Sonic Delights: Exploring the Design of Food as An Auditory-Gustatory Interface

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Figure 1: Showcasing Sonic Delights at an art exhibition.

Abstract

While interest in blending sound with culinary experiences has grown in Human-Food Interaction (HFI), the significance of food's material properties in shaping sound-related interactions has largely been overlooked. This paper explores the opportunity to enrich the HFI experience by treating food not merely as passive nourishment but as an integral material in computational architecture with input/output capabilities. We introduce "Sonic Delights," where food is a comestible auditory-gustatory interface to enable users to interact with and consume digital sound. This concept redefines food as a conduit for interactive auditory engagement, shedding light on the untapped multisensory possibilities of merging taste with digital sound. An associated study allowed us to articulate design insights for forthcoming HFI endeavors that seek to weave food into multisensory design, aiming to further the integration of digital interactivity with the culinary arts.

CCS Concepts

• **Human-centered computing**; • **Interaction design**;

Keywords

Human-Food Interaction, Edible Interface, Food Design

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1 Introduction

"Sound is the forgotten flavor sense" [54]. This statement, cited in recent research on auditory experience and its impact on consumption [54], highlights the significant role sound plays in the gustatory experience – a role that remains underexplored in HCI. Prior studies on crossmodal psychology [31, 52] have demonstrated that auditory stimuli significantly impact taste and flavor perceptions, shaping eating experiences and behaviors. These effects hold potential for changing eating habits across various contexts, such as improved diet. For instance, sounds can be used to compensate for certain taste perceptions, enabling reductions in sugar or salt intake, or to create sound-taste contrasts that enhance the enjoyment of food and beverages [51, 53, 54, 56].

Recently, there has been a concerted effort to integrate digital technologies into culinary practices to generate external auditory stimuli, enhancing consumption experiences [13, 32, 51, 57, 65]. This approach emphasizes the controllability of sound-related eating experiences to cater to needs across different occasions. Notably, culinary innovators like Heston Blumenthal have introduced a novel auditory-augmented dish, "Sound of the Sea," that uses a concealed MP3 player to simulate an oceanic atmosphere to enhance the enjoyment of seafood. [31]. Similarly, sound artists have created a "Tasty Album" [9] featuring five soundtracks each corresponding to one of the five basic tastes, designed to create a crossmodal experience when eating, that blends the distinct senses of hearing and taste [62]. Progressing from a one-way flow of auditory experiences – such as with Sound of the Sea and the Tasty Album, where sound is delivered independently of the diner's action (i.e., consumption) – emerging interactive technologies have advanced the auditory-augmented food experience by offering more dynamic interactivity. For example, the "iScream!" project [64] promotes a more interactive relationship between the consumer, the sounds, and the food by actively engaging diners with auditory stimuli during the eating process [64]. However, despite these advancements, the approaches used in these existing sound-related interactive food systems primarily focus on deploying technology around ready-made food items (i.e., they are adding sound to food instead of food to sound), neglecting to view food itself as a focal material for interaction design. This is probably most evident in the fact that many of these existing systems can function independently of actual food consumption, i.e., diners can still experience digital sounds without eating the food. Consequently, a notable opportunity has emerged in the design of sound-related food interactions, specifically in reconciling the material affordances of food with digitally generated sounds [44].

This observation sparks a forward-thinking speculation: what if food could be designed to function as an autonomous audio device, capable of producing sound on its own? Such a "food device" could possibly maximize the potential to "celebrate the pleasurable and enjoyable experiences that people have with food" [16]. We believe that integrating digital technology into edible forms presents several compelling advantages, making it both an important and worthwhile endeavor: 1) Reimagine culinary engagement: allowing for more immersive and engaging interactions with food, elevating everyday meals into delightful experiences [38], It also leads to creating a dining experience that is less cluttered and more streamlined, reducing the dependence on additional devices and hardware that may detract from the aesthetic or practical aspects of eating; 2) Foster widespread accessibility: ensuring that consumers do not need specialized equipment to enjoy enriching eating experiences, making it easier to incorporate them into various settings, from casual dining to high-end restaurants; 3) Promote sustainable technologies: we present our work as an exploratory step toward reducing reliance on traditional non-edible components in food-technology interfaces. Leveraging edible electronics (EE) [49, 71] inspired by green principles [4], focusing on biodegradable, non-toxic materials to reduce e-waste while rethinking devices as food-integrated systems [49]; and 4) Advance integration research [39] rethinking devices as food-integrated systems. Our speculation also draws inspiration from the notion of the "material turn" in HCI [69] that sheds a light on the convergence of physical materials (i.e., food) with computational features, and highlights the diminishing boundaries between digital devices and everyday objects. This notion points towards a future where interactions

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with technology are seamlessly integrated into our physical world [19, 68, 69]. Through our work, we aim to contribute to this vision by incorporating food into material interactions.

In this paper, we embark on a design speculation that integrates food and auditory computing [47], resulting in a novel food system called "Sonic Delights". With a specially crafted cracker, this system serves as an integral composite of an eatable loudspeaker. The eatable loudspeaker is engineered to convert electrical signals received from an amplifier into corresponding sound waves, facilitating a concurrent experience of consuming the sound while biting into the food. We envision that the food will eventually transition into a sole auditory-gustatory interface, becoming the computer's architecture, simultaneously acting as a sensor, capturing the diner's actions (bite by bite), and an actuator, dynamically complementing the food's consumption through the progressive attenuation of sound. In other words, the food plays digital sound, and once eaten, the sound is also gone.

Our contributions through this work are threefold:

- System design: We introduce Sonic Delights, a novel auditory-gustatory interface that employs a material-focused approach, enabling to "eat digital sound". This showcases how food can be reimagined as both a sensory medium and an interactive element. Sonic Delights can serve as inspiration for developers aiming to create novel interfaces as well as culinary practitioners who want to envision new experiences for their customers.
- Thematic insights: Our study identified five themes that illuminate user experiences with Sonic Delights: These themes offer a first understanding of how auditory-gustatory interface design can shape engagement of both sound and food. Researchers can use these themes when aiming to understand user experiences of novel combinations of digital content and food material.
- Design implications: Based on the identified themes and our craft knowledge having designed Sonic Delights, we distilled three actionable design implications. These implications can be useful for designers aiming to create cross sensory dining experiences.

Ultimately, we aim to advance our understanding of how to weave food into multisensory design, aiming to further the integration of digital interactivity with the culinary arts.

2 Related Works

This section reviews related works, detailing our learnings from auditory-augmented HFI designs and extending to food electronics as I/O interfaces.

2.1 Auditory-Augmented HFI Designs

Recent research in HFI [3, 6, 10, 60, 61] has highlighted the significant impact of auditory perception on the eating and drinking experience [58]. While eating is inherently a multisensory activity involving various sounds, such as the crunch of chips or the sizzle of a steak that enhances engagement and palatability, crossmodal studies reveal a broader spectrum of auditory influence. These include sounds produced by the food itself (e.g., crunchiness), external noises (e.g., ambient noise), soundscapes, and music – all of which significantly affect perceptions of taste, smell, texture, and flavor [25, 53, 70, 72]. This raises a critical question: how can auditory stimuli – both intrinsic and digitally augmented – be controlled to benefit individuals with specific dietary or sensory needs in various contexts?

Prior works, such as the "Chewing Jockey" [32] and "Auditory Seasoning" [30] have explored the use of devices to enhance flavor perception by modulating mastication sounds. These works demonstrate the potential of auditory-augmented systems in shaping taste experiences and offer valuable insights for developing customizable flavor- and satiety-enhancing tools that leverage controlled sound stimuli in real-world applications. Beyond mastication sounds, the auditory experience of eating can extend to interactions with the food itself. For instance, "Edible Vinyl Records" [1], are crafted out of chocolate and can play music on a record player. However, the diners can eat the record only after having listened to the music, i.e. our understanding of how eating and listening simultaneously is incomplete. Furthermore, the authors have not investigated how sound generated from such food affects the user's experience, leaving a gap in our understanding of such user experiences where diners consume edible containers of digital sounds.

Recent advancements, such as "EducaTableware" [24], can generate sounds based on food's electrical resistance and eating dynamics. Similarly, "iScream!" [64] and "Sonic Straws" [66], which pairs unexpected sounds like screams with licking ice cream and drinking beverages, illustrate the potential of integrating digital soundscapes into eating. These innovations expand the scope of auditory interaction to create novel and engaging eating experiences. Furthermore, researchers have recognized the potential of atmospheric sounds in dining environments [36]. Velasco et al. [58] proposed developing Mixed Reality (MR) systems that merge real food consumption with immersive virtual environments, emphasizing the role of sound in enhancing taste and enjoyment [55]. These advancements suggest exciting directions for future research and design in HFI, bridging auditory stimuli with personalized and immersive dining experiences.

Taken together, the current landscape of HFI design acknowledges sound's pivotal role, yet often treats it as a separate entity from the food through the use of external audio devices. This traditional approach maintains a distinction between sound and food with the auditory component persisting even after the food has been consumed. However, this reveals a missed opportunity for a more holistic integration, where leveraging the material properties of food could forge a cohesive bond between sound and sustenance. To investigate this, we have delved into food electronics, believing it offers insightful perspectives on designing food as auditory computational composites, which will be discussed in the following section.

2.2 Food Electronics as I/O Interfaces

The exploration of organic, biodegradable materials in HCI [27, 41] has introduced edible composites to computational architecture. Recent developments are extending this area into devices that use only food-derived or edible synthetic functional materials that can be fully digested within the human gastrointestinal (GI) tract [49, 71]. Notably, prior works have crafted edible electronic devices from

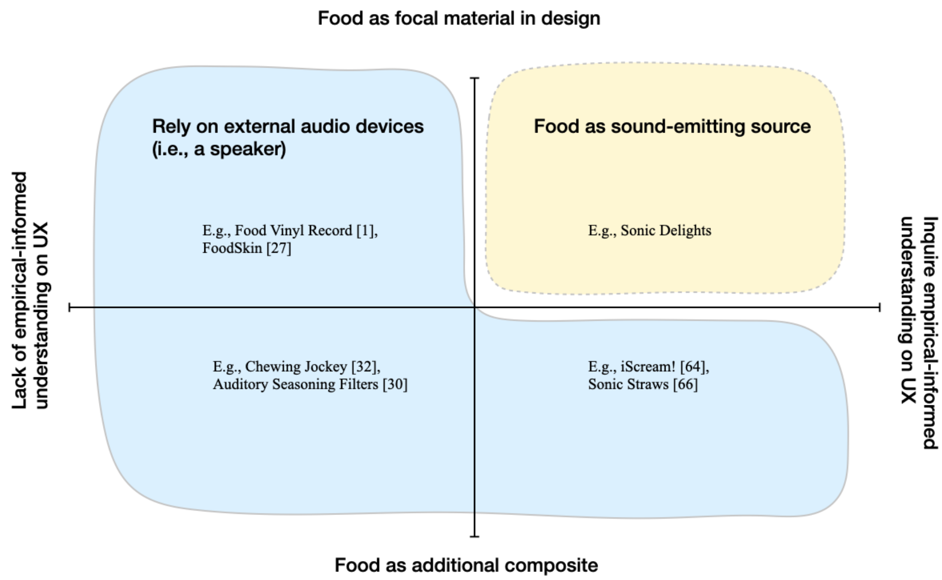


Figure 2: Plotting prior works to identify the underexplored space.

food-based materials, including 3D-printed electric circuits using vegemite [17]; supercapacitors that were made from sandwiched seaweed, activated charcoals, gold leaves and energy drinks [63]; and electrochemical sensors for health monitoring using food-grade activated charcoal and penne, cookies, and almonds [29]. These advancements showcase the potential for creating functional electronics from food substances, paving the way towards using food as comestible computational composites.

However, the focus of these advancements was not centered around dining-related scenarios, but rather on technical implementation challenges. Hence, the potential of integrating food electronics within the eating experience remains largely untapped. We noted that recent works have begun to experiment with novel ways to engage with food devices. For example, the "BubBowl" [18] enables users to interact with a drinkable display that projects digital information in coffee through bubble formation via electrolysis. Beyond beverages, "FoodSkin" [27, 28] introduces a novel interactive food experience by embedding edible electronic circuits on food surfaces. This approach allows for a broader range of interactions between the diner and the food, with the latter serving as the interface itself, aiming to enhance the engagement and interactivity of the eating experience. These innovative approaches suggest a future where food materials are not only functional electronic components but also integral parts of interactive, edible computational composites. However, prior research has not examined user experiences with these systems, leaving an empirical gap in understanding their impact and how to effectively design food as an auditory-gustatory interface. Bridging this gap could provide valuable insights for creating more meaningful and immersive eating experiences.

In summary, our review highlights the need for more research on integrating food's material properties with sound, aiming to create food experiences through auditory-gustatory computing (Figure 2). This approach promises to enhance the sensory dining experience in areas that have yet to be fully explored. Therefore, with this paper, we aim to answer the question: *How do we design food as an auditory-gustatory interface for engaging eating experiences?* To address this question, our aim in this paper was to design a system that using food, as a focal material of interaction design [67], employing food itself as a sound-emitting source, transforming the act of eating into an experience of consuming audio directly, without the need for external audio devices.

3 Methodology

Our investigation was anchored in the "Research through Design" (RtD) tradition, which positions our design of "Sonic Delights" as a reflective practice generating "topical, procedural, pragmatic and conceptual" [14] knowledge. In this way, we see our design not as a final product but as a form of "material speculation" [59] that is "at the boundary of the actual and the possible", serving as a catalyst for speculation for future HFI possibilities [12, 59].

Recognizing RtD as a complex blend being "a multitude of legitimate intersections" between design practice and research [35], our investigation unfolds across two aspects. First, we document the conceptualization and prototyping of Sonic Delights, using this process as a means of inquiry into novel interactions with food through auditory-gustatory interfaces. Second, our system acts as a research artifact to engage potential consumers in a study to draw insights into design implications, leveraging our designs to advance the future of HFI.

4 Designing Sonic Delights

4.1 Conceptual Development: Designing Food as A Sound-Emitting Source

Our work highlights the use of food as an integral material in synergy with computing processes, which diverges from a conventional approach that typically embeds external speakers into food items [64]. This urges us conceiving the idea: to create a food item that is a loudspeaker itself, and can be ultimately consumed by the user.

We hence devised a conception that places food at the forefront, designing it as an auditory-gustatory interface. To shape our design process, we set forth initial design considerations: 1) The food itself should emit sound directly, making it the central element of auditory output; 2) The food functions as the interactive interface for auditory-gustatory experiences with sound serving as an indicator to signal various stages of consumption; 3) We wanted to seek a balance between the food's palatability, authenticity, aesthetics, and its computational functionality.

4.1.1 Drawing inspiration from planar flexible speakers & initial experiments. We noticed that prior works have successfully merged everyday materials with interactive technologies, enabling them to function as both conventional mediums and modern electronic interfaces [40, 42]. Among these innovations, the design of planar speakers [34] and soft speakers [40] has paved the way for embedding auditory input/output within common materials such as paper [26], textiles [42], and homewares [45]. The underlying design principle is based on creating a magnetic field through oscillating current within a spiral circuit, similar to the voice coil mechanism in conventional loudspeakers. This circuit is placed on a diaphragm, which, when vibrated by the magnetic field, generates a range of audible frequencies [45]. These speakers double as interactive interfaces by combining sensing and actuation, acting as antennas for touch and proximity sensing through capacitance variations in response to external stimuli [45].

Inspired by these advancements, we began conducting initial experiments with food-based speakers. To start, we built a quick prototype of an audio circuit based on existing approaches [2, 37] (Figure 3). This circuit featured a low-power audio amplifier connected to a speaker. In our initial tests, we used non-edible materials, such as aluminum foil, as sound diaphragms. The foil allowed us to experiment with various shapes and thicknesses, mimicking the forms of potential food-based materials. Key insights from these initial tests highlighted differences from existing approaches and limitations of the materials:

- Unlike traditional methods like paper speakers, aluminum foil could produce sound directly without requiring an attached spiral circuit. This property allowed us to explore simpler designs and unconventional configurations.
- Thinner diaphragms consistently delivered better and clearer sound quality. Larger magnets generated stronger magnetic fields, amplifying vibrations and producing louder sounds. However, there was a limit to the material's performance: once the diaphragm reached its seemingly optimal physical and acoustic capacity, further increases in magnetic field strength or material adjustments no longer resulted in louder or clearer sound output.

Subsequently, we explored various food materials in laminar forms (Figure 4). While promising, these experiments highlighted a challenge: the audio volume was often too low to be perceptible by human ears.

4.1.2 Tackling design challenges: Consultation with sound engineers. Through our initial experimentation, we identified the key design challenges. The audio quality generated by the food was insufficient for effective interactions, as the volume was often inaudible. Additionally, the system's stability was compromised, with the uncontrollable magnet frequently damaging the fragile diaphragm.To address these challenges, we consulted three sound engineers through online and offline discussions, focusing on improving audio volume and sound quality. Based on their suggestions and prior sound theory [23], we made the following adjustments:

Firstly, we integrated an electromagnet (5V, 10 kg holding force) into the circuit to enhance control by allowing the power to be toggled on and off. Second, we added a neodymium magnet (N42, 0.7 kg pull) above the food diaphragm to strengthen the magnetic field, creating a sandwich configuration around the speaker diaphragm. These modifications represent a departure from conventional designs that typically rely on permanent magnets for the magnetic field.

This resulted in significant improvements in audio output. We hence developed a basic circuitry for Sonic Delights (Figure 5). At its core, is a "food speaker" that transforms electrical signals into audible sound waves. The speaker's primary component is a food diaphragm, etched with a layer of food-grade gold leaf that functions as the voice coil. The diaphragm was made fully of food-based material, serving as the system's sound-emitting source. The diaphragm is connected in series with an electromagnet and an amplifier. The amplifier is powered by an external power supply and receives digital audio signals via Bluetooth or a mobile device (e.g., a laptop). When a music signal inputs, it travels through the gold leaf on the diaphragm, while the magnetic fields generated by the magnets on both sides trigger physical vibrations of the diaphragm. These vibrations produce audible sound, allowing the music to be heard by the human ear.

4.2 Fabrication of the Food Speaker

4.2.1 Engaging with food materials. Our initial step in developing Sonic Delights was to select an appropriate food material and devise a fabrication method to create a functional speaker diaphragm. Our food speaker diaphragm comprises two elements: the diaphragm made out of food and a "voice coil" made from a food-grade gold leaf. As outlined by Dong [11], an ideal diaphragm should be both lightweight and stiff to enhance signal resolution and maintain consistent output sensitivity. Through our experimentation, we encountered three primary challenges in fabricating food-based diaphragms: 1) crafting a diaphragm that is simultaneously thin, light, and rigid enough for optimal sound performance; 2) ensuring the diaphragm is perfectly flat to allow for the precise application of the gold leaf, acting as the voice coil; and 3) mastering the technique of cutting gold leaf into a functional circuit, such as a spiral pattern, onto the food's surface.

Figure 6 summarizes an evaluation of various food materials and recipes, rated on a scale from 1 to 5, based on three criteria: 1)

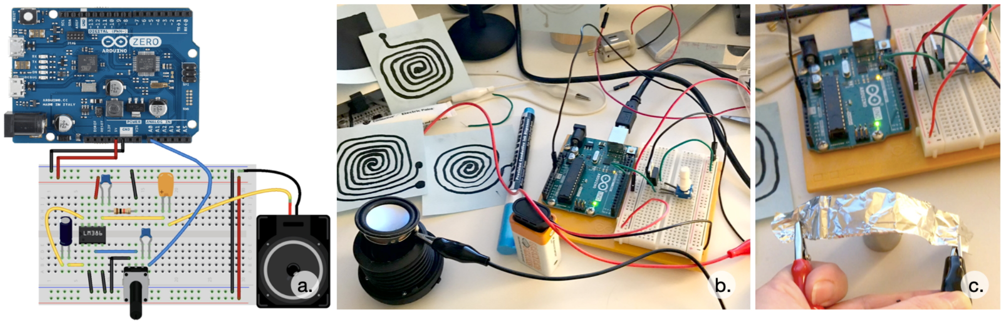


Figure 3: Prototype for audio system testing: a) Original schematic of an audio circuit featuring a low-power audio amplifier using Arduino [2]; b) Assembled audio circuit based on the schematic; c) Initial tests using non-edible materials, such as aluminum foil, as a diaphragm.

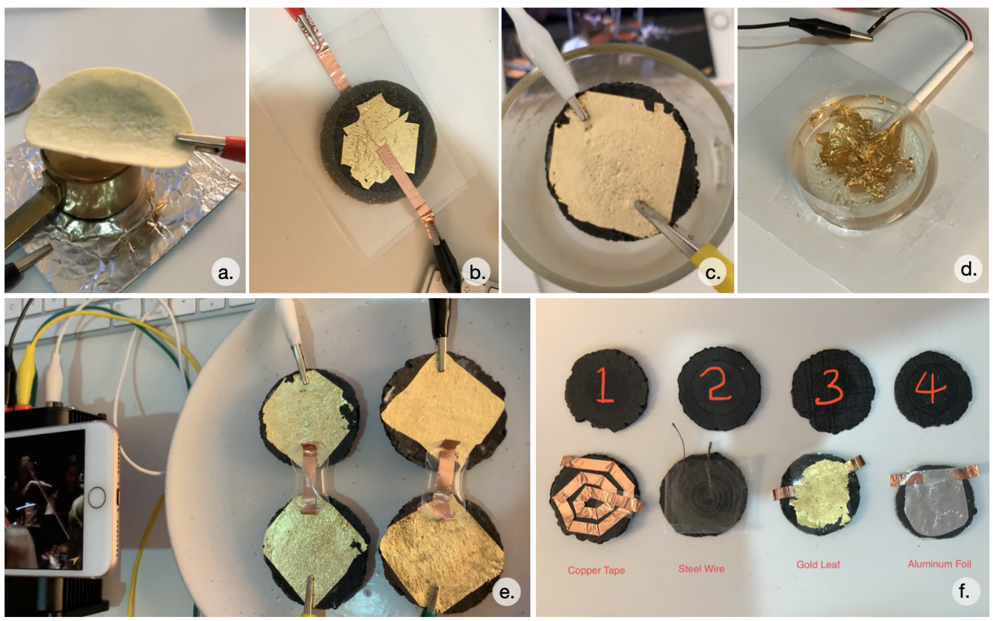


Figure 4: Early-stage experiments with food materials: a) Using a Pringle's potato chip as a sound diaphragm; b) Testing a piezo speaker using a food-based diaphragm made from broccoli powder and gelatin, inspired by the edible microphone [71]; c) Playing music using a cookie: d) Designing a jello lollipop that functions as a speaker; e) Connecting multiple cookie speakers in series to amplify sound; f) Testing various coil materials and shapes applied to edible components.

Palatability, assessing the food's taste and mouthfeel; 2) Applicability, specifying the food's material qualities and the outcomes of our tests; 3) Attainability, measuring the difficulty of handmaking the diaphragm from scratch. Additionally, we indicate the availability of commercial substitutes. Note that this list is not exhaustive but serves as an initial comparison guide to assist in identifying suitable candidates for future developments of auditory-gustatory interfaces. Our findings suggest that the rice cracker category offers the most optimal balance between palatability and applicability for our purposes, with readily available substitutes being "Ebi-senbei" and "Feng Chui Bing" crackers.

4.2.2 Crafting food speakers. The construction of our food speaker involves two key steps: making the food diaphragm, and applying the voice coil circuit onto it. We identified a range of food materials and recipes suitable for crafting the diaphragm, each with distinct preparation methods. With this paper, we highlight rice crackers as the optimal choice for our design objectives. For expedited prototyping and testing, we employed the readily available Feng Chui Bing crackers as substrates.

For the voice coil circuit, we opted for food-grade gold leaf, a material traditionally used in culinary and beverage products for decorative purposes. Gold leaf's inert nature makes it a non-reactive element and is not absorbed during digestion. We note that prior works, such as Food Skin [27] demonstrated an approach for applying gold leaf to the surface of food items, using wafer paper, wax-coated paper, and an adhesive agent like potato starch

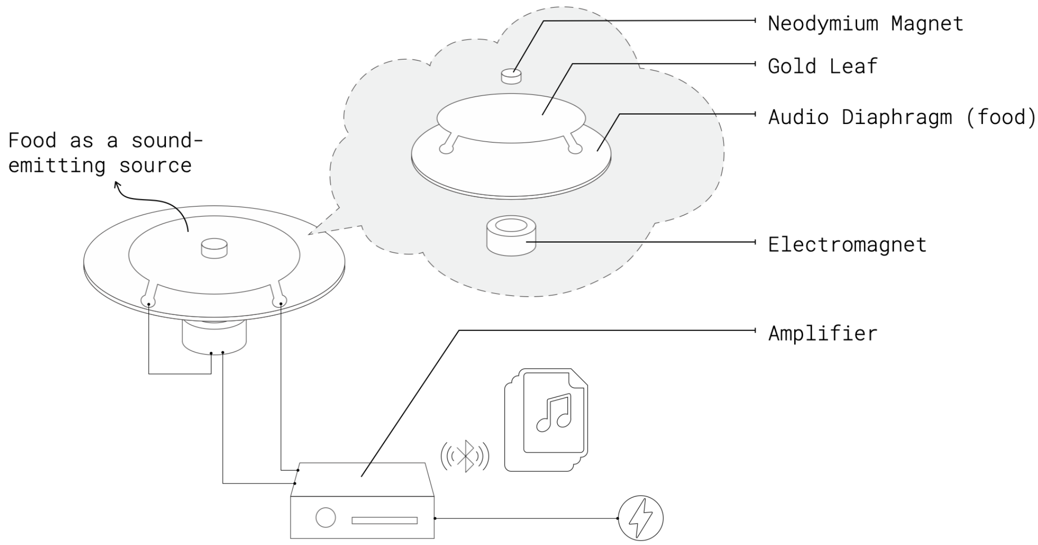
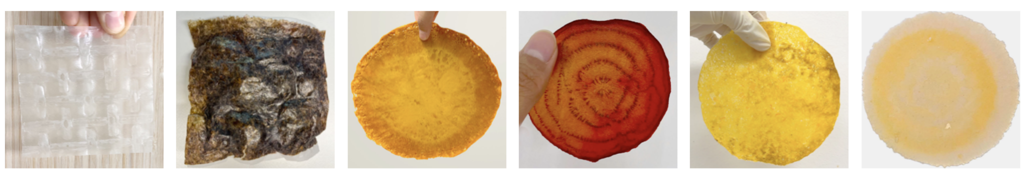


Figure 5: The circuitry and the components of the Sonic Delights system.



Category	Edible papers (e.g., Raw rice paper)	Rosted seaweeds (e.g., Nori)	Sugar (e.g., Honeycomb sugar)	Dehydrated vegetable/fruits (e.g., Beetroot crisp)	Lace cookies (e.g., Butter lace cookie)	Rice crackers (e.g., Ebi-senbei)
Palatability	☆	☆☆☆	☆☆☆☆	☆☆☆	☆☆☆☆☆	☆☆☆☆☆
• Taste	Unpleasant, bland	Savoury	Sweet	Slightly sweet	Sweet, buttery	Versatile
• Mouthfeel	Dry, pliable, chewy	Crispy, oceanic umami	Crunchy	Crispy	Crispy	Crispy
Applicability	☆	☆☆	n/a	n/a	☆	☆☆☆☆☆
• Material quality	Pliable, bendy, uneven surface	Light, friable, bendy, soft	Friable, stiff, humid	Stiff, uneven surface	Friable, rough surface	Light, stiff, smooth surface
• Testing results	Unstable performance	Unstable performance	Not functioning	Not functioning	Unstable performance	Well functioning
Attainability by handmaking	Unknown	Unknown	☆☆☆☆	☆☆☆	☆☆☆☆	☆☆☆☆
Off-the-shelf substitutions	Available	Available	Non-available	Non-available	Non-available	Available

Figure 6: A summary of food materials investigated.

to bind the gold leaf for application on various surfaces. The author highlighted a limitation of this method: during the laser cutting process, some portions of the wafer paper melted and adhered to the wax-coated paper, potentially damaging the gold leaf when peeling it off. In our work, we present an alternative approach inspired by the ancient technique of "gilding" used in artwork creation. We adopted a hybrid method that incorporates additional specialized tools and techniques to apply gold leaf to food diaphragms (Figure 7), which can effectively avoid the limitations identified in prior work. Specifically, our approach consists of two main phases: In phase 1, preparing for laser cutting, the process begins with gathering the necessary materials and tools such as crackers, honey, baking paper, paper tape, scissors, and a brush. Honey is then applied as an adhesive agent on top of the crackers, followed by placing a sheet of baking paper over them. These prepared crackers are then placed into a laser cutter for precise cutting. In phase 2, applying gold leaf to create a voice coil, the process continues with removing the laser-cut crackers from the machine and peeling away the cutout parts of the backing paper. A sheet of gold leaf is then carefully applied to the exposed areas of the crackers. The

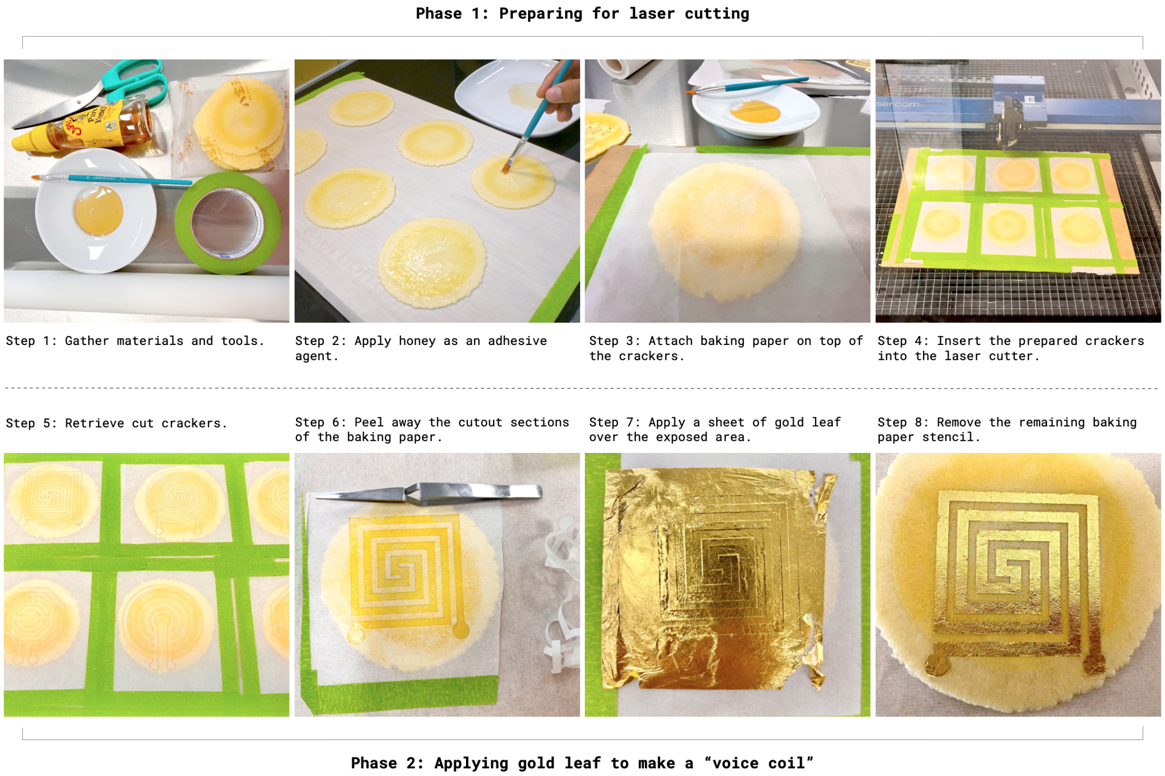


Figure 7: Fabrication process of a food speaker.

process concludes with the removal of the remaining backing paper stencil, leaving the gold leaf adhering to the intricately designed areas of the crackers. However, we acknowledge that this approach also has its limitations. For instance, the gold leaf pattern may be damaged due to accidental tearing in step 6. Additionally, because of the lack of adhesive agents binding the gold leaf, cracks may appear in the circuits, which could lead to malfunctioning of the system.

4.2.3 Design variations of the edible voice coil. Although conventional flexible speaker designs often use a spiral circuit as the voice coil, we observed that some works intentionally designed the circuit for artistic reasons, indicating that the circuit does not necessarily have to adopt a spiral form [45]. These artistic explorations pave the way for applications in sound art and installations, diverging from the norms of standard sound reproduction aesthetics. Rowland [46] identified three primary circuit topologies for flexible speakers, each with distinct characteristics and applications:

Spiral is effective for audio performance but limited to a single circuit path, with challenges in extending the connection without altering the diaphragm.

Parallel overcomes the *spiral's* limitations by allowing serial connections within the diaphragm, offering flexibility and expressive potential.

Sparse acts as a modified version of a *spiral* or *parallel* designs, hiding the circuit path for aesthetic freedom but is less precise in directing current flow, making it less efficient for audio output.

Expanding on this classification, we developed and tested various voice coil circuit designs (Figure 8). We categorized our designs into two distinct groups: The first group (G1) includes traditional configurations such as spiral, labyrinth, and parallel designs commonly utilized in planar electronics like inductors, antennas, and sensors. Group two (G2) explores artistic variations of circuitry, featuring tiling art with hexagon and wave patterns, stroke art depicting butterflies and cats, and silhouette art showcasing two human faces (a and b).

4.3 Designing a Vessel to Facilitate Sonic Delights Engagement

Inspired by the popular glass dessert and canapé bowls used in the catering industry, we conceptualized the Sonic Delights vessel in the form of a bowl with a similar glass-like design (Figure 9 - Figure 11). This vessel aims to: 1) Ensure food safety by encapsulating the non-edible components, preventing accidental consumption; 2) Act as a versatile container that supports ease of use and consumer mobility, enabling them to enjoy Sonic Delights in diverse settings, such as social events; and 3) Its unique shape doubles as resonate cavity that improves audio performance.

Additionally, we developed a storyboarded scenario to illustrate a potential application of telematic commensality using the Sonic Delights system (Figure 10). We acknowledge the vast body of prior work exploring telematic dining through various interactive devices. However, this study specifically highlights the unique experience of

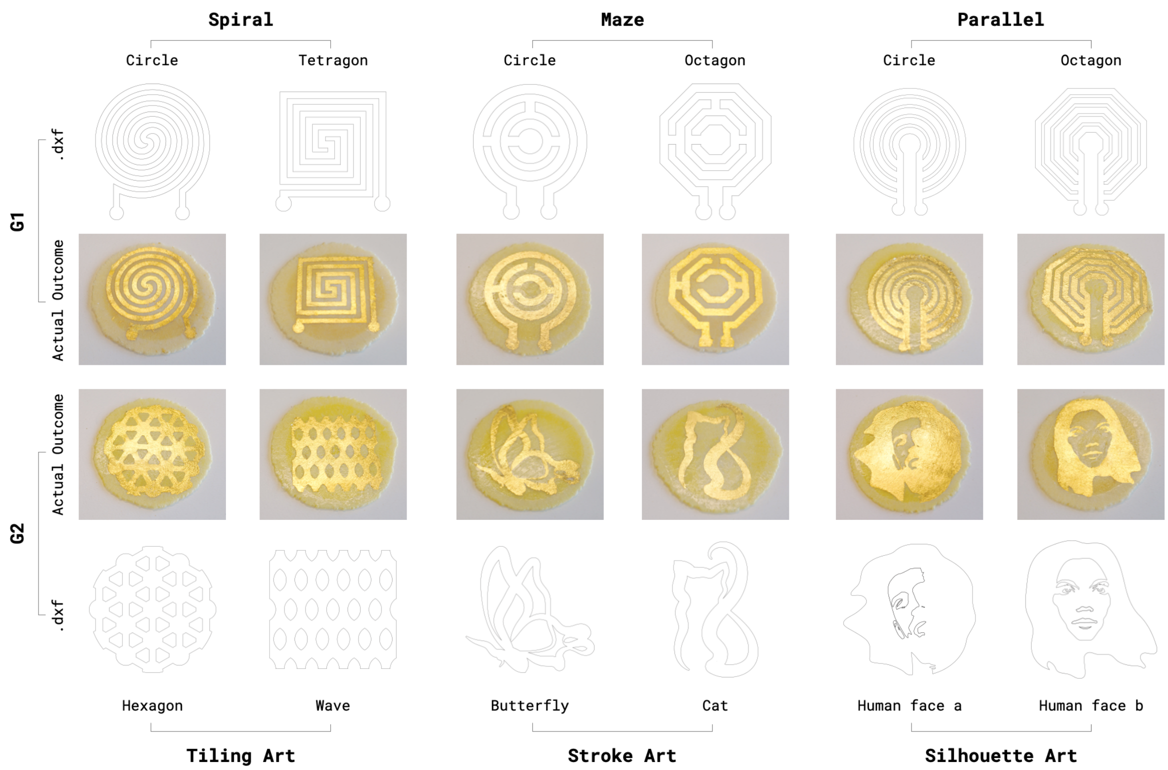


Figure 8: Design variations of the voice coil circuit, showing the Drawing Exchange Format (.dxf) drawings and photographs.

consuming a loved one's voice, aiming to evoke a deeper emotional connection through this system. That said, the storyboard serves as an illustrative example rather than a definitive context. Through this process, we anticipate that more specific scenarios will emerge as the system develops further. Future designed experience could embody the idea of "eating the sound," where consumers take a bite in response to the sounds they hear, creating a sensory interaction that goes beyond merely consuming the food.

4.4 Measurements of the Sound

Our initial assumption posited that audio performance could differ among varied circuit configurations, leading us to undertake a comparative analysis using Audacity Software's (https://www.audacityteam.org/) frequency spectrum analysis. This involved inputting samples from diverse designs to evaluate the sound quality of our food speakers. The results (Figure 12) demonstrates an audio output from 86 Hz to 21,000 Hz. Initial variations in decibels (dB) at lower frequencies highlight different handling of bass to midrange sounds by each design. Above 3,000 Hz, the output becomes more uniform across designs, indicating less variance in higher frequencies. Additionally, the plot also indicates that even artistic, non-traditional circuit designs such as human faces can achieve sound outputs comparable to traditional configurations in the higher frequency range. However, it is important to note that despite the statistical differences we observed, they did not translate into significant perceptual differences to human ears.

Nevertheless, the results shown in the plots can still provide some potential insights:

- Design Variability: Different designs are likely to exhibit different response characteristics across the frequency spectrum.
- Audio Output Levels: The variations in volume (dB) at specific frequencies indicate how each design responds to different parts of the audio spectrum. For example, a design that maintains a higher dB level at low frequencies would suggest a better bass response.
- Circuit Design Effectiveness: The plot might reveal that certain designs (like those in Figure 8, G1) perform consistently across a wider range of frequencies, while others (Figure 8, G2) have more specialized responses, which could be due to the intricacy of the circuit patterns.
- Perceptual Impact: Circuit designs that result in higher dB levels at certain frequencies could enhance the perception of those frequencies when listening to the speaker.

Additionally, we recognize that food presentation is a crucial element affecting taste perception and consumption [7]. We hope that varying circuit designs introduce another layer of visual stimuli when consuming the food speaker; this aspect will be further investigated in our study detailed in the next section.

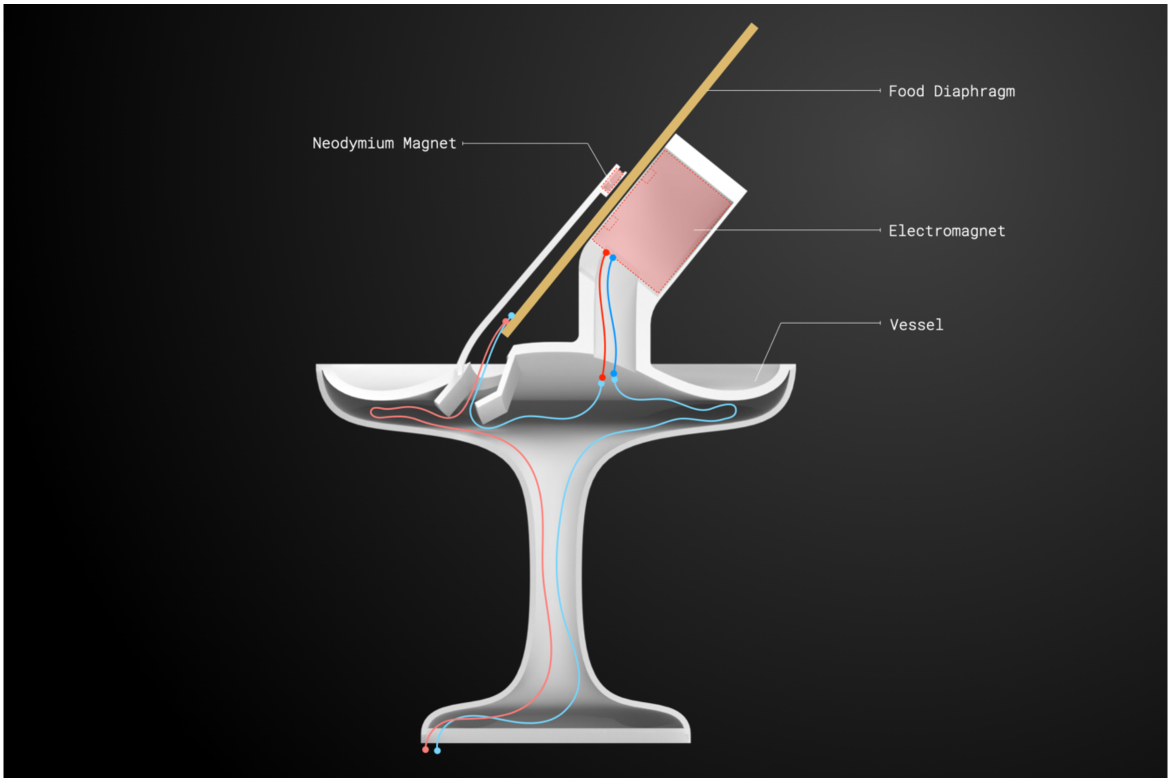


Figure 9: Section view of the vessel design of Sonic Delights, showcasing its key components.

5 A Study on Experiencing Sonic Delights

We conducted a study to understand the eating experiences with Sonic Delights. Ten participants were recruited through online advertisement and word of mouth, ranging in age from 20-32 years (M=25.8, SD= 3.99). Among them, eight identified as female, two as male, and none identified as non-binary or self-described (Table 1). Prior to the study, an online pre-study consultation was conducted to ensure no participants had allergies to the system's ingredients and to confirm that participants' hearing ability fell within the normal range. This study was approved by our organization's ethics committee.

5.1 Study Procedure

The study spanned approximately 70 minutes per session, with each participant attending three distinct phases: pre-eating, in-eating, and post-eating (Figure 13).

5.1.1 Pre-eating (10mins). Participants engaged in a warm-up discussion about their previous experiences with interactive foods, followed by an introduction to the prototype. They were then asked to select four food speakers based on their personal preferences, each featuring different circuit designs. Table 1 shows each participant's choice of coil circuit designs respectively.

5.1.2 In-eating (30mins). This phase involved participants engaging with Sonic Delights through a series of three activities designed to progressively deepen their experience. The activities included comparing eating experiences with background music and the system (activity 1, 2), as well as customizing their own eating experiences (activity 3).

The first activity aimed to establish a baseline experience of eating with sound in a typical dining environment. Participants were asked to eat crackers while listening to two audio tracks with distinct features played from nearby speakers connected to a laptop: one featuring a piece of light music [15] and the other featuring a piece of human vocal rehearsal [21]. We chose these two types of audio to initially establish a benchmark, comparing melody-driven sounds with speech-driven sounds, to facilitate distinct hearing experiences. Participants were encouraged to note any feelings, emotions, or images that emerged during the experience.

In the second activity, participants ate crackers while the audio emanated directly from the system, rather than external speakers, and were asked to describe how this experience differed from the first.

Finally, in the third activity, participants customized their experience by selecting an audio track of their choice, either from their mobile phone or an online library accessible via a provided laptop. They could pick one of the crackers they initially selected before eating to explore potential connections between sound and visual design. Their task was to create a personalized Sonic Delights experience based on their individual preferences.

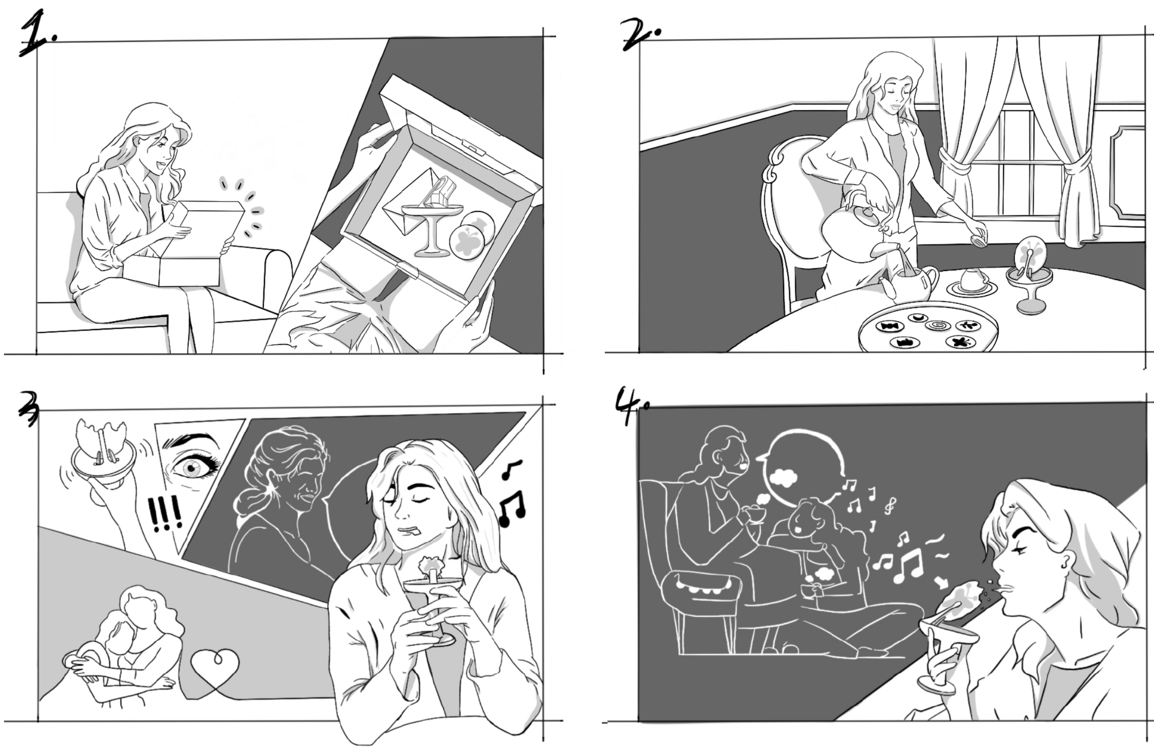


Figure 10: A storyboard themed "Asynchronous Commensality," centers around a daughter, an international student studying abroad and living alone in her flat. In this scenario, Sonic Delights becomes a bridge for connection, allowing her to share her experience with her mother across long distances and different time zones. 1) The daughter is seen unpacking a Sonic Delights kit with a secret message sent by her mother; 2) It is afternoon teatime, and she sets the table meticulously, then activates the system, poised for a deeply personal experience; 3) As she begins to eat, she gets to hear the voice message from her mother, which feels like a secret whisper bridging the miles between them; 4) This moment is not just about food but about recreating cherished memories of tea times they once shared.

5.1.3 Post-eating (30mins). After consumption, participants were interviewed about their Sonic Delights experience. The semi-structured interview encompassed both broad reflections and specific questions, such as: "*How did it feel to eat the crackers that emitted sound?*", "*How did consuming food speakers compared to eating in a typical restaurant with background music?*", and "*How did the audio influence your eating experience?*"

5.2 Findings

Utilizing a reflexive thematic analysis approach [5], three authors collaboratively coded the transcriptions, identifying emerging patterns and insights relevant to our research question. They then engaged in reflective discussions to reach a consensus on the coding. As a result, the findings were grouped into five distinct themes, capturing the essence of the Sonic Delights experience. Participants generally found the experience to be "*very innovative and enjoyable*" (P7, P9, P2), and expressed a desire "*to share it with other people*" (P9).

5.2.1 Theme 1: Human-food bond through interconnectedness between perception, consumption and personal identity. This theme illuminates the "interconnectedness" participants felt while interacting with Sonic Delights, attributed to the integrated auditory-gustatory experience where the food itself is an auditory device. Sisley (P1) noted:

> "The sound comes from the food itself, not the containers, which changes the experience for me. The food is no longer just food; it becomes another device."

Miley (P4) emphasized how the system created a link between eating and listening, which are "*normally separate activities*," by making them occur simultaneously. One participant noted that the two actions became "interconnected," as their eating behavior directly influenced "*whether the music continues*," with the cracker acting as "*a player, a speaker*." She expressed a preference for this integration, stating, "*I prefer them to work in tandem; they exist and cease together*."

Jo (P2) explained how the audio and circuit patterns complement each other, particularly when listening to a selected audio track featuring audio track featuring a vocal rehearsal, where a coach is instructing a student:

Figure 11: Design iterations of the Sonic Delights bowl.

> "I think the vocal exercise part suits this pattern well because the image of the teacher in the audio complements the pattern."

Additionally, the findings suggest that participants often intentionally forged connections between their personal experiences and the sensory inputs (visuals, sounds, and tastes) they encountered while eating. For example, when choosing circuit patterns on the crackers to accompany selected sounds, Linsey (P7) explained that her pattern selections were influenced by personal associations, noting that the parallel pattern, especially the circular design, *"reminds me of rock music, echoing some music videos I've seen with strong lines and rhythm,"* while the butterfly pattern *"evokes a calmer, more serene feeling."*

Furthermore, participants often searched for deeper meanings within the integrated sensory experience, seeking connections that resonated personally. For example, Miley (P4) commented on the visual similarity between herself and the pattern on the cracker:

> "I was wondering if the girl on the cracker looks like me [. . .] I thought about customizing the crackers to match my outfits." She associated the pattern of a human face on the cracker with her own face while eating, which stirred complex emotions. Miley described her emotional response to the visual stimuli, saying:

> "It feels like I'm eating a representation of my own face that generates sound. It's a complex feeling, partly regretful about consuming my own face." This reflection highlights how the visual aspect of the sensory experience can evoke a nuanced array of feelings, linking personal identity closely with the act of consumption.

5.2.2 Theme 2: Sensing aliveness of food through multimodal stimuli. This theme concerns how participants experienced a unique sense of "aliveness" in the food. Our finding showed that such a

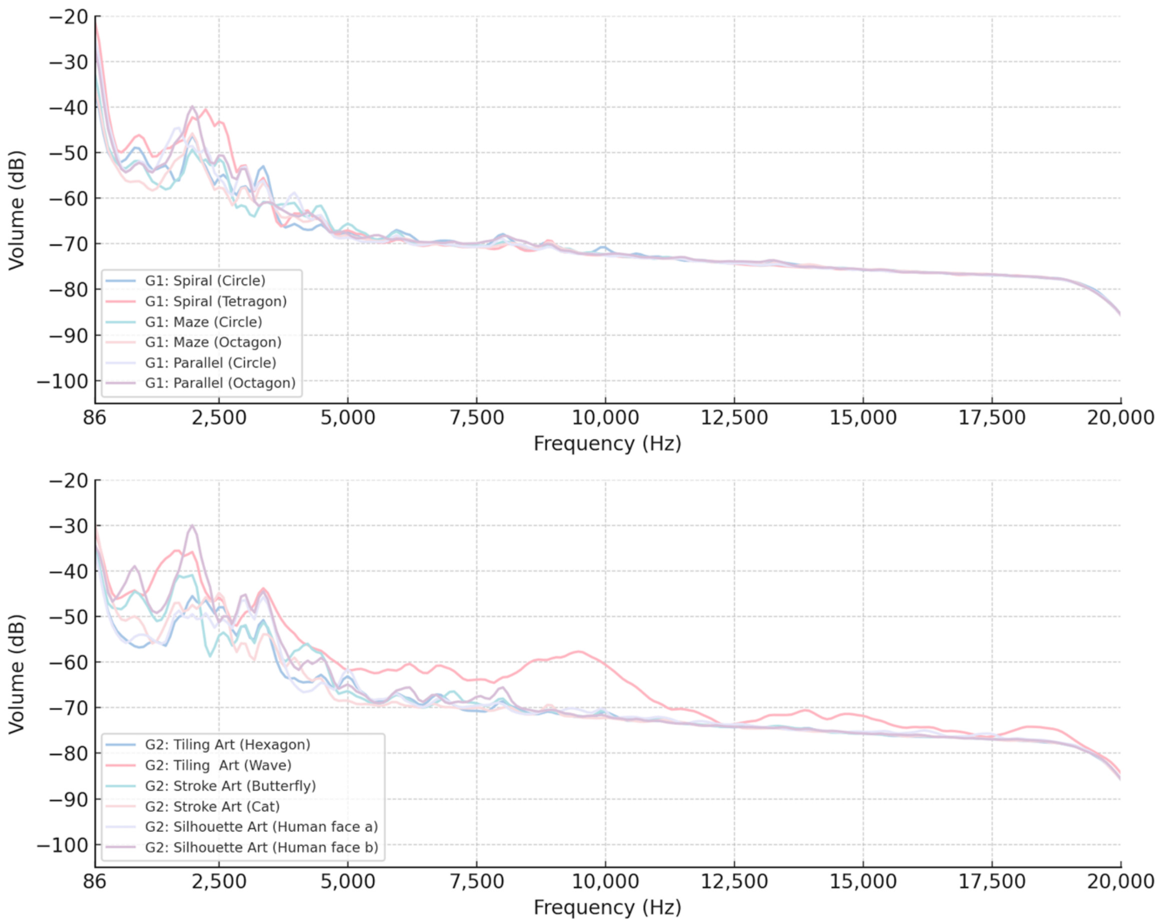


Figure 12: Frequency spectrum analysis, comparing different designs of the voice coil circuit in figure 5. Top: results from G1; Bottom: results from G2.

Figure 13: Snapshots from the study: a) A participant selecting crackers with their preferred coil circuit designs; b) The participant placing a food speaker within the system; c) The participant selecting their preferred audio content online; d) The participant engaging with Sonic Delights.

perception was primarily derived from multimodal stimuli during consumption.

Firstly, participants noted an additional layer of sensory experience when biting into the cracker, describing vibrations that added a tactile dimension to the auditory-gustatory interaction. These vibrations, along with the visible motion of the shaking food diaphragm, appears to have contributed to the perception of the food being "alive". For instance, Linsey (P7) and Harry (P8) mentioned that:

> "Seeing the gold leaf shake, it feels like both the music and food were alive. Especially when paired with my favorite music, they both felt alive." (P7)

> "I saw it vibrating and jumping in response to the cracker's movements, which is intriguing." (P8)

Table 1: Participants' demographics and their choices of the coil designs and sounds

Participant	Pseudonym	Occupation	Choice of coil circuit design on the speaker	Choice of pairing
P1 (30, F)	Sisley	PhD student in Information Technology	Butterfly; Hexagon; Human face b; Maze-circle	A pop song paired with Hexagon
P2 (25, F)	Jo	Kitchen utensil shopkeeper	Spiral-circle; Hexagon; Wave; Human face b	An audio recording of human vocal rehearsal paired with a human face b
P3 (20, F)	Pearl	Undergraduate student in Information Technology	Spiral-Tetragon; Parallel-circle; Parallel-Octagon; Human face b	A piece of traditional dance music paired with Human face b
P4 (32, F)	Miley	High school teacher	Parallel-circle; Hexagon; Wave; Butterfly	A piece of K-pop paired with Wave
P5 (25, F)	Mia	Software developer	Spiral-circle; Maze-Octagon; Hexagon; Butterfly	An audio clip from a horror movie paired with a butterfly
P6 (25, M)	Lewis	Photographer	Spiral-Tetragon; Wave; Cat; Human face b	A piece of light music paired with Wave
P7 (28, F)	Linsey	PhD student in Information Technology	Parallel-circle; Maze-Octagon; Wave; Butterfly	Background music of nature paired with Butterfly
P8 (24, M)	Harry	Postgraduate student in Information Technology	Spiral-circle; Hexagon; Cat; Human face a	Pop music paired with Spiral-circle
P9 (29, F)	Eva	Pharmacist	Spiral-Tetragon; Maze-Octagon; Wave; Human face b	A live symphony paired with Human face b
P10 (20, F)	Chelsea	Undergraduate student in Design	Parallel-circle; Hexagon; Butterfly; Human face b	A piece of ASMR (sound effects) paired with Parallel-circle

Pearl (P3) elaborated on such a sense of aliveness, suggesting an embodied experience through a cross-sensation between hearing and tactile. She described experiencing the music through vibrations, noting that *"the beats and different vibrations"* added a tactile dimension to the experience. She explained, "*The vibrations definitely helped because it's like you feel more. Music becomes not just something to hear, but something you can actually feel through your body.*"

Similarly, Eva (P9) compared the Sonic Delights experience to background music typically played in normal restaurants. She highlighted the unique experience of music emanating from the cracker, stating, *"It's an entirely different experience [...] I could feel the vibration, that's when it feels alive." She* added that this made the cracker *"more impressive,"* noting that *"everything about that cracker is more interesting and leaves a stronger impression on me."*

Furthermore, an anthropomorphic association significantly enhanced the perceived sense of aliveness, influenced by both the visual elements (such as the circuit pattern) and the auditory stimuli emanating directly from the food. Miley (P4) described her reaction when biting into a cracker designed with a human face:

> "It feels like a living face that might cry if I bite it." This statement illustrates how the visual representation on the food can evoke a sense of emotional response, suggesting that the face is reacting to being consumed.

Chelsea (P10) offered a striking description while listening to an Autonomous Sensory Meridian Response (ASMR) recording featuring various abstract sound effects, associating these sounds with a horror movie scenario by anthropomorphizing the food as if it were human flesh:

> "I liken these cookies to a living entity, as if when I'm eating them, I'm consuming its body, and it could feel pain [. . .] because when you eat them, you feel the crunchiness. like biting into someone's bone." This vivid imagery highlights the deep psychological impact that such multisensory integration can have, transforming the act of eating into a dramatically visceral experience that merges taste, sound, and imaginative perception.

5.2.3 Theme 3: Reinforcing immersiveness via exclusivity. This theme underscores how participants experienced Sonic Delights as intensely personal, fostering a sense of "exclusivity" that heightened privacy and intimacy, thereby possibly enhancing the depth of their eating experience.

> Participants like Harry (P8) noted that personalization played a significant role in this exclusivity, stating: "When you play my favorite music, I put all my intention on this 'speaker', [like] my personal speaker that can play whatever I want."
>
> Miley (P4) echoed this sentiment, remarking, "It's like my private speaker, where I can choose my favorite patterns and music."

The sense of exclusivity also arose from the necessity of close interaction due to the limited sound volume from the crackers. Pearl

(P3) described her experience as more intimate and immediate with Sonic Delights:

> "It feels more personal, closer, like the music's closer to me now than it was [. . .] I felt like the music surrounded me while I was eating the cracker."

This proximity contributed to a more enveloping and immersive ambiance. Chelsea (P10) observed a stark difference in her sensory engagement. She pointed out the contrast between the two experiences, explaining that with external music, "*I felt a significant distance between the experience of the cookie and the music [playing from the laptop].*" However, when the music came from the cookie itself, "*I felt it was around me, like being surrounded by 3D music.*"

Furthermore, we found that the exclusive immersion can be manifested through a reminiscence of participants' personal memories and subconscious imaginations.

> Mia (P5) shared: "It makes me feel that I am eating in the small room, watching the horrible movie with my friend, and we shared the food together."

> Eva (P9) experienced a surge of imaginations that enhanced her sense of presence: "When I saw the pattern (Human face a) and heard the music, it felt like I was at a concert [...] The woman in the pattern felt like the leader at the concert, with the music seemingly led by her due to the visual and auditory factors."

Linsey (P7) reflected on the profound impact of multisensory synchrony on her "*reflexive imagination.*" Allowing her thoughts to flow freely, this synchronization deepened her immersion, rendering the sensory experience more significant and memorable. This natural alignment of senses helped to seamlessly integrate her sensory perceptions, enhancing the overall impact and resonance of the experience. Linsey described experiencing "*an unnatural sense of immersion*" that occurred passively, noting, "*It wasn't that I actively chose to think about something [. . .] the music and the crackers matched well and attractive.*" She explained that this "*passive immersion" evoked vivid imagery, such as "a lawn and a peaceful lakeside environment.*"

5.2.4 Theme 4: Boosting wholeness encompassing all sensorial elements. This theme illustrates that participants viewed their interactions with Sonic Delights not merely as consuming food but as engaging in a comprehensive sensory experience that integrates various elements into a cohesive whole. They perceived the consumption of Sonic Delights akin to appreciating art, where every sensory input – visual, auditory, and gustatory – is meticulously coordinated to enhance the overall experience.

Participants compared the consumption experience of Sonic Delights to savoring a work of art, emphasizing that it involves harmonizing all sensory perceptions – visual, auditory, and gustatory stimuli – to fully appreciate the experience. For example, Sisley (P1) reflected on how the act of eating transcends its usual bounds:

> "I think at that moment, the food is no longer just food. It becomes something like an artwork [. . .and I found that] I'm not just eating, but also enjoying the whole experience."

Linsey (P7) highlighted the importance of sensory integration, which is crucial for crafting an experience that feels complete and tailored to individual preferences, enhancing the overall enjoyment and engagement with the food.

> "It's all about aligning the visual, auditory, and gustatory elements to create a personalized experience." Linsey stated.

Furthermore, the sense of ambiance and aesthetic effect played a significant role in shaping the dining experience. Chelsea (P10) echoed this sentiment, saying: *"I enjoyed the experience, it's like eating a landscape. It doesn't feel like just eating a cookie [...] It's about eating [the] atmosphere [around it], not just consuming the actual item. It's like I'm staying in and enjoying the atmosphere."* Here, Chelsea described how the setting and mood contributed to a deeper, more immersive experience, elevating the act of eating to an act of immersive engagement with one's surroundings.

Harry (P8) stressed the synergy of multiple sensory inputs – visual (the pattern and design), auditory (the sounds from the Sonic Delights system), and possibly even tactile (the texture of the food) – working together to create a more holistic and satisfying dining experience. By matching the design elements visually and sonically, the experience becomes more cohesive, encouraging continued engagement with the food. Harry also suggested the importance of consistency between visual and auditory elements, explaining, "*If the geometric pattern [referring to the circuit with the hexagon tiling pattern (8)] matches with a honeycomb-shaped food, it'd encourage me to eat more because of the consistency in visual and auditory experience [. . .] it's like a complete sensory loop.*"

5.2.5 Theme 5: Empowerment through auditory-gustatory integration. This theme captures the heightened sense of control and personal agency participants experienced when interacting with the Sonic Delights system. They noted an increased ability to manage their immediate sensory environment using the Sonic Delights system.

Pearl (P3)'s observation highlights this empowerment, as she describes how the system allowed her to control the continuation of the music based on her actions with the food. She highlighted the sense of control provided by the system, stating, "*It feels more within my control. When I stop eating, like when I set the biscuit aside, it's entirely up to me to decide if I want to continue hearing the music or not.*" Pearl also added, "*If I choose not to listen, I can simply move it away [. . .or] I can just stop [eating] by myself,*" contrasting this with the first activity where "*the music is more distant, so anyone could stop it.*"

This direct control over the auditory output linked to their eating actions contrasts with more traditional setups where soundscapes are ambient and not influenced by individual interactions. The ability to continue or stop the music by simply choosing how and when to eat adds a layer of interactivity and personalization that traditional dining experiences lack.

The theme also reveals the desire for customizable experiences in entertainment and dining. Being able to dictate the stopping of the music allowed individuals not only to control the digital outputs but also to tailor these experiences to fit their mood, setting, or personal preference at any moment. This capability is particularly valuable in environments where background noise can be distracting or overwhelming, providing a sanctuary of tailored sensory input that aligns with the individual's needs. Miley (P4) described the experience as "*a customization process*," explaining, "*I can decide when the music stops, like having my own private speaker.*" He added, "*Sometimes I want to turn the background music off because it can be noisy and unsettling.*"

6 Discussion

From the above insights, while participants expressed positive feedback about Sonic Delights, we now highlight the valuable critiques they provided for future optimization. For instance, participants noted challenges with the food speaker's durability, as connections occasionally disconnected during use. They also suggested incorporating more modularity to allow for customization, enabling consumers to personalize their experiences. Additionally, participants highlighted the need to improve the palatability of the food speaker, focusing on expanding the range of tastes, forms, and ease of consumption. Taken together, these participant insights, together with our craft knowledge of having designed Sonic Delights, allows us to now present three implications for design to inform future developments of auditory-gustatory interfaces.

6.1 Cross-sensational Experience via Material Interactions

The themes emphasize a cross-sensory experience by blending material elements (visual and gustatory stimuli from food) with digital elements (auditory stimuli), creating a cohesive and holistic experience. This integration intensifies emotional engagement, making the eating experience more intimate and memorable (theme 4 and theme 5). This material interaction with Sonic Delights, aligns with Jung and Stolterman's [22] argument that HCI design can be enriched by emphasizing form alongside function, incorporating materiality into design. While this approach opens possibilities for innovative products that go beyond current user needs, some sensory qualities – such as physical sensations and material sentiment – are still underexplored [22]. Sonic Delights addresses this by considering the system's visual, physical, and temporal aspects, as well as real-world perception for a multisensory food experience.

6.1.1 Design implication 1: Incorporate the aesthetic qualities of the system's materials with digital outputs to enhance multisensory engagement.

The findings indicate the potential to enhance eating experiences by coordinating material and digital stimuli in the design of multimodal interactions. This potential addresses the question of "when and how to merge multiple modalities" in multimodal interaction designs, as raised by prior research [48]. In our case, material stimuli were primarily related to the gustatory qualities of foods, including visuals, textures, and tastes, while digital stimuli were derived from sounds. The study observed that participants tend to have certain expectations when perceiving patterns on Sonic Delights, mapping visual stimuli with their personal experiences and memories, and imagining a taste that corresponds with the visuals. This suggests that designers can utilize the aesthetic language of the system's form (e.g., pattern), taste (e.g., sweetness), and texture (e.g., crunchiness) to pair with audio outputs, creating a rich eating experience across multiple modalities. Designers must consider the material expressiveness and storytelling of food within the eating experience, making it immersive and meaningful.

The finding also aligns with recent studies on multisensory integration [7], demonstrating how researchers can leverage emerging technologies for cross-sensory stimuli to create an environment where all sensory inputs (taste, smell, sight, sound, and touch) are integrated, thereby enhancing the overall enjoyment and appreciation of the meal. The findings from Sonic Delights suggest that designers should consider multiple sensory stimuli in future food designs. For instance, in addition to visual, taste, and audio stimuli, the design of Sonic Delights enabled tactile stimulation through vibrations from the sounds, which could be synchronized with events in real-time eating, thus enhancing the multisensory engagement in HFI.

6.2 Personalization of Multisensory Experiences

Our themes highlighted the benefit of incorporating customization into multisensory experiences: connecting personal identity and past experiences (theme 1), facilitating exclusivity (theme 3), and empowering the consumer in multisensory experiences (theme 5). Understanding that users value the ability to modify their sensory experiences suggests that future designs could benefit from the inclusion of customizable elements that users can adjust according to their individual needs. By allowing for customization on a multisensory level, a system can bring elements of personal identity and self-expression into daily eating actions, potentially enhancing the emotional and psychological depth of the experience.

6.2.1 Design implication 2: Consider real-time adaptation of sensorial stimuli to reinforce emotional association within the food interactions.

The above insights suggest a design implication that future designs could consider adapting crossmodal outputs in HFI design to enhance emotional engagement. In general HCI design, the consideration of user diversity plays an increasingly important role, as users differ in their perception and utilization of technology [50]. Prior research has defined crossmodal interactions as perceptual processes by which information is transferred between the senses, and influences each other [33]. Therefore, it has been argued that it is crucial to consider these aspects and build interaction systems capable of supporting and reacting to changing user wishes and needs by "providing adapted capabilities to the user of a system" [8] on a multisensory level.

Our research explored edible artefacts that may result in multisensorial interactions. For example, matching design elements visually and sonically, the crossmodal feedback in the Sonic Delights system created a more cohesive experience, encouraging continued engagement with the food (theme 4). The findings suggest the significance of allowing consumers to take control over their preferred sensorial outputs to match their chosen food, pairing these with interpreted meanings and their present moods.

6.2.2 Design implication 3: Leverage dynamic system features to create an anthropomorphic interaction for enhancing personal attachment.

Jameson argues that personalization encompasses other features besides adaptation to the individual user, such as "anthropomorphism" [20], where the system exhibits human-like features, like a depicted face, for input or output and lifelike behaviors. This anthropomorphized aspect aligns with prior HCI research on shape-changing interfaces that proposed "expressive parameters" based on kinetic attributes, drawing out specific traits and qualities from certain movements [15]. For instance, rapid oscillating movements might be reminiscent of "agitation" or "enthusiasm" [43]. Our themes indicated that participants often interpreted the food speaker as if it were alive, attributing anthropomorphic characteristics to the food items (Theme 2). The rhythmic vibrations and motions of the food speaker reminded participants of various emotions or traits, with one describing a cracker as a human face that would cry if bitten, or how eating the cracker would evoke vivid imagery of biting into human bones. We noted that such anthropomorphic experiences appeared to foster deep emotional bonds, highlighting the significant psychological impact that such multisensory integration can have.

The above insights suggest that by intentionally embedding human-like traits within the design of digital-food integration, it might be possible to deepen the emotional ties diners have with their food. Also, allowing consumers to customize the presentation of the food items that connect to their personal identity, or pair other sensorial stimuli (e.g., audio) with the dynamic motions of their food to evoke varied emotional associations, can enhance the overall food experiences. This implication also connects with the future direction of HFI that calls for anthropomorphized food interactions, intending to bolster customer loyalty by establishing an emotional bond between consumers and food items [10]. Additionally, we note that one of the biggest challenges is evoking complex emotions, like regret or discomfort, when consuming items that feel living or human-like. Future HFI designs should take this into account and thoughtfully address these emotional aspects.

Taken together, the insights gained from our design practice and study could contribute to HCI in a broader sense by demonstrating how Sonic Delights leverages sensory augmentation to create immersive, emotionally engaging experiences through the integration of material (e.g., taste, texture) and digital (e.g., sound) stimuli. We emphasize the value of personalization, allowing users to adapt sensory inputs to their preferences, fostering emotional connections. Additionally, incorporating human-like traits into food-based interfaces highlights the potential of anthropomorphism to enhance engagement and resonance. These contributions open new possibilities for HFI and sensory interface design, focusing on multisensory integration, user adaptation, and emotional engagement.

7 Limitations & Future Works

Our exploration of the auditory-gustatory interface is still in its early stages, with findings highlighting key opportunities for future research in multisensory integration, personalization, and anthropomorphism to enhance engagement and emotional connection in food experiences. Integrating material properties (taste, texture, visuals) with digital elements (sound, vibration) could create more immersive interactions, while allowing users to customize sensory outputs may foster deeper emotional engagement. Additionally, embedding expressive features in food-based interfaces can strengthen emotional attachment, though designers must carefully balance engagement with potential discomfort.

While Sonic Delights demonstrates the potential of an edible sonic interface, its current design still relies on non-edible components such as amplifiers, magnets, and wires. This study marks a first step toward fully edible and digestible alternatives, paving the way for future research on self-contained, food-integrated sound systems. Additionally, the study was limited to a small range of food items and audio stimuli, restricting the creative potential of edible interfaces. Expanding the variety of food materials and structural forms could enable more diverse and sophisticated interactions. Moreover, this study focused solely on sound, leaving other sensory modalities – such as touch, smell, and visual cues – unexplored. Future research should examine how these elements can be integrated to create a fully immersive multisensory dining experience.

8 Conclusion

This paper introduced Sonic Delights, a novel system that reimagines food as an auditory-gustatory interface, integrating taste and sound to enrich dining experiences. By positioning food as a core material for interaction, this work demonstrates its potential as both a sensory medium and an interactive interface. Through the design and study of Sonic Delights, we explored how cross-sensory integration can deepen HFI. Our findings reveal opportunities to enhance dining through the integration of material and digital stimuli, supporting multisensory engagement, real-time adaptation for personalization, and the incorporation of anthropomorphic traits to foster emotional connections.

Our work advances the concept of food as a dynamic computational material, redefining it as a multisensory interface for interactive experiences. By blending auditory and gustatory elements, Sonic Delights highlights the untapped potential of food in HFI and lays a foundation for future research into engaging multisensory dining experiences.

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