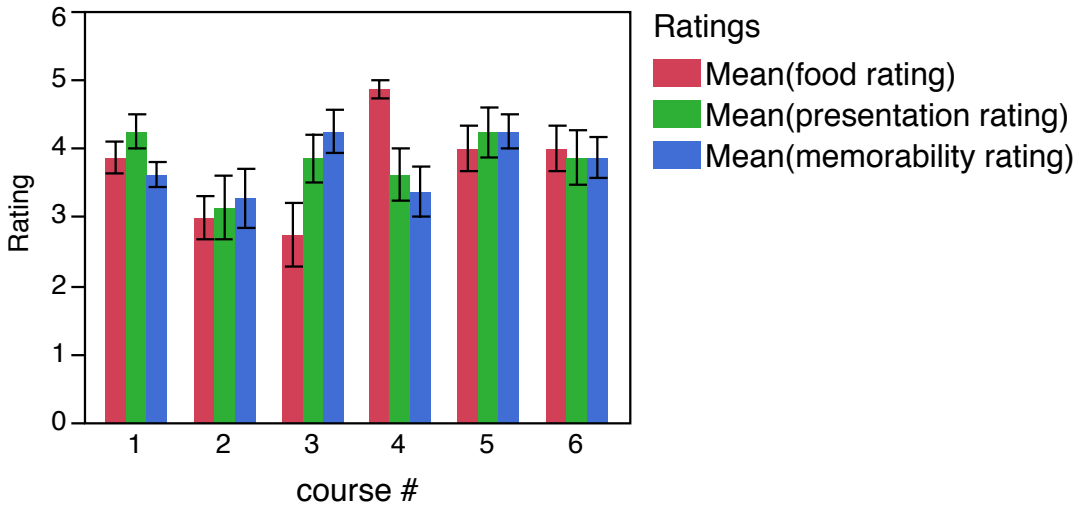


Figure 24. Mean ratings for each course.

The questions about favorite and least favorite courses revealed participants' different personalities. Some participants picked favorites (and least favorites) based on taste, while others went for the surprise factor. When it came to favorites, six participants picked based on the uniqueness of the experience and two participants picked based on taste. For the least favorite course, the ratio was reversed - two participants picked based on their lack of interest in the presentation and five participants picked based on taste (one participant did not answer). Perhaps when it comes to favorites, the experience trumps taste, but when it comes to least favorites, taste trumps experience. It's also possible that as there was no truly negative experience during the dinner, participants gravitated towards poor taste as a marker for displeasure.

Several patterns emerged based on participants' written feedback. The Eating Together course was positively received from everyone, notably because it promoted socializing amongst a group where people didn't all know each other. Almost every participant commented on how enjoyable sensory deprivation in the Eating Alone course was. Most participants only used the blindfold, but a participant who also used

earplugs observed that their sense of smell was enhanced along with their perception of chewing and swallowing sounds. Another side effect of sensory deprivation was that it encouraged discussion amongst the group as participants started guessing the ingredients and sharing stories of difficulties while eating blindfolded. The last course, Tea, was also uniformly well received as participants enjoyed the change of location, including the blindfolded trip, and the opportunity to relax at the end of the meal.

3.2.4.2 Personal Critique

Some of the dishes did not work as well as intended. Participants did not find the cupcake course surprising, and I overlooked the differences in texture in the cheese course that easily gave away the surprise factor. On the other hand, I thought the sharing course would be an overly simple idea, but that turned out to be surprisingly popular because it served as a good ice breaker for the participants. The dessert course with eye masks and ear plugs was also a surprisingly big hit. From this pop-up dinner, I took the ideas of sharing foods, encouraging discussions, sensory deprivation, and surprise to help me design the Media Lab Feast in April (see Chapter 5).

3.2.5 Summary of Learnings

One, people enjoy the unexpected. The blindfolded trip to the smell lounge (pop-up #4), the sensory deprivation dessert (pop-up #4), and the routine course (pop-up #1) were all very popular. In addition, novelty promotes socialization amongst the diners, even if they are strangers. In extreme cases such as the elevator speakeasy installation, being in an unusual situation created bonding opportunities for people and quickly established a friendly atmosphere.

Two, social interaction between participants is an important factor for consideration. I observed that participants started ignoring crossmodal interventions once they became engaged in conversation. Music also has a significant impact on the social atmosphere of the room. If the music is uncomfortable or creepy (as in the case of pop-up dinner #2), participants tended to quiet down and focus on the food. As social

interaction is a key part of a meal, explicitly designing social interaction into the eating experience is an important future direction.

Three, look to underutilized modalities to enrich the dining experience. Pop-up dinners #1 and #4 showed the effectiveness of smell as a sensory intervention. Unlike music, which might become overlooked once people start talking, people are less likely to ignore smell. As smell has been shown to influence people's mood (Herz 2002), pop-up dinner #3 could be restaged with the addition of smell as a mood modifier. Similarly, I believe that touch is a modality with much potential for expression. For instance, the hardness, temperature, and texture of the utensils and serving ware can be manipulated convey meaning. Designer Jonhyun Jeon used this idea to design tableware that doubled as sensory stimuli (Jeon 2012).

Four, drawing the line between experiment and experience is difficult. Pop-up dinners #2 and #3 were semi-experiments where participants were asked to fill out questionnaires in the middle of each course. However, this interrupted the flow of the dinner and made for a less in-depth experience. On the other hand, dinners #1 and #4 did not ask participants to fill out the questionnaire until the very end of the dinner, but by that point it was difficult for some participants to remember everything that had happened during the night. In the future, non-intrusive, real-time methods of recording participant response such as biometric signals are definitely new avenues to consider.

Partial Recipe for Brunswick Stew

Ground beef in enough water
to cover. Simmer. Add canned

tomatoes, lima beans, corn and celery,
Tabasco, onion, bell pepper. That's what

the dead do: leave us
with a list of ingredients, with

meager instruction, without
measurements. This is the partial

recipe, penciled in my mother's hand,
on a child's scrap of red and blue

ruled paper. There are no
rules for bringing up

the rear: only hunger
and the fiery memory

of the bowl we believed
could never be empty.

- Andrea Cohen

4 Experimental Design

"Statistics show that of those who contract the habit of eating, very few ever survive."

- William Wallace Irwin

This chapter is divided into three sections. First, I describe the informal experiments we carried out at the Cheap Wine Society. While casual, these experiments helped inform the more formal sensory experiments I would later carry out. The first sensory experiment deals with the notion of crossmodal congruence between music and taste, and explores whether people experience consistent enhancement or suppression effects across different tastes. The second sensory experiment examines the effect of musical and visual stimuli on the duration of aftertaste.

4.1 Proto-Study: Cheap Wine Society

Media Lab student Shahar Ronen and I formed the Cheap Wine Society in January 2012 as a response to a wine tasting class we took in January. Tired of drinking thirty-year-old Bordeauxs, we decided to host our own tastings where we only tasted wines under ten dollars.

Cheap Wine Society meetings eventually evolved into a platform where we would casually try out ideas for science. I will describe three of our meetings below as an introduction to the more rigorous experiments later.

4.1.1 Music and Wine Pairing

For our second meeting, we asked everyone to come with a bottle of wine and a musical suggestion. As we sampled each wine, the person who brought the wine also played the music that they thought matched well with the wine.

Results. We discovered that ten-dollar wines goes much better with hiphop, which made people want to drink more, than classical music, which highlighted the rough and unpleasant characteristics of the wine.

4.1.2 Color and wine pairing

For this meeting, I was inspired by the research of Borchet et al. (2001) on how color can change one's sense of smell. I asked everyone to bring a white wine, and I added food coloring to each wine. We had dark blue, magenta, gray, green, red, and orange wines.

Results. The blue riesling elicited comparisons with "Gatorade", and "Kool-aid". The gray chardonnay scared most people and was rated as "tasteless". The most salient example was when I took the same bottle of wine and dyed half of it green and half of it red. The green wine was reported to be more tart when I gave participants a glass of each to taste.

4.1.3 Blind Tasting

For this meeting, we blindfolded everyone and performed three pairs of blind tastings. The pairings were 1) old world vs. new world, 2) red vs. white, and 3) cheap vs. expensive. For old world vs. new world, we paired a 2010 Alsatian Riesling with one from Finger Lakes. For red vs. white, we paired a heavy-bodied white wine with a light-bodied red wine. For cheap vs. expensive, we paired a $13 wine with a $37 wine, both from Southern Rhone.

Results. As a group, people were not able to distinguish old world from new world wines as they performed exactly at chance level – with five out of ten people correctly identifying the old world vs. new world pairing. Everyone correctly identified the red wine from white wine. Eight people out of eleven correctly identified the expensive wine from cheap wine.

4.2 Experiment 1: Congruous-Incongruous Influences

4.2.1 Introduction

Crossmodal congruency is the tendency for people – not just synesthetes – to experience correspondences between attributes of stimuli from different sensory modalities (Crisinel et al. 2011). In particular, auditory and taste crossmodal congruency effects have been observed over the last forty years (Holt-Hansen, 1968; Mesz et al. 2011; Crisinel et al. 2010). However, most of the experiments have addressed the matching between music and a taste (often the abstract concept of a taste), there has been relatively little work on studying the actual effect of music on taste perception. To my knowledge, the only work comes from Crisinel et al. (2012), who showed that music crossmodally congruent to sweetness and bitterness can alter people's perceptions of sweetness and bitterness in chocolate. As I described in the last chapter, I played with the idea of using music to change flavor in the Musical Condiments pop-up dinner. From the post-dinner surveys, I noticed that some people had opposite reactions to the flavor-enhancing music; for instance, while sweet music made foods taste sweeter to some people, it made foods taste less sweet to others. This led me to hypothesize that perhaps there are two groups of people: one group for whom crossmodally congruent music has a taste-enhancing effect, and another group for whom crossmodally congruent music has a taste-suppressing effect. Furthermore, I was curious if enhancement/suppression effects were consistent. For example, if someone experiences enhancement for sweetness, will they also experience enhancement for sourness?

In addition, I wanted to test the effect of sour music on taste perception. In Crisinel et al.'s 2012 paper, only sweet and bitter music were tested. I also introduced a control condition into the experiment, where subjects rate the food without any musical stimuli.

My goal for this experiment is twofold: 1) to test the effectiveness of my composed sour music and to replicate Crisinel et al.'s results with a control condition, 2)

to test whether there are groups of people who consistently experience congruency effects.

4.2.2 Methods

Participants. Fifty participants took part in the experiment (28 female, 24 male, 18-62 years old). The participants reported no cold or other impairment of their sense of smell and taste and no hearing impairment. The experiment lasted for approximately 40 minutes. After discarding incomplete test data, we analyzed data from forty-two participants

Stimuli. To make a sample that contained sweet, sour, and bitter tastes, I prepared a mixture of cranberry juice and grapefruit juice. The two musical stimuli for sweet and bitter music came from Crisinel et al.'s 2012 experiment. I composed the sour music with Ableton Live with the features of having high pitch, fast tempo, and high dissonance (Mesz et al. 2011). It consisted of notes played by synthetic instruments. The pitch of the notes ranged from C2 to C6. The sounds were edited to last for 30 seconds.

Procedure. Subjects were given 10-ml samples in 30-ml cups at room temperature. A straw was placed in each cup to ensure the solution went straight to the back of the mouth instead of lingering in the front parts of the mouth. Subjects were given water and crackers to cleanse their palate before each trial.

For each trial, subjects were given a sample to drink while the music stimuli played in the background for 30 seconds. Subjects were asked to complete a questionnaire after drinking each sample, where they were asked to rate on a scale of 1 to 9 the sweetness, sourness, bitterness, pleasantness, and intensity of the sample.

Four different types of trials were administered, one with sweet music stimulus, one with bitter music stimulus, one with sour music stimulus, and one with no music. The trials were administered in random order, and each trial was repeated for a total of eight trials. A test trial with no external stimuli was done before hand to accustom subjects to the experiment procedure.

4.2.3 Results

Consistency. When presented with the same music upon the second occasion, did participants give the same taste ratings?

For ratings of sweetness, participants gave equal ratings on the second occasion 47/168, or 28.0% of the time. This is significantly different from what would be expected if the participants had simply made a random choice among the 9 possible ratings (1/9=11%), $t(167)=4.86$, $p<0.01$. For ratings of sourness, participants gave the same rating 25.6% of the time (chance level: 11%), $t(167)=4.29$, $p<0.01$. For ratings of bitterness, participants gave the same rating 33.9% of the time (chance level: 11%), $t(167)=0.475$, $p<0.01$.

Eight participants had all three ratings the same (4.76%), which is significantly different from the chance level of 1.23%, $t(168)=2.14$, $p=0.033$. 32.7% of the time, participants were within an one point difference for all three ratings, which by chance would happen no more than 9.88% of the time, $t(167)=6.29$, $p<0.01$.

Ratings of flavors. Figures 13 and 14 show the mean sweetness, sourness, bitterness, pleasantness, and intensity ratings. Figure 13 groups ratings by stimuli type to give an overall idea of how each condition impacts all the ratings, and figure 14 groups ratings by rating type to make it easier to compare single ratings (like sweetness) by stimuli type.

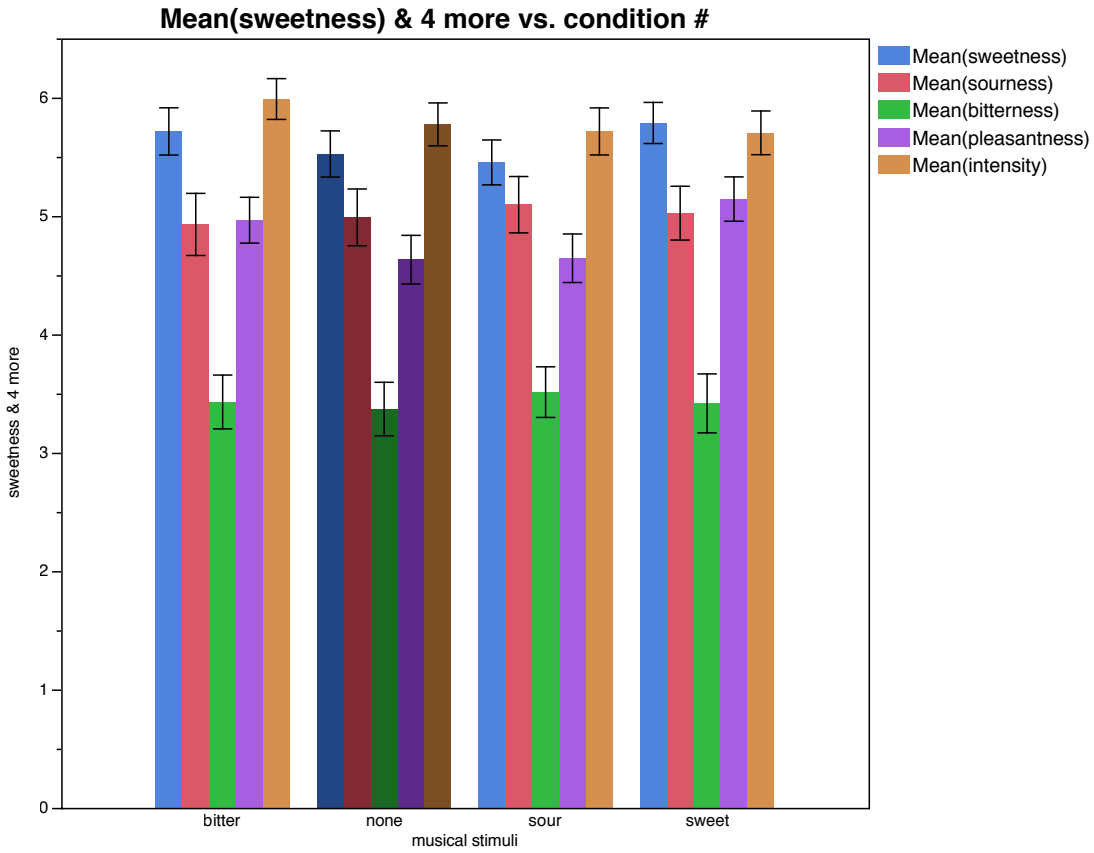


Figure 25. Mean values of participant ratings grouped by musical stimuli.

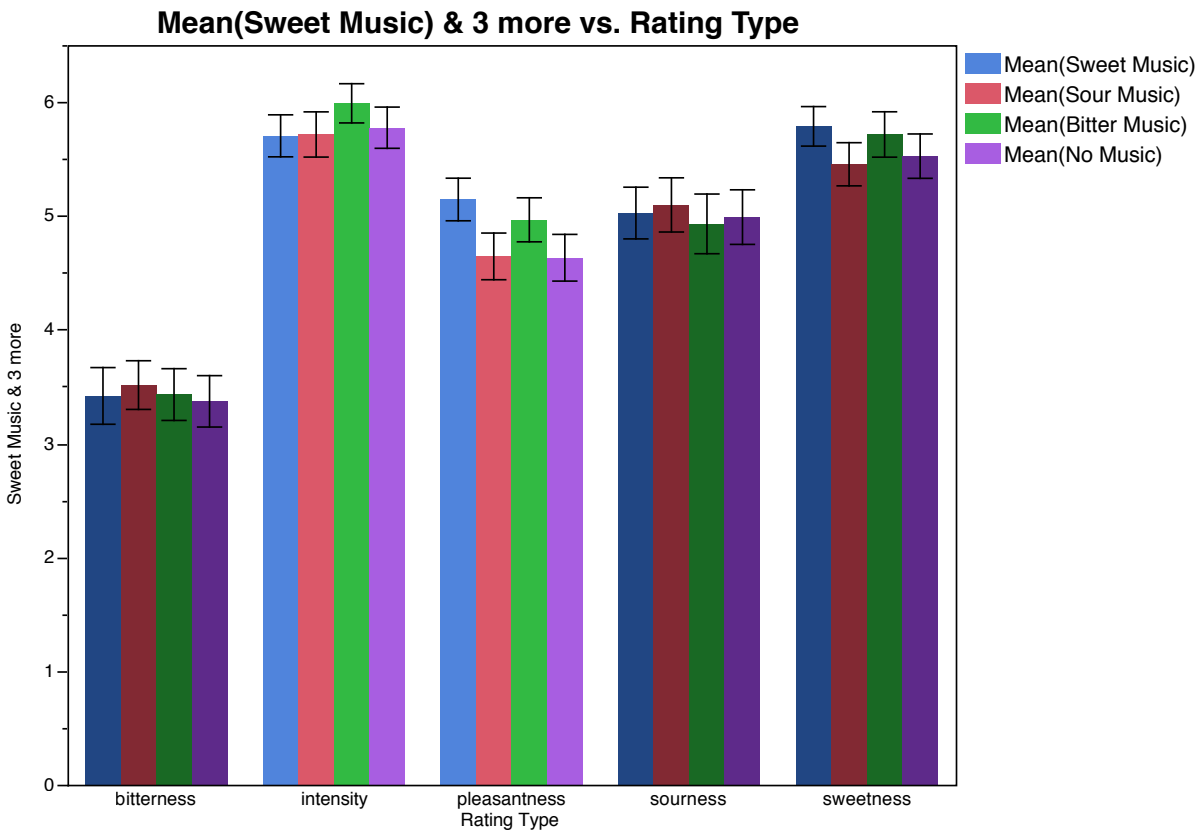


Figure 26. Mean values of participant ratings, grouped by rating type.

For sweetness, M = 5.79, SD = 1.59 with the 'sweet' soundtrack, M = 5.45, SD = 1.74 with the 'sour' soundtrack, M = 5.71, SD = 1.83 with the 'bitter' soundtrack, M = 5.52, SD = 1.79 with no soundtrack.

For sourness, M = 5.02, SD = 2.08 with the 'sweet' soundtrack, M = 5.09, SD = 2.18 with the 'sour' soundtrack, M = 4.93, SD = 2.40 with the 'bitter' soundtrack, M = 4.99, SD = 2.20 with no soundtrack.

For bitterness, M = 3.42, SD = 2.28 with the 'sweet' soundtrack, M = 3.51, SD = 1.96 with the 'sour' soundtrack, M = 3.43, SD = 2.08 with the 'bitter' soundtrack, M = 3.37, SD = 2.07 with no soundtrack.

For pleasantness, M = 5.14, SD = 1.72 with the 'sweet' soundtrack, M =4.64, SD = 1.88 with the 'sour' soundtrack, M = 4.96, SD = 1.77 with the 'bitter' soundtrack, M = 4.63, SD =1.88 with no soundtrack.

For intensity, M = 5.70, SD = 1.69 with the 'sweet' soundtrack, M = 5.71, SD = 1.82 with the 'sour' soundtrack, M =5.99, SD = 1.58 with the 'bitter' soundtrack, M = 5.77, SD = 1.66 with no soundtrack.

Over all the ratings, sourness has the greatest standard deviation at 2.21, and sweetness has the least standard deviation at 1.74.

A repeated measures ANOVA was tested in order to assess whether there were any differences among the average sweet/sour/bitter/pleasantness/intensity ratings for each musical condition. For sweetness, Mauchly's test indicated that the assumption of sphericity held, $\chi^2(5)=5.60$, p = 0.347. The results show that there was no significant effect of musical conditions on the ratings of sweetness, F(3, 249) = 1.325, p = 0.267. For sourness, Mauchly's test indicated that the assumption of sphericity was violated, $\chi^2(5)=14.8$, p = -0.011, therefore degrees of freedom were corrected using Huynh-Feldt estimates of sphericity (epsilon=0.925). The results show that there was no significant effect of musical conditions on the ratings of sourness, F(2.775, 230.32)=0.212, p=0.874. For bitterness, Mauchly's test indicated that the assumption of sphericity held, $\chi^2(5)=7.21$, p = 0.206. The results show that there was no significant effect of musical conditions on the ratings of bitterness, F(3, 249) = 0.193, p = 0.901. For pleasantness, Mauchly's test indicated that the assumption of sphericity held, $\chi^2(5)=9,65$, p = 0.086. The results show that there was significant effect of musical conditions on the ratings of pleasantness, F(3,249)=3.67, p=0.012. For intensity, Mauchly's test indicated that the assumption of sphericity held, $\chi^2(5)=5.59$, p=0.349. The results show that there was no significant effect of musical conditions on the ratings of intensity, F(3,249)=0.989, p=0.398.

Overall, these results show that different musical conditions did cause a significant different in the ratings of pleasantness, but not of sweetness, sourness, bitterness, and intensity.

To figure out which conditions cause a difference in the pleasantness ratings, I used multiple paired samples t-tests with Bonferroni correction. Since there are six corrections, the p value is 0.05/6=0.0083. The only pair with a significant difference in

pleasantness ratings was between the sweet music condition and no music condition, t(83)=-2.93, p = 0.0044, r=0.607.

Correlations in Participants' Ratings. The correlation between bitterness and sweetness, bitterness and sourness, pleasantness and sourness were statistically significant ($p < 0.05$). In addition, all the pairwise correlations with intensity were also significant (See Table 1) .

Table 1. Correlation coefficients between the five ratings.

*** indicates significant correlation (p<0.05)**

	Sweetness	Sourness	Bitterness	Pleasantness	Intensity
Sweetness	1.000	-0.091	-0.154*	0.083	0.302*
Sourness	-0.091	1.000	0.379*	0.157*	0.397*
Bitterness	-0.154*	0.379*	1.000	-0.022	0.270*
Pleasantness	0.083	0.157*	-0.022	1.000	0.250*
Intensity	0.302*	0.397*	0.270*	0.250*	1.000

Sour Music. To assess the effectiveness of my composed "sour music" in inducing sourness, a paired-samples t-test was performed between participants' sourness ratings in the sour music condition (M = 5.10, SD = 2.18) versus the no music condition (M = 4.99, SD = 2.20). There were not any significant effects: t(84) = -0.555, p = 0.581, r = 0.673.

Enhancement and Suppression. I defined enhancement such that, a participant experiences enhancement for taste T if their rating of taste T was higher in the T-inducing music condition than in the no music condition. Furthermore, since each participant rated each condition twice, I averaged the ratings for each condition. For instance, a participant would experience sweetness enhancement if their average sweetness rating in the sweet music condition is higher than their average sweetness rating in the no music condition. Using this comparison, 19 out of 42 participants experienced enhancement for sweetness, 20 out of 42 participants experienced

enhancement for sourness, and 16 out of 42 participants experienced enhancement for bitterness.

On the other hand, I had also observed what I call suppression effect during pop-up dinners (see chapter 3), where people's perception of flavor T would diminish in the presence of T-inducing music compared to the no-music condition. In this study, 15 out of 42 participants experienced suppression for sweetness, 17 out of 42 participants experienced suppression for sourness, and 15 out of 42 participants experienced suppression for bitterness.

To address the question of whether the enhancement/suppression effect is consistent between different tastes, four participants experienced enhancement for all three tastes, while two participants experienced suppression for all three tastes. Since the juice sample was not bitter to start with, I also examined the number of participants who experienced enhancement with just sweetness and sourness - nine participants experienced enhancement for both tastes and eight participants experienced suppression for both tastes.

4.2.4 Discussion

Figure 14 shows that there are small differences in the taste (sweet/bitter/sour) ratings for different conditions – for instance, sweetness rating is highest for the sweet music condition and sourness rating is highest for the sour music condition – but the differences are not statistically significant. Specifically, there was no significant effect of the sour music on sourness ratings, which did not confirm results obtained previously by Crisinel et al. (2010) and Mesz et al. (2011) that high-pitched notes are associated with sourness. Crisinel et al. (2010) had also shown that brass instruments are associated with sourness; perhaps if I had used a more traditional brass sound in the sour music composition, participants would have detected a bigger difference. In addition, I did not collect musical expertise information from the participants: it is possible that musical effects are more salient for those who are musically trained.

The sweetness rating was also unexpected. According to Crisinel et al (2010) and Mesz et al. (2011), low pitch is associated with bitterness and high pitch is associated

with sweetness and sourness. On average, I found sweetness ratings to be actually higher for low-pitched bitter music condition than the high-pitched sour music condition.

The ANOVA analysis did show that pleasantness ratings were significantly different under the different musical conditions. In particular, the sweet music condition was associated with higher pleasantness ratings than the no-music condition. The fact that pleasantness is a significant factor in music-taste integration has been shown in multiple studies (Ferber et al. 1987, Crisinel et al. 2010). An intriguing question would be to measure how much participants liked each musical stimulus and correlate the pleasantness rating of the music with the pleasantness rating of the food. This gives rise to the possibility that restaurants and home cooks can increase diners' preference for food by the choice of music. It has already been shown that people's liking of music affects their ratings of cafeterias and their likelihood of returning (North et al. 1996), so it would be interesting to explore whether musical preference extends to actual food preference as well.

There were several significant correlations in the participants' ratings, such as sourness and bitterness ratings ($r=0.379$) and sweetness and bitterness ratings ($r=-0.154$). Intensity ratings was shown to correlate with sweetness, sourness, and bitterness ratings, which makes intuitive sense since something is judged as more intense when it has stronger flavors.

The observation that participants were not all enhancement-oriented or suppression-oriented is confirmed by another study that showed people's perception of sweetness could be altered by closing their ears, but whether the taste was enhanced or suppressed depended on the person (Srinivasan 1955). Crisinel et al's results for bitter and sweet music had suggested that the majority of their participants had experienced an enhancement effect for sweetness (Crisinel et al. 2011), but perhaps this is not the case for everyone. As I will address in Chapter 7, figuring out indicators for enhancement or suppression effects is an interesting question for future research.

An alternative explanation for the observed inconsistencies is that the results were simply random. In the current study, the experiment was limited to one session with each stimuli presented twice. To show consistent enhancement or suppression effects amongst participants, a more robust study for the future could involve multiple sessions with the same stimuli.

4.3 Experiment 2 - Duration of Flavor

4.3.1 Introduction

Crisinel et al.'s 2012 paper established that it is possible for crossmodally congruent music to change participants' taste perception. Specifically, the especially designed music changed the participants' ratings on a sweetness-bitterness scale (Crisinel et al. 2012). I was curious whether music had influences on other aspects of flavor perception, like texture or taste duration. To my knowledge, no one has looked at how music affected the duration of aftertaste. For this study, I used the sweet and bitter music from Crisinel et al.'s 2012 experiment. In addition, I added video as a third condition to compare the effect of auditory versus visual stimuli in taste duration. A fourth condition with no audio or visual stimuli was added as a control.

4.3.2 Methods

Participants. Twenty-four participants took part in the experiment (10 female, 14 male, 22-46 years old). The participants reported no cold or other impairment of their sense of smell and taste and no hearing impairment. The experiment lasted for approximately 30 minutes.

Stimuli. After consulting Lawless et al. (1979), I prepared a 0.3 M sucrose solution, which had an average aftertaste duration of 60 seconds. I decided on a pure sucrose solution to isolate the sense of taste from olfactory influences, and the choice of a fluid was intentional, to avoid artifacts from the food breakdown process. The two musical stimuli for sweet and bitter tastes came from Crisinel et al.'s 2012 experiment. The video stimuli came from a two-minute segment of National Geographic's *Desert Seas* documentary. The segment was selected for its neutrality of subject matter and consistency in shooting angle (in a pilot study, one subject reported that a fade-out in the scene gave them the sensation of losing taste perception).

Procedure. Before the experiment, each subject was given a pre-experiment questionnaire whether they were asked about their active musical experience (none, 0-2 years, 2-5 years, 5+ years) and how much they liked to eat sweet foods (on a scale of

1-5). They were also asked to rank each of the five senses in order of importance for them.

During the actual experiment, subjects were given 10-ml samples in 30-ml cups at room temperature. A straw was placed in each cup to ensure the solution went straight to the back of the mouth instead of lingering in the front parts of the mouth. Subjects were given water and crackers to cleanse their palate before each trial.

For each trial, the subjects were given one sucrose sample and were told to start drinking at the "start drinking" signal. Five seconds afterwards, subjects were given the "zero" signal, at which point they were asked to swallow and rate their initial sweetness rating on the form provided (see Appendix F). Thereafter, subjects were given verbal cues at intervals of 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, and 120 seconds. At each interval, they were asked to mark their perceived sweetness rating on the form.

Sweetness intensity rating was measured using an 11-point scale, with the following descriptors labeled: no sensation (0), threshold (1), weak (3), moderate (6), strong (9), and very strong (10).

A total of four trials were administered, one with sweet music stimulus, one with bitter music stimulus, one with video stimulus, and one with no external stimuli. For the music stimuli, music was started before the subjects were asked to start drinking. For the video stimuli, the video was started before the subjects were asked to start drinking, and subjects were asked to watch the video the entire time while they were rating aftertaste intensity. The trials were administered in random order. Two test trials with no external stimuli were done beforehand to accustom subjects to the experiment procedure.

4.3.3 Results

Analyses were performed on total duration of aftertaste, time it took the perceived intensity of a stimulus to fall to half its peak value (time to half peak), and peak intensity during the trial. Because participants were quite varied in the range of their responses, plots of the medians of taste intensity ratings are shown for each of the four conditions.

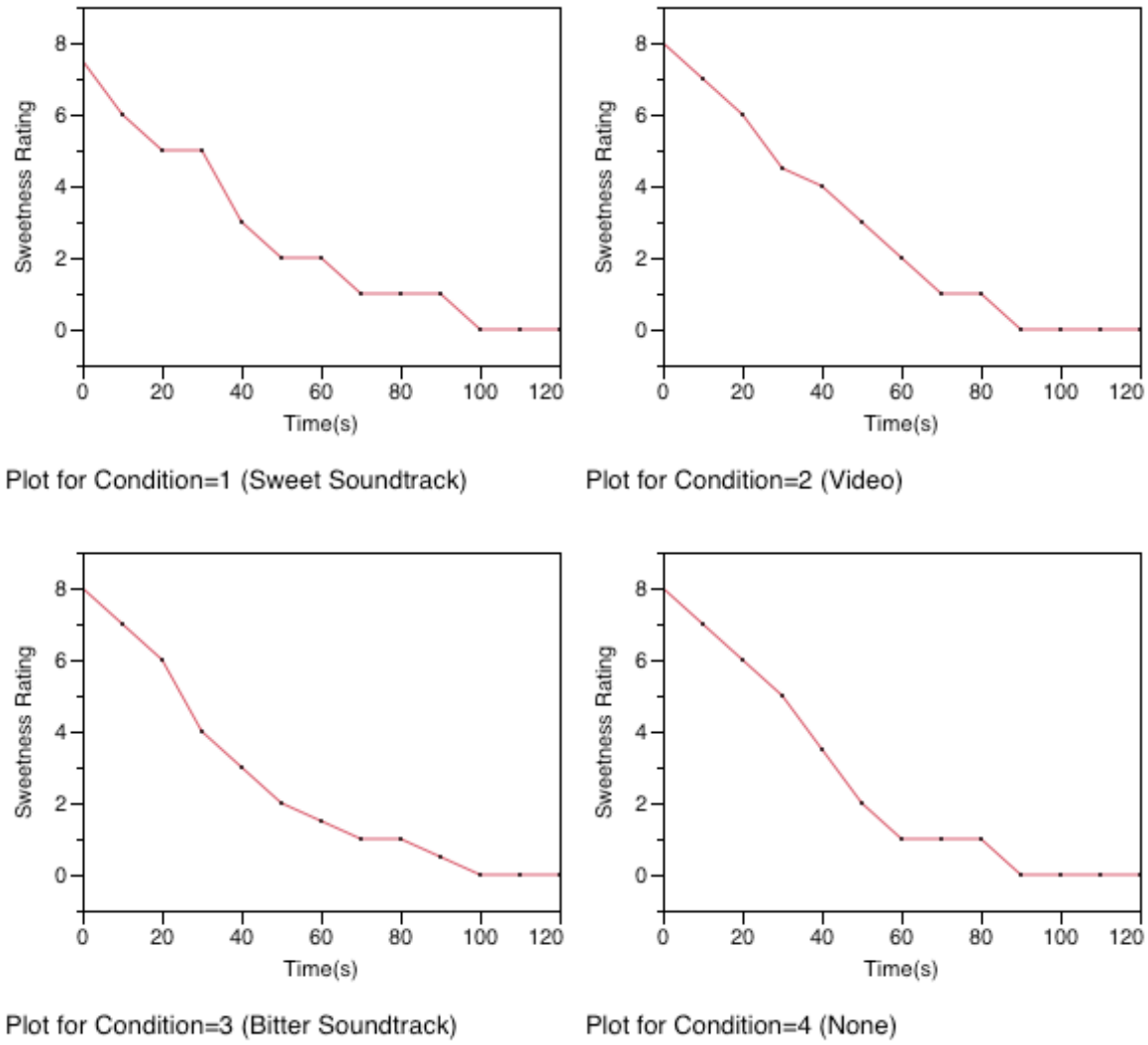


Figure 27. Plots of median sweetness ratings for all four conditions.

For time to half peak, M = 42.96, SD = 23.94 with the sweet soundtrack, M = 41.25, SD = 26.64 with video, M =44.05, SD = 27.44 with bitter soundtrack, M = 39.90, SD = 21.26 with no stimuli.

For total duration, M = 92.50, SD = 31.79 with the sweet soundtrack, M = 88.33, SD = 24.47 with video, M =92.50, SD = 27.70 with the bitter soundtrack, M = 88.33, SD = 30.74 with no stimuli.

A repeated measures ANOVA was tested in order to assess whether there were any differences among the duration measurements for each audio/visual condition. For

time to half peak, Mauchly's test indicated that the assumption of sphericity was violated, $\chi^2(5)=14.99$, $p = 0.010$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (epsilon=0.672). The results show that there was no significant effect of audio/visual conditions on time to half peak, $F(2.02, 46.36)=0.370$, $p=0.694$. For total duration, Mauchly's test indicated that the assumption of sphericity held, $\chi^2(5)=6.25$, $p = 0.282$. The results show that there was no significant effect of audio/visual conditions on total taste duration, $F(3, 21) = 0.904$, $p = 0.456$. Overall, the results indicated that no one stimulus affected the participants' duration ratings differently than the others.

There was no significant correlation between the participants' age or gender and their responses. There was, however, a significant correlation between musical experience and the standard deviation in a participant's time to half peak response ($r=-0.412$, $p=0.041$). In other words, more musical experience was correlated with consistency in one's aftertaste ratings across different conditions.

The Effect on Sweetness. Given that the solution was sweet, a paired-t test was conducted to assess whether playing sweet music has an impact on the duration of sweetness perception, compared to the no stimuli condition. There was no significant difference in time to half peak measurements, $t(23)=--0.856$, $p=0.401$, $r=0.705$, or in total duration measurements, $t(23)=-1.225$, $p=0.233$, $r = 0.859$. In addition, how much participants like sweet foods is not correlated with the peak sweetness rating in the sweet music condition ($r = 0.311$, $p=0.139$).

However, when participants are grouped by how much they like sweet foods, on a scale of 1(least) to 5 (most), the group who responded with 5 had significantly longer time to half peak measurements between the sweet music condition and the no-music condition, $t(9)=-2.41$, $p=0.042$, $r=0.972$.

The Effect of Video. The video stimulus was included to compare the effect of the visual stimulus on taste, and to evaluate whether music was unique in its ability to affect taste. The video stimulus condition did not have a significant effect on time to half peak or total duration. However, I noticed that there was a group of participants for

whom the video condition resulted in noticeable longer-than-average duration ratings, and there was another group of participants for whom the video condition resulted in noticeable shorter-than-average duration ratings. More precisely, there were 16 participants out of 24 whose time-to-half-peak ratings in the video condition was more than one standard deviation away from their average time-to-half peak ratings; Out of those, 10 experienced shorter-than-average duration ratings in the video condition, and 6 experienced longer-than-average duration ratings in the video conditions.

Peak Intensity and Duration. Correlations were calculated between peak intensity values and time to half peak for each condition. There were no significant correlations between intensity and duration measures.

Sensory Ranking. All participants were asked to rank the senses of sight, hearing, smell, taste, and touch in order of importance to them (1=least important, 5=most important). A multivariate correlation showed that significant correlations existed between smell and sight ($r = -0.561$, $p=0.005$), hearing and touch ($r = -0.570$, $p = 0.005$), and hearing and taste ($r = -0.574$, $p = 0.004$).

I performed a multivariate correlation between time to half-peak values in different conditions and participants' sensory rankings. The correlations of statistical significance were between touch and time to half peak for the sweet music condition ($r=0.499$, $p=0.0131$), between touch and time to half peak for the video condition ($r=0.533$, $p=0.0073$), and between hearing and time to half peak for the sweet music condition ($r=-0.4319$, $p=0.0351$).

4.3.4 Discussion

To the best of my knowledge, there has been no clear explanation for the mechanism underlying the effect of music on the duration of taste. Studies to date have shown the effect of music on the type and intensity of flavor (Crisinel et al. 2010, Crisinel et al. 2011, Mesz et al. 2011, Bronner et al. 2008), but not on the duration.

None of the audio and visual conditions in this study made a significant difference on the taste duration measurements. It is possible that these trends would have reached statistical significance had a larger number of participants been tested.

However, once the participants were partitioned by how much they liked to eat sweet foods, people who loved to eat sweets reported significantly longer time to half peak measures in the sweet music condition than the no-music condition. Perhaps people who like to eat sweet foods are especially sensitive to sweetness, and a crossmodally congruent trigger like the sweet music increased their sensitivity to the trace amounts of sweet solution remaining in their mouths. It is interesting to note that this group did not experience a significant difference in the peak sweetness ratings between the sweet music condition and no music condition ($t(9)=1.35$, $p = 0.215$, $r = 0.597$). In other words, even though there was a significant effect on the duration of sweetness, there was not a significant effect on its intensity. Furthermore, given the finding from Experiment 1, that people may experience either enhancement or suppression effects, it's possible that this group of sweets-loving participants did not all experience enhancement effects (therefore explaining the lack of difference on the peak sweetness ratings), but they were consistent in experiencing longer taste duration. This opens up the possibility to view taste duration as another measurement of crossmodal congruency effects that is independent of taste intensity.

The effect of video was notable in the bifurcation of participants into those for whom the video stimulus lengthened taste perception, and those for whom the video stimulus shortened taste perception. It's been shown that cognitive task load can reduce taste perception by limiting attentional capacity (van der Wal et al. 2013), so it would be natural to hypothesize that the participants who experienced notably shorter taste duration with the video stimuli must be highly attuned to visual stimuli. However, it is difficult to correlate video effects with participants' sensory ranking because the sensory ranking was done by a forced-choice ordering, and most participants ended up rating sight first, hearing second, and touch, smell, and taste were ranked last. This reflects traditional sensory dominance theory (Zampini et al. 2010), but it also hid more subtle differentiations in how much people valued their sense of sight. A different test of participants' sensory disposition, perhaps one that tested how much people pay attention to stimuli from different sensory modalities, would have been useful.

By the same token, the correlations observed between the ranking of touch and time to half peak measurements in the video and sweet music conditions could also be an artifact of the forced-ranking system. Or, it may be simply that, as touch is often overlooked, participants who value touch may be less distracted by visual and auditory stimuli, thus explaining their longer duration measurements in those conditions.

4.4 Science vs. Art – Why Both?

This chapter had a markedly more quantitative approach than the previous chapter, where I relied more on qualitative analysis. I believe it is important to incorporate both design and experimentation in crafting multisensory experiences. Much of the basis of experience design lays in scientific findings; a chef might choose a particular soundtrack for their restaurant on a whim, but there also exists deep, psychological connections between different senses to be explored.

That said, it is not enough to rely only on experimental results. Controlled laboratory conditions do not always apply to the real world, where there is a plethora of confounding factors. For instance, food and music in experimental settings are carefully chosen to avoid having any previous cultural or emotional associations. In my experiments, I chose simple juice mixtures and sucrose solutions. In the real world, however, people eat complex foods with various degrees of familiarity. In addition, design experiments like the pop-up dinners are useful in getting a more realistic sense of what is likely to happen in real life, especially in locating previously unconsidered factors. For instance, I did not foresee the influence of music on participants' socialization patterns, but it became an important factor in future design.

To me, the value of experimentation lies in discovering new avenues for design. For instance, experiment #2 tested the plausibility of taste duration as a parameter in design. Experiment #1 attempted to uncover patterns in people's response to music, which also cannot be easily tested in a design setting.

An example of how both approaches work together is in the synthesis of Experiment #1. Based on the known associations between various musical attributes

and basic tastes, I designed pop-up dinner #2 with real music and real food. Based on the dinner, I discovered curious discrepancies in participants' responses, and designed a quantitative experiment to measure those differences. As an example of how experiment can impact design, experiment 1# showed that music had a significant impact on the participants' hedonic experience. Inspired by this, I used different kinds of music in the emotions pop-up dinner to assess how music affected real-world eating experiences. In summary, I chose to embrace this hybrid approach, which gave me the freedom to explore new ideas while keeping me grounded in a scientific foundation.

Recipe for S&M Marmalade

Blood oranges
should be eaten
naked.
blushing.
cupped
in the palm.
Easily entered,
fingers
separate skin from flesh,
carefully pulling flesh
segment by segment,
opening the ruby-
orange,
rosy-wet.

Ignore
the rest:
the bitter Sevilles,
Hamlins
the under-ripe
green-tinged,
the rusty orange.
Mottled.

Rough.
Sour.

Leave them
to the flash
of a newly whetted blade
sharp and cold
cutting into skin and flesh.
Slice.
Soak.
Turn up heat.
Boil until flesh melts
and bubbles blister
thick deep orange.

Think only of the end,
the mouth-feel,
the stew of dark sweet
and juice
and thickened pulp

to swallow.

- Judith Pacht

5 FEAST

"Strange to see how a good dinner and feasting reconciles everybody."

- Samuel Pepys

The culmination of my design and experimental work was a Lab-wide feast where I showcased my studies in sensory interaction in a production of dinner-as-art. After several false starts, the final Feast took place with some modifications to the original design, but the new location also provided new opportunities for design. The feast combined food, music, spectacle, creativity, and social interaction to produce an unique event that celebrated the Media Lab community.

5.1 Original Design

The Feast was originally scheduled to take place on April 20th at midnight as part of the MIT Media Lab Other Festival, a festival of art and design by and for the Media Lab. I designed the feast to have five components, each with a distinct look and feel, to explore the expressive potential of food; highlight the active, creative role of the eater; and build community around food and companionship. The goal was to show that eating could indeed be a meaningful, interactive, and unexpected experience.

Set-up. The Feast was scheduled to take place on the 6th floor multipurpose room at the Media Lab, with controllable lighting and surround sound. As an unorthodox touch, the tables were arranged in a maze-like pattern (see Figure 16), with the intention of giving participants the experience of navigation through a dark, fog-filled maze upon arrival.

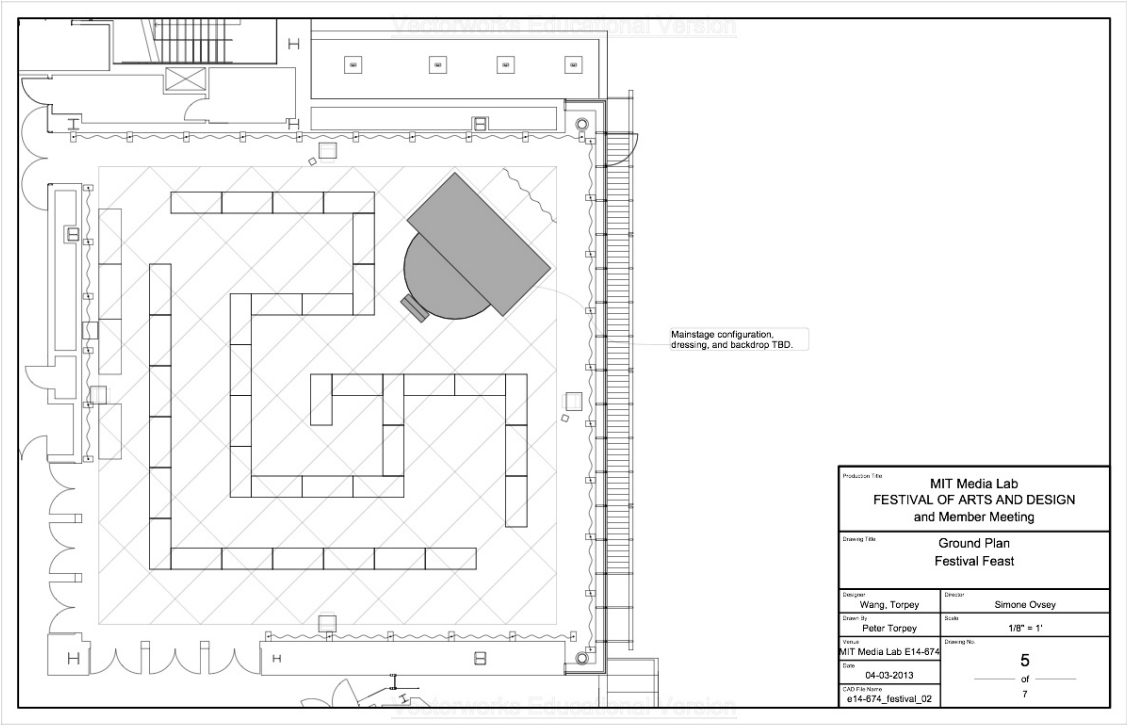


Figure 28. Original floorplan for the Feast, the tables are represented by rectangles.

The following imagined narrative describes the experience of a diner as they experience the feast:

Act 1 – Darkness.

You are handed a glass of sparkling wine as you walk into the space. You can barely make out the entrance into the maze of tables, each lit by a glowing white pyramid-like centerpiece. You explore the space, watching your step as swirls of dry ice fog dance around your feet. You find an empty seat at a table. You hear sound of farming and harvest, of barn animals and fishing boats. The scent of cilantro and citrus fill the air. Gradually, you hear familiar sounds from the kitchen - chopping, slicing, boiling, grilling, searing. You realize you are getting hungry. The sounds of cooking are replaced by the sounds of people chatting, laughing, forks hitting plates, glasses clinking. The smell is rich with cinnamon, cloves, and orange. You feel the warmth of home and good company.

Act 2 - Play

The music gradually fades. All of a sudden, the centerpiece starts blinking orange and blue and the music picks up a bright, happy tune. With the aid of people at your table, you tear open the centerpiece to find components for utensil building inside. You bind toothpicks and tongue-depressors with rubber bands to make spiky chopsticks.

Act 3 - Communal

Platters start appearing. You notice that each table is covered in different dishes. You pass around plates and try to barter with the table behind you for their lamb meatballs. The music is loud and rambunctious and it feels like a giant party.

Act 4 - Expression

You receive a cup of vanilla mousse with a postcard, describing how this dessert mirrors the creative, DIY spirit of the Media Lab. You arrange berries and nuts from the platter to turn the mousse into a snowman. As you ponder over the right blueberries for the eyes, you hear the plaintive notes of a saxophone solo.

Act 5 – Contemplation & Dream

The light grows dimmer and a soothing lullabye fills the air. You are handed a chocolate chip cookie and a glass of milk. Is it bed time? The lights gradually fade to black.

Suddenly, you are awakened by strobe lights and electronic dance music. The glass of milk turns out to be a potent cocktail. You leave the table to join the growing dance party in the middle of the room.

5.2 Research@ML FEAST

Due to the events of the Boston Marathon bombing, the feast was postponed until the Research@ML event in May. The feast had new constraints – earlier start time, new location, a smaller space, and no lighting control. I designed the feast with five new acts; each act reflected a different artistic style to suggest that food can in fact be considered art.

5.2.1 Infrastructure

A central DJ table was set up in the front of the feast area. An eight-channel surround sound audio system was set up to modulate the music for each course.

To keep track of the volunteer group of fifteen servers, I gave each server an infrared-controlled LED pin (Jacoby 2012) that would blink when they were needed. I wrote a Processing program to control a central infrared transmitter that would summon the servers on command. This way, the servers could engage with the community and eat like a regular diner when they were not working.

5.2.2 Pre-Feast

The tables were arranged in long rows. Menus were placed on the tables that showed the names of the acts and a picture associated with the artistic style of the act. To enhance the anticipation of the experience, I created a soundscape in the feast area that consisted of a piano soundtrack overlaid with sounds of cooking and eating. Each speaker was set up to play a different sound loop, including sounds of chopping, boiling, sautéing, grilling, and recorded restaurant noise.

5.2.3 Act 1 – Beginnings

The first act did not involve food. Instead, it was a utensil-making course. With the help of Philippa Mothersill from the Media Lab, we designed a modified "Christmas cracker" that encouraged participants to tear open the cracker with the help of others (see Figure 1). Inside, we included pictures of example utensils as well as a variety of popsicle sticks, tongue depressors, toothpicks, and rubber bands. A postcard inside asked diners to submit pictures of the utensils they built (see Figure 2).

To accentuate the playful and primitive feeling, each audio channel played a different djembe drumming pattern so that the total sonic effect approximated a drum circle.

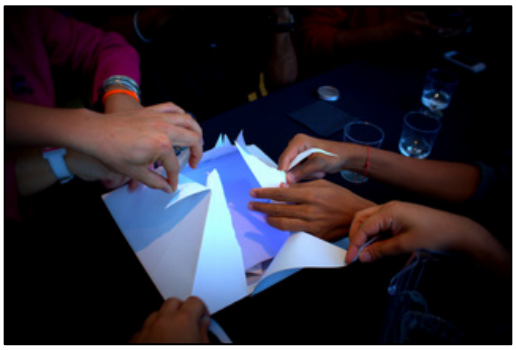


Figure 29 Opening the Christmas cracker.

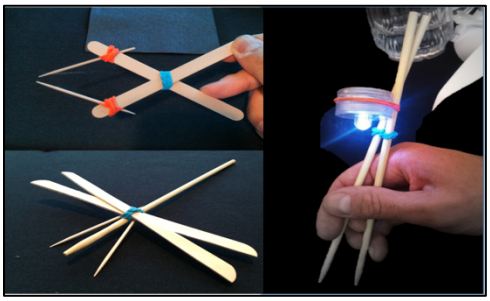


Figure 30 Examples of user-created utensils

5.2.4 Act 2 – Nature

The second act was inspired by Asian brush painting, to evoke a feeling of simplicity and being in nature. Diners were served a salad course, accompanied by sounds streamed live from a nearby cranberry bog, courtesy of the Tidmarsh project (Mayton 2013). Diners experienced sounds from nature such as crickets, running water, and (sometimes shrieking) geese.

5.2.5 Act 3 – Spectacle

For the third act, I explored the medieval notion of food as spectacle and diversion. To create the initial spectacle, Dan Novy from the Media Lab constructed a homemade fog machine with a bucket heater, dry ice, and LED lights. The act began with a colorful cascade of rosewater-scented dry ice fog, followed by trumpet fanfare and the arrival of dishes. The food was Turkish-inspired and heavily spiced, to evoke the feeling of luxury and exoticism (by medieval standards). The dishes were served family-style. Each table received five random dishes from a total of ten varieties, with instructions to share their food with other tables.

Figure 31. Dry ice fog spectacle.

5.2.6 Act 4 – Expression

The fourth act was centered on the idea of expression. Like other branches of art, dessert often reflects the social and cultural conditions of the society it comes from (Krondl 2011). My goal was to create a dessert that reflected the creative, do-it-yourself spirit of the Media Lab. A platter of colorful toppings – including berries, chocolate, nuts, and herbs – was placed on each table. Each diner received a cup of cream cheese mousse to use as his or her canvas. Jazz music played in the background to enhance the improvisational nature of the course.

As in Act I, I asked diners to submit pictures of their creations (see Figure 3).

Figure 32 Examples of Act IV creations

5.2.7 Act 5 – Dream

The final act was designed to invoke a sense of dreaming and fantasy in the tradition of Surrealist art (Ades et al. 2001). First, each table received a platter of assorted petit fours on a bed of brightly colored cotton candy.

Shortly after the plates were served, I changed the sonic atmosphere by playing a simple, lullaby-like song (Lullatone – *A Mobile Over Your Head*). The music acted as the trigger for a balloon drop from the floor above. To enhance the dreamlike effect, I used large, silver teardrop-shaped balloons. The balloons were filled with a mixture of helium and air so they would fall slowly. The first balloon carried a sign that read, "watch out for candies." Subsequent balloons had packets of Pop Rocks attached to them and carried signs that read, "please share me" (see Figure 4).

Figure 33 Balloon drop.

5.3 Media Scores Rendition

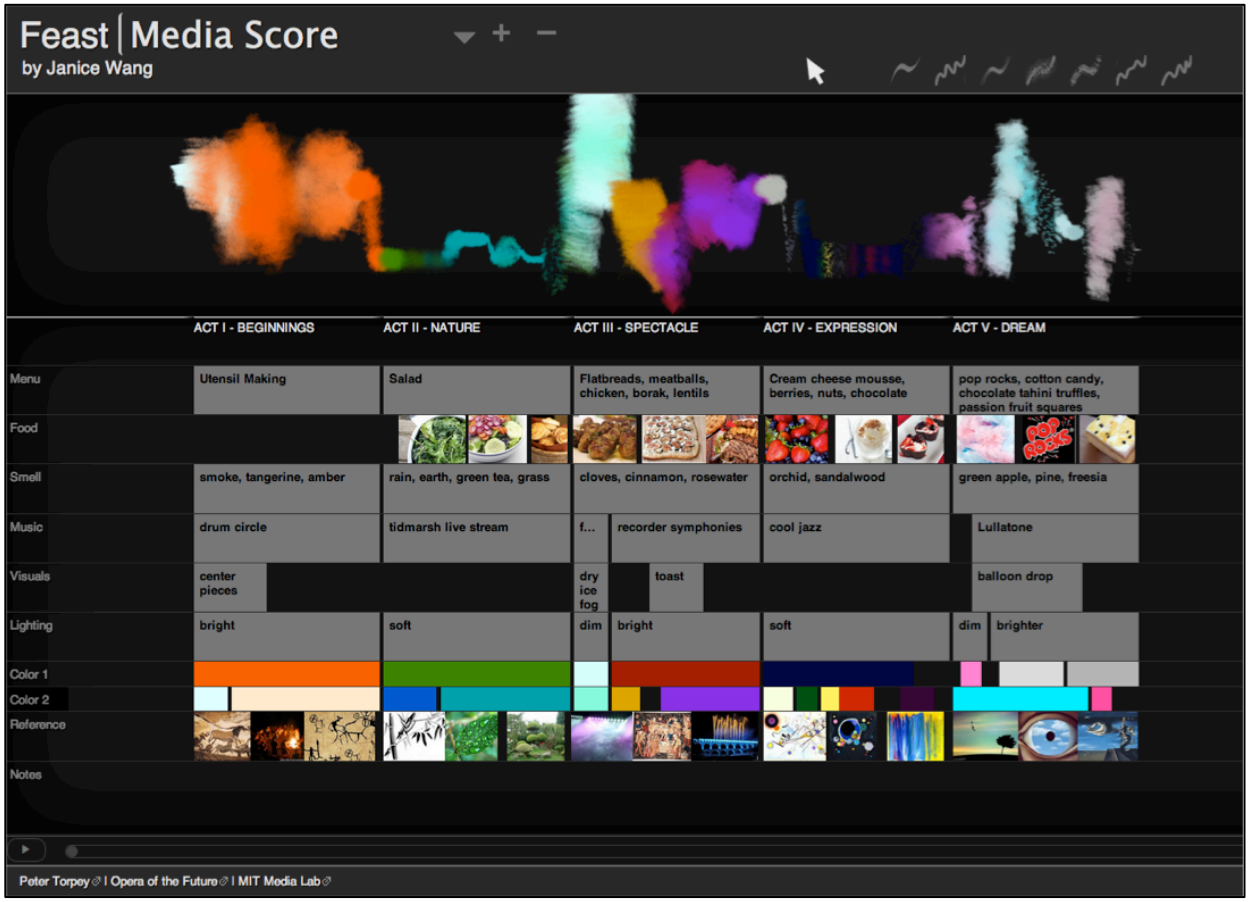


Figure 34. Media Scores rendition of the Feast.

Media Scores, designed by Peter Torpey at the Media Lab, is a tool for orchestrating multiple modalities in the creation of expressive works of art and performance. The tool serves as a traditional score in the sense of encoding the artists' vision for further performance; but unlike a traditional score, it focuses on capturing the creative intent of the artist so that multiple modalities of the artwork can be brought together. Unlike a traditional, symbolic score representation, Media Scores also conveys an expressive feeling in the score itself. The intent of Media Score is to facilitate multiple representations of the same underlying artistic idea while being a control system that can be used during live performance. The expressive parameters captured by Media Scores are: weight, intensity, density, complexity, texture, regularity, and rate.

I used Media Scores to document my intended expressive design for the Feast, incorporating the menu, food, smell, music, visuals, and lighting. The media score itself of the feast can be seen on the top line. I did not use the show control aspect of Media Scores to orchestrate the actual feast, but I wanted to capture the feeling of the feast in all its multimodal glory.

5.4 Feedback

A post-feast survey was sent to all the participants after the feast. There were 30 responses.

I asked everyone to rate how much they enjoyed each act on a scale of 1-10. The average ratings were for Act I, *M = 7.82, SD = 1.61*; for Act II, *M = 6.54, SD = 2.20*; for Act III, *M = 7.26, SD = 1.65*; for Act IV, *M = 8.00, SD = 1.30*; and for Act V, *M = 8.19, SD = 1.52*. In general, the acts with stronger narrative components and personal involvement were ranked more favorably.

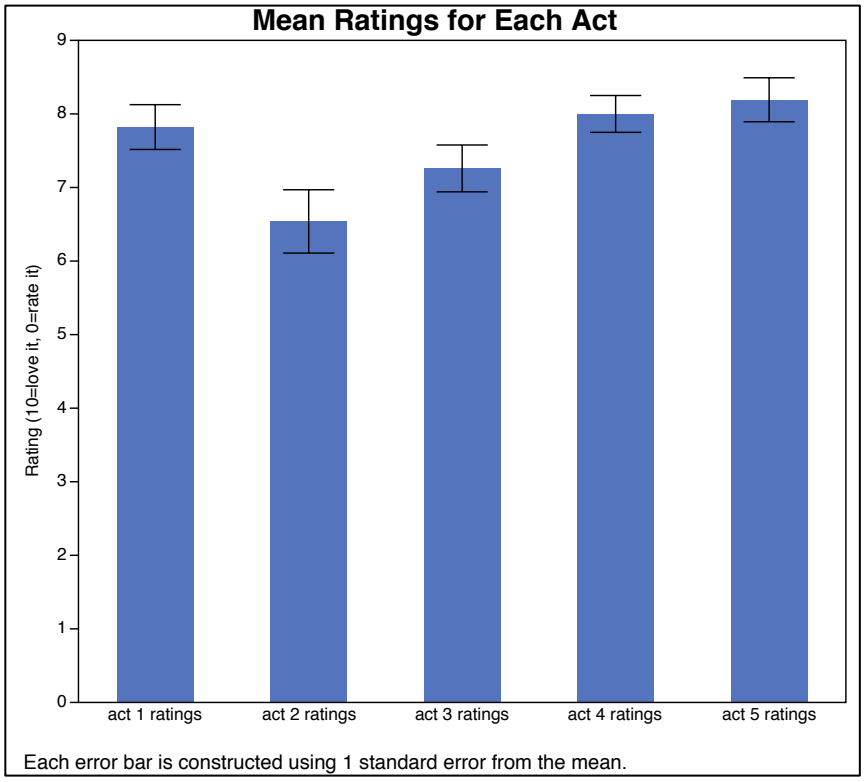


Figure 35. Mean participant ratings for each act.

According to the survey, the most memorable courses were Acts I, III, and V. In their comments, people responded very favorably to making their own utensils because it was something creative and unusual. The spectacles of the dry ice fog and the balloon drop were also received favorably. It would seem that the unexpected elements of the Feast were what caught people's attention.

Another question I asked participants was the effect of music on their experience. Most participants noticed the drumming in Act I and nature sounds in Act II, but in Acts III and IV, the number of people who ignored the music was greater than the number of people who noticed it. One theory is that as participants engaged in more actual eating and socializing in Acts III and IV, they stopped attending to the music. When music was highlighted again during the balloon drop in Act V, more people recalled hearing the music.

When asked what they wanted to see in the future, participants suggested swapping seats, lighting control (something we had cut from our plans due to location constraints), embedded electronics in the servingware, and more deliberate social interactions like puzzle solving built into the feast.

5.5 Analysis

My next step was to analyze the key components of immersive eating experiences to facilitate future designs. In order to give a coherent structure to the discussion, I've grouped the design tactics under four categories: congruent multisensory stimuli, emotion, participation, and social interaction. While these categories are not strictly orthogonal, my intention was to provide a framework for analyzing a complex experience.

5.5.1 Congruent Multisensory Stimuli

Eating has always been a multisensory experience, engaging sight, hearing, taste, smell, and touch (especially mouthfeel). In creating multisensory dishes, the aim is to add additional sensory stimuli to complement the food itself.

In Act II, sounds from nature were paired with the salad course. Hearing the sounds of birds and insects helped put participants in the mindset of being outside in the garden, where they might find green, leafy vegetables. The idea of multisensory accompaniment was taken further in Act III, where the trumpet fanfare and the dry ice fog were used to give a sense of spectacle and courtly extravagance. In addition, the dry ice was scented with rosewater to reinforce the use of once-costly spices in the food. In Act IV, jazz music and colorful toppings helped set an improvisational, exploratory mood for the dessert creation. Finally, the pink and blue colors of the cotton candy, the simple melodic music, and the Pop Rocks all conveyed a sense of childlike wonder to complement the balloon drop.

5.5.2 Emotion

As in any experience design, the emotion of the eater is a crucial component in the design process. I designed the emotional arc of the feast to alternate between high and low points to keep the participants' interest (see Figure 5).

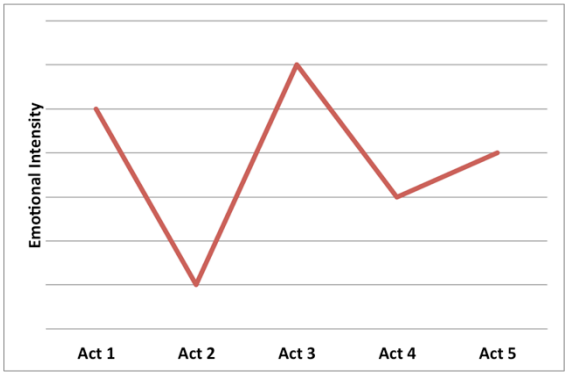


Figure 36. Emotional intensity map of the feast.

5.5.2.1 Music

The music accompanying each course was designed to influence the emotions of the diners. The drumming sounds in Act I helped build up excitement for the Feast, while the nature sounds in Act II gave a sense of tranquility. The freely improvisational jazz in Act IV encouraged diners to create, and the lullaby-like music in Act V reinforced the idea of dreaming.

5.5.2.2 Expectations and Surprise

A key element in managing emotions is the notion of conforming or breaking expectations. In Act I, I created surprise by having people open the Christmas cracker only to discover that they needed to make their own utensils. Similarly, the dry ice fog ritual in Act III and the balloon drop in Act V were both unexpected elements in a traditional dinner.

5.5.3 Participation

Another element that enhances an immersive experience is audience participation. By actively participating in the experience, participants retain a longer impression of the event. In Act I, I used the notion of discovery in the design of the Christmas crackers. The process of discovery began with participants figuring out how to open the Christmas crackers, and continued through the utensil building process. In addition, I encouraged people to be creative and expressive in building their own utensils (see Figure 2). In Act IV, I once again gave participants the opportunity to build their own design, this time with dessert. According to one participant's feedback, "people's topping styles (minimalist vs. all-in) were also clear indicators of personalities".

5.5.4 Social Interaction

Closely tied to participation is the notion of social interaction. Eating has always been a social experience (Luard 2001), and this attribute can be manipulated to create memorable experiences. In Act III, each table randomly received five out of ten possible types of dishes. As a result, participants had to share plates with other tables in order to try all the possible dishes. In Act V, participants were encouraged to get up from their seats to catch the balloons and get the Pop Rocks tied to the bottom. Once they had obtained the Pop Rocks, they were asked to share with others. An important part of the feast was the idea of individual creation followed by sharing with others, as shown by the utensils in Act I and desserts in Act IV. As a testimony to the importance of social

interaction, a point that many participants brought up in the feedback was how much they enjoyed spending time with friends sharing food and building utensils.

5.6 Constraints and Future Directions

The area of creating immersive eating experiences is an exciting one. Using the preexisting cultural associations and multisensory nature of eating, it is possible to build on those properties to create immersive experiences. It appears that, using a wide range of tactics, designers can build engaging eating experiences that do more than just feed the stomach. As an example, the Research@ML feast used multiple senses to tell a story with an emotional arc, encouraged individual expression, and strengthened social connections.

Due to last-minute venue changes for the Feast, I was unable to proceed with the original plan of including lighting changes and dynamic seating changes. In the feedback, there were multiple suggestions that the inclusion of these attributes would have made the dining experience more unusual. Another constraining factor of the Feast was that, given the size of the Feast, I had to use catered food instead of making the food in house, which limited the creative possibilities for integrating the food more closely into the whole experience.

I designed the feast as an immersive, fun experience for the lab. In that respect, the feast was better than I expected. I was surprised by the vibrant, lively, and friendly atmosphere generated by the feast generated, and most people seemed to enjoy themselves. Design-wise, Act I with the utensil building was a success. I had envisioned Tidmarsh sounds in Act II to be more calming, but the level of background noise made it difficult to concentrate on the sounds of nature. The pairing of food and sound seemed organic to me, but in the feast setting it was probably too boring compared to the excitement of the other courses. The spectacle in Act III was attention-grabbing, but not everyone had a view; for future consideration, it would definitely be crucial to consider a seating arrangement where everyone would be able to participate equally. Like Act II, Act IV was under-designed, in the sense that people were underwhelmed with the actual dessert. The concept of a create-your-own dessert implied much more than what

appeared to be a make-your-own sundae bar. One of the most consistent findings from my work is that using elements of the unusual or unexpected is key to creating a positive experience, as shown in the Act V balloon drop. With respect to sound level, a social setting will generate a high level of background noise, but novelties such as a new course or spectacle will significantly lower the sound level. Finally, in terms of logistics, I realized the importance of teamwork; having an organized volunteer wait staff was crucial to the feast's smooth execution. In fact, the volunteers felt like they were "in the know" because they were summoned via a specialized IR signal. Many of them reported enjoying the feast because they had actively contributed to the evening.

From the enthusiastic response of the participants surveyed, there is much future potential in applying immersive principles to create meaningful eating experiences. For instance, the entire process of engagement with food, from cooking to digestion, can be considered. In addition, I'm interested in creating strong emotional experiences. More targeted emotional responses – especially unpleasant responses like anger or anxiety – would be interesting to incorporate into a meal. Like theatre, the story arc of a dinner does not need to be entirely pleasant. Can we create a cathartic dinner that leaves people weeping at the end?

Food for Thought

Here is the space I'm sitting in: a garden
closed by fuchsia hedges, two sycamores,
a mountain ash, sally trees, some brambly
blackberry bushes. I note the grass is mostly
not grass at all but a tall-stemmed weed
with slim, down-covered, light green leaves.
I love the boulder with its pelt of moss,
and in one corner, low to the ground,
a patch of sheep's sorrel that I'll pick
and nibble for its cool and tart. Grass
too: I pull a blade or two and chew:
green butteriness fills my mouth. When a
poet mentions "a last dry fig," I remember
your hand holding a fresh almond in its
velvety green shell: you put the knife in
and out popped the heart you handed me:
cool crisp whiteness between my teeth.
What I like about poetry is porousness,
the way it will not fill its cracks but
seems linked in some set body-circuit
(ear, muscle, nerves, blood) with how
the brain is honeycombed, those spaces
between cell and cell where something
charged with light and riddled with affinities
is happening, where Hermes—keeper of
secret recipes—is bringing everything
to a steamy boil, is figuring things out.

- Eamon Grennan

6 Discussion and Analysis

"When from a long distant past nothing subsists, after the people are dead, after the things are broken and scattered, still, alone, more fragile, but with more vitality, more unsubstantial, more persistent, more faithful, the smell and taste of things remain poised for a long time, like souls, ready to remind us, waiting and hoping for their moment, amid the ruins of all the rest; and bear unfaltering, in the almost impalpable drop of their essence, the vast structure of recollection."

- Marcel Proust

At the end of last chapter, I identified several categories for designing food-related, immersive experiences. In this chapter, I look more specifically at the interaction between music and taste, and address some patterns that emerged from my experimental and design work. In Challenges and Pitfalls, I discuss some of the challenges in setting up such experiences.

6.1 Trends in Music and Taste interaction

Crossmodal correspondence can manifest itself in multiple forms. In my studies, I noticed several different ways in which music affects taste perception:

6.1.1 Enhancement and Suppression of Flavor

I first noticed in pop-up dinners #2 and #3 that music designed to correspond to certain flavors can either enhance or suppress those flavors. Moreover, the same music evokes different responses in different participants. For instance, for the same musical stimuli and coffee panna cotta dish, some participant reported increased sweetness while other participants reported increased bitterness. Experiment 1 showed that participants were roughly divided in terms of experiencing enhancement or suppression effects. One interpretation is that the results were simply random; further study with more trials is needed to establish reliable responses for single subjects across sensations. If people indeed consistently experience enhancement or suppression

effects, depending on the person, the question remains: is there a way to predict whether someone will experience enhancement or suppression effects?

6.1.2 Duration of Flavor

Experiment 2 explored whether the duration of flavor (aftertaste) can be influenced by musical or visual stimuli. In general, none of the stimuli had a significant effect of the duration of aftertaste. When the participants were partitioned by their preference for sweetness, the group of participants who most liked sweets experienced significantly longer flavor duration in the sweet music condition. In addition, the video stimulus, unlike the musical stimuli, partitioned participants into ones either experienced noticeable longer or shorter durations.

Controlling the duration of flavor might be difficult to implement in a practical setting, since most people are continuously moving food around in the mouth while eating (Lyman 1989). The one area where manipulation of taste duration might be noticeable is in isolated tasting situations (e.g. wine tasting), where people are trained to note the length of finish as a critical element of the experience.

In my study, I confined the food sample to a single flavor. In a realistic dining setting, the food eaten usually contains complex flavors. A direction for further study is the effect of music on a combination of flavors; for instance, could sweet music affect the balance of flavors in a sweet and sour solution?

6.1.3 Hedonic Effect

Both pop-up dinners (#2 Musical Condiments, #3 Music and Emotion) and Experiment 1 demonstrated the effect of external stimuli on food liking. Empirically, Experiment 1 revealed that different musical conditions had a significant effect on participants' food pleasantness ratings. However, a key missing element is *how* music changes hedonic food evaluations. It seems natural to speculate that music liking should be correlated with food liking, but this remains to be tested. In pop-up dinner #3, I collected participants' music preference and food preference ratings, but could not find a significant correlation between them. In Experiment 1, I did not collect participants'

hedonic evaluations of the musical stimuli, which would have shed some light on this issue.

6.1.4 Distraction Effect

Aside from liking, complexity and intensity are also key attributes in both music and food. Pop up dinners #2 and #3 revealed some interesting trends. For instance, the loud rock music in pop up dinner #3 made the popcorn dish less spicy for some participants. A common complaint was that loud music made it hard to focus on the flavor as a whole. On the other hand, when music was calming and soft, participants reported a better appreciation of the food. This appears to be an effect of music as a distraction factor to limit participants' attentional capacity for assessing taste intensity and complexity. It's been shown that numerical cognitive tasks and loud background noise both have the effect of reducing taste perception (van der Wal et al. 2013, Woods et al. 2011); anecdotal evidence from the pop-up dinners shows that music may have the same effect. This invites further study on the effect of music as a source of cognitive load; perhaps very familiar music would be less distracting than unfamiliar music, for example.

Depending on an individual's sensitivity to different sensory stimuli, the effect of distraction on taste also varies. In Experiment #2, 10 out of 24 participants were sufficiently distracted by the video stimulus such that their duration ratings during the video stimulus was a standard deviation less than their ratings in other conditions. In contrast, the group of participants who love eating sweets experienced significantly longer taste duration in the sweet music condition than the no-music condition. It's been shown that attention enhances visual contrast detection (Goldstein 2007), does it also enhance taste perception? If this is the case, then perhaps the crossmodally congruent sweet music made participants attend to the sweet taste in food such that they were able to detect it for longer periods of time.

6.1.5 Music and Texture

Another trend I noticed during the pop-up dinners was the influence of music on food texture. Over pop-up dinners #2 and #3, 6 out of 14 participants reported a change in food texture with different music. Specifically, the comments addressed how food felt creamier or smoother with certain music.

It is not a coincidence that we use the term texture to describe auditory, visual and tactile stimuli. While texture is more about the sense of touch than smell or taste, it is nevertheless a key component in eating and food evaluation. It's been shown that food texture can be influenced by auditory stimuli (Zampini et al. 2004), but to my knowledge, there has been no studies using auditory stimuli beyond the sounds of chewing or opening packages. In a real world setting, it would be much more relevant to study the impact of music on texture perception.

6.2 Challenges and Pitfalls

By reaching outside the controlled lab environment and setting up real dinner experiences, I discovered several unforeseen challenges in carrying out multisensory designs.

6.2.1 Designing for Social Interaction

No matter how well designed the experience is, people will not be eating in isolation, with full attention on the food (with the exception of a few elite restaurants, such as Sukiyabashi Jiro in Tokyo). Eating is a social activity, and people tend to socialize during dinner. The feedback from the Feast showed that participants quickly overlooked the musical stimuli when they were sharing foods and creating desserts. In Ben Houge's food opera, it was hard to pay attention to sounds coming from personal speakers when diners became engrossed in conversation with each other. In addition, some music-induced taste effects are subtle and can be easily lost. In a crowded restaurant, it will be impossible to pay enough attention to the music to appreciate a subtle change in flavor.

The goal of multisensory design is not to take away from the social function of food, but to enrich the overall experience. For instance, instead of interrupting the

natural flow of conversation and demanding the diner's attention the entire time, we can make use of natural gaps in the dinner ritual. The moment when a dish arrives at the table is a good example of when people naturally break off conversation to admire the food, and this could be a good time to introduce musical interventions. On the other hand, some senses, such as smell, can be effectively used throughout the course of a meal without interrupting the social flow, as shown in pop-up dinner #1.

Another observation is that since the additional sensory stimuli could be a point of interaction for the participants, the potential social impact of these sensory interventions should be kept in mind while designing multisensory experiences. For example, the eye masks and earplugs in pop up dinner #4 actually became a topic of discussion for participants as they shared their experiences of eating blindfolded. As I will discuss in the next chapter, building opportunities for play into the dining experience is an exciting area with much unexplored potential.

6.2.2 Unintended associations

As shown in pop up dinner #1, it's hard to be free of pre-existing personal and cultural associations with food or music. For example, the cheddar cheese dish was seen as exotic by some and familiar by others. In my experiments, I was careful to avoid using food or music that had prior meaning for participants. However, this may be hard to avoid, or just plain impossible, in designing a dinner.

This is not to say that individual perspectives can't be embraced. Like a Pollock painting or Shakespeare play, part of the charm of a great work of art is in offering meaningful individual interpretations.

6.2.3 Taking Measurements

One of the great challenges I have experienced is in collecting data from participants. For designed experiences such as the pop-up dinners, too much intrusion meant breaking the flow of the dining experience; on the other hand, leaving all questions until the end risks losing the freshness and saliency of the experience. As I proposed in the end of Chapter 3, non-intrusive and even non-conscious data collection

techniques such as biometric data would be very useful in this scenario. For instance, pressure sensors on the back and seat of a chair can measure the excitement level of a diner.

6.2.4 Designing for Individual Differences

Everyone experiences different levels of crossmodal correspondence, as shown in my experiments and popup dinners. For some people, crossmodally congruent music enhances flavor; for others, it suppresses flavor. The same stimuli can induce different responses in different people, making a uniform, one-size-fits-all design difficult. Unlike emotional effects of music, where much of people's reactions are learned (e.g. minor key is considered sad by some cultures but not by others), there is less learned behavior in sound-flavor association.

On a related note, one approach restaurants can take is to build up learned associations during the meal. For instance, if a high-pitched flute melody always appears with a citrus flavor throughout the meal, by dessert time the same flute melody might induce a citrus sensation without the diner eating any actual citrus.

I will discuss more about individual predictors in the next chapter, as I believe this is an important field for future work.

Senryu

out of chocolate
giving a trick-or-treater
canned vegetables

upscale coffee shop…
a third grader ordering
a six dollar drink

his grandmother
making onion soup
for a good cry

Polish restaurant…
a rail-thin teen requesting
low-fat kielbasa

mid-dinner
informing her husband
that he is full

asking the rabbi
what the poodle should eat
during Passover

400-pound man
hoping his weight won't appear
in the obit

a homeless man
sharing a cup of soup
with a homeless dog

on a mountaintop
a revered Kung-Fu master
ponders what's for lunch

his son inquiring
if a scoop of lime Jell-o
is a piece of fruit

Thanksgiving morning…
a vegan sculpting drumsticks
out of tofu

on Yom Kippur
their unorthodox uncle
eating foods he hates

anorexic teen
sticking a birthday candle
into a rice cake

death camp survivor
teaching her great-granddaughters
the joy of blintzes

holding two cans
a young boy asking whether
all tuna are round

his girlfriend's pantry…
canned potatoes stacked beside
fiber laxatives

an autistic girl
making sure her sixteen peas
don't touch each other

a condemned man
requesting for his last meal
brie and champagne

all-you-can-eat night…
counting how many patrons
have double chins

force of habit…
a mother of five cutting
her husband's steak

a celiac patient
willing to pay the price
for a marble rye

over lunch
three proctologists
talking shop

asking her waiter
whether French fries or home fries
are more fattening

Halloween evening…
a thin man in a cow suit
drinking skim milk

- Robert H Deluty

7 Last Words…

"Tell me what you eat and I will tell you what you are."

- Brillat-Savarin

This thesis represents an investigation into the history, design, and experimental work for the integration of music and food. In this last chapter, I briefly summarize the conclusions of the thesis work, and offer some exciting directions for further research.

7.1 Conclusions

In the course of this work, I have studied the interaction effects between hearing and taste. Collecting relevant background information in historical cultural practices, scientific studies, and artistic designs, I embarked on a hybrid course of exploration that included both experimental and design work. The study and application of crossmodal congruence is a new, exciting field. In the course of my work, I uncovered several areas that offer tantalizing clues for future work and discovery, including flavor enhancement/suppression effects, the influence of music on flavor duration and texture, hedonic effects, and the role of attention. I also discovered pitfalls and challenges involved in implementing multisensory experiences in real life outside the laboratory setting. Based on my experimental and design works, I defined a framework for designing immersive dining experiences and applied it to the Research@ML Feast that combined congruent multisensory stimuli with elements of surprise, social interaction, and creativity to explore new directions in eating experiences.

7.2 Future Directions

The work I've presented has far-reaching implications for future research and applications in the field of cooking, restaurant design, food marketing, and entertainment. However, I foresee wider applications in physiology, health

management, and social interaction. All these areas are ripe for deeper exploration, using the ideas in this thesis as a springboard for future innovation.

7.2.1 Predictors of Individual Effect

How can we predict which way people will experience crossmodal effects? According to Deliza et al. (1995), confidence in sensory evaluation, self monitoring, and sensitivity to physiological change are all potential factors in determining the degree of sensory perception impact due expectations formed by external stimuli. Experiment #2 showed that liking for sweets may be a predictor for the effectiveness of crossmodally sweet music in extending aftertaste duration. In addition, liking for the musical stimuli and how easily one is distracted by different sensory modalities may also be predictors in the effect of music-taste congruence.

Furthermore, data mining techniques to learn individual backgrounds and preferences can be a tool to better customize eating experiences. For instance, in a food and music pairing setting, someone for whom the music has a special meaning may have a completely different eating experience than someone who has never heard the music before.

The potential to create generative experience designs based on a few customized parameters is a powerful one with applications beyond restaurant design. The ability to explain, predict, and design an experience can be used for therapeutic purposes as well.

7.2.2 Social Change

I've shown that external factors can change people's hedonic response towards food. This ability for changing food preferences is a powerful tool for social change. With the rising obesity issue worldwide and the increasing environmental consequence of unsustainable farming, changing the way people eat is a critical issue. Multisensory dining experiences are not confined to elite, experimental restaurants; school cafeterias and home kitchens are places where it's most crucial.

7.2.3 Play

In Huizinga's seminal work *Homo Ludens*, play is defined as a free activity separate from ordinary life with no material interest and its own system of rules and order (Huizinga 1949). The dinner party, for instance, is a ritual that fosters play (Barden et al. 2012). I touched on elements of play in the design of the feast; the balloon drop and food sharing can be seen as a form of social play, and the utensil- and dessert-making activities can be seen as forms of individual play, as play and creativity are often intertwined. In fact, the tendency for play is so predominant that during the utensil-making act, participants quickly invented their own game of telephone (see Figure 35).

Figure 37. Media Lab students engaging in impromptu play during the Feast.

The traditional dining room is ripe for technical innovation. Playful serving ware – either by design or by embedded sensors – can promote new ways of eating as well as novel social interaction patterns. The structure of a dinner can be altered for reinterpretation. The paradigm of sharing food as social bonding can be remodeled to encourage engagement and creativity.

The future of eating – as an artistic venue, as a playground, as a tool for social change – is open like never before.

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Figures

Figure 1. A female aulos-player entertains men at a symposium. c. 420 B.C. http://en.wikipedia.org/wiki/Symposium

Figure 2. Paolo Veronese's The Wedding Feast at Cana, 1563. Note the musicians prominently in the middle of the feast. http://en.wikipedia.org/wiki/The_Wedding_at_Cana

Figure 3. Dragon boat festival celebration. http://commons.wikimedia.org/wiki/File:Dragon_Boat_Festival_in_Haiwei,_Ronggui,_2011.jpg

Figure 4. Setting for a Japanese tea ceremony. http://en.wikipedia.org/wiki/Japanese_tea_ceremony

Figure 5. A course in a kaiseki meal. http://en.wikipedia.org/wiki/Kaiseki

Figure 6. Sound of the Sea at The Fat Duck provides an auditory accompaniment to the eating experience. Photo credit Ashley Palmer-Watts.

Figure 7. The dining room at Ultraviolet. Photo credit Scott Wright of Limelight Studio.

Figure 8. Dish from Next's Childhood menu. http://jetcitygastrophysics.com/2011/10/24/the-i-ate-the-childhood-menu-at-next-restaurant-piece/. Photo credit Jeth Rollins Odom.

Figure 9. Musicians recording for Mugaritz BSO, with a picture of the dish for inspiration. http://www.mugaritz.com/contenidos/contenido.php?id=en&se=4&su=5&ap=1344923565&co=1295530945

Figure 10. The maze set-up in the Waft that Woos. http://bompasandparr.com/projects/view/the-waft-that-woos. Photo credit Ann Charlott Ommedal.

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9 Appendix

A. Pop Up Dinner 1 Questionnaire (Abstract Concepts)

1. Each course is trying to convey a concept. What do you think it's trying to say? Please write down your interpretation of each course in a sentence or two.

First Course
Theme: ?
Grapefruit, rosemary

Second Course
Theme: ?
White bread, cheddar

Third Course
Theme: ?
Asparagus

Fourth Course
Theme: ?
Mushroom

Fifth Course
Theme: ?
Coffee, cinnamon

2. Here are the concepts I had in mind when I designed the menu. Can you match them to the corresponding courses?

A. Remembrance
B. Solace
C. Routine
D. Ephemeral
E. Spring

Course 1:

(grapefruit)

Course 2:
(cheese and bread)

Course 3:
(asparagus)

Course 4:
(mushroom)

Course 5:
(coffee)

3. What was your favorite course and why?

4. What was your least favorite course and why?

5. How did you like the music? Did it change the eating experience? Did it match the food in some way?

6. Any other comments?

B. Pop-up Dinner #2 Questionnaire (Musical Condiments)

1. (Answer during dinner) Describe the effect of each musical "condiment". What flavors do you think it enhances?

First Course

Condiment 1:

Condiment 2:

Second Course

Condiment 1:

Condiment 2:

Third Course

Condiment 1:

Condiment 2:

2. What was your favorite course and why?

3. What was your least favorite course and why?

4. Can you see restaurants playing with the music they play to create different flavor impressions?

5. Any other questions or overall feedback?

C. Pop-up Dinner #3 Questionnaire (Food & Emotions)

1. (Answer during dinner) Please rate each of the following attributes for each course

First Course

Please answer two questions before eating:

1) How did the music make you feel? Please fill out the GEMS-9 scale labeled "course 1".

2) Please circle: how did you like the music? (1 = hate it, 9 = love it)

1 2 3 4 5 6 7 8 9

Please answer the questions below once you've eaten:

3) Please circle: how did you like the food? (1 = hate it, 9 = love it)

1 2 3 4 5 6 7 8 9

4) Please circle: how would you rate the complexity of the dish? (1 = not at all, 9 = very complex flavors)

1 2 3 4 5 6 7 8 9

5) Please circle: how would you rate the intensity of the dish? (1 = not at all, 9 = very intense flavors)

1 2 3 4 5 6 7 8 9

6) In your own words, how did the music affect your mood and your eating experience? Was there a change in the food and the eating experience once the music stopped?

Second Course

Please answer two questions before eating:

1) How did the music make you feel? Please fill out the GEMS-9 scale labeled "course 2".

2) Please circle: how did you like the music? (1 = hate it, 9 = love it)

1 2 3 4 5 6 7 8 9

Please answer the questions below once you've eaten:
3) Please circle: how did you like the food? (1 = hate it, 9 = love it)

1 2 3 4 5 6 7 8 9

4) Please circle: how would you rate the complexity of the dish? (1 = not at all, 9 = very complex flavors)

1 2 3 4 5 6 7 8 9

5) Please circle: how would you rate the intensity of the dish? (1 = not at all, 9 = very intense flavors)

1 2 3 4 5 6 7 8 9

6) In your own words, how did the music affect your mood and your eating experience? Was there a change in the food and the eating experience once the music stopped?

Third Course

Please answer two questions before eating:
1) How did the music make you feel? Please fill out the GEMS-9 scale labeled "course 3".

2) Please circle: how did you like the music? (1 = hate it, 9 = love it)

1 2 3 4 5 6 7 8 9

Please answer the questions below once you've eaten:
3) Please circle: how did you like the food? (1 = hate it, 9 = love it)

1 2 3 4 5 6 7 8 9

4) Please circle: how would you rate the complexity of the dish? (1 = not at all, 9 = very complex flavors)

1 2 3 4 5 6 7 8 9

5) Please circle: how would you rate the intensity of the dish? (1 = not at all, 9 = very intense flavors)

1 2 3 4 5 6 7 8 9

6) In your own words, how did the music affect your mood and your eating experience? Was there a change in the food and the eating experience once the music stopped?

Fourth Course

Please answer two questions before eating:

1) How did the music make you feel? Please fill out the GEMS-9 scale labeled "course 1".

2) Please circle: how did you like the music? (1 = hate it, 9 = love it)

1 2 3 4 5 6 7 8 9

Please answer the questions below once you've eaten:

3) Please circle: how did you like the food? (1 = hate it, 9 = love it)

1 2 3 4 5 6 7 8 9

4) Please circle: how would you rate the complexity of the dish? (1 = not at all, 9 = very complex flavors)

1 2 3 4 5 6 7 8 9

5) Please circle: how would you rate the intensity of the dish? (1 = not at all, 9 = very intense flavors)

1 2 3 4 5 6 7 8 9

6) In your own words, how did the music affect your mood and your eating experience? Was there a change in the food and the eating experience once the music stopped?

Post-Dinner Questionnaire

2. What was the most memorable part of the meal and why?

3. What was your favorite course and why?

4. What was your least favorite course and why?

5. Any other questions or overall feedback?

D. GEMS-9 Scale for Pop-up Dinner #3 (Music and Emotion)

Course 3

Instructions

When providing your ratings, please describe how the music you listen to makes you *feel* (e.g., this music makes me *feel* sad). Do not describe the music (e.g., this music is sad) or what the music may be expressive of (e.g. this music expresses sadness). Keep in mind that a piece of music can be sad or can sound sad without making you feel sad. Please rate the intensity with which you *felt* each of the following feelings on a scale ranging from 1 (*not at all*) to 5 (*very much*).

		1 Not at all	2 Somewhat	3 Moderately	4 Quite a lot	5 Very Much
1.	**Wonder** Filled with wonder, Dazzled, Moved	1	2	3	4	5
2.	**Transcendence** Fascinated, Overwhelmed, Feelings of transcendence and spirituality	1	2	3	4	5
3.	**Power** Strong, Triumphant, Energetic	1	2	3	4	5
4.	**Tenderness** Tender, Affectionate, In love	1	2	3	4	5
5.	**Nostalgia** Nostalgic, Dreamy, Melancholic	1	2	3	4	5
6.	**Peacefulness** Serene, Calm, Soothed	1	2	3	4	5
7.	**Joyful Activation** Joyful, Amused, Bouncy	1	2	3	4	5
8.	**Sadness** Sad, Sorrowful	1	2	3	4	5
9.	**Tension** Tense, Agitated, Nervous	1	2	3	4	5

E. Pop-up Dinner #4 Questionnaire (Unexpectations)

1. For each course, please rate how you like food, the presentation, and how memorable you find the dish.

First course – "cupcake"
How did you like the food? (1=hate it, 5 = love it)
1 2 3 4 5

How did you like the presentation? (1=hate it, 5 = love it)
1 2 3 4 5

How memorable is the dish? (1= will forget it tomorrow, 5 = will remember 10 years from now)
1 2 3 4 5

If you like, please write a few sentences about why you gave the ratings above.

Second course – cheese and white chocolate
How did you like the food? (1=hate it, 5 = love it)
1 2 3 4 5

How did you like the presentation? (1=hate it, 5 = love it)
1 2 3 4 5

How memorable is the dish? (1= will forget it tomorrow, 5 = will remember 10 years from now)
1 2 3 4 5

If you like, please write a few sentences about why you gave the ratings above.

Third course – red, green, and blue gels with music

How did you like the food? (1=hate it, 5 = love it)

1 2 3 4 5

How did you like the presentation? (1=hate it, 5 = love it)

1 2 3 4 5

How memorable is the dish? (1= will forget it tomorrow, 5 = will remember 10 years from now)

1 2 3 4 5

If you like, please write a few sentences about why you gave the ratings above.

Fourth course – Mediterranean inspired dips and salads

How did you like the food? (1=hate it, 5 = love it)

1 2 3 4 5

How did you like the presentation? (1=hate it, 5 = love it)

1 2 3 4 5

How memorable is the dish? (1= will forget it tomorrow, 5 = will remember 10 years from now)

1 2 3 4 5

If you like, please write a few sentences about why you gave the ratings above.

Fifth course – sensory deprivation trifle

How did you like the food? (1=hate it, 5 = love it)

1 2 3 4 5

How did you like the presentation? (1=hate it, 5 = love it)

1 2 3 4 5

How memorable is the dish? (1= will forget it tomorrow, 5 = will remember 10 years from now)

1 2 3 4 5

If you like, please write a few sentences about why you gave the ratings above.

Sixth course – "mint tea" aroma

How did you like the food? (1=hate it, 5 = love it)

1 2 3 4 5

How did you like the presentation? (1=hate it, 5 = love it)

1 2 3 4 5

How memorable is the dish? (1= will forget it tomorrow, 5 = will remember 10 years from now)

1 2 3 4 5

If you like, please write a few sentences about why you gave the ratings above.

Overall Experience

2. What was your favorite course and why?

3. What was your least favorite course and why?

4. What was the most memorable dish and why?

5. Any other questions or overall feedback?

F. Duration Experiment Sample Rating Form

Subject #: ____

Condition #:____