FlavorDesigner App: Capturing Multisensory Experiences and Crafting Personalized Flavors for Cueing their Recall

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Food experiences integrate multisensory bodily experiences within social interactions infused with rich emotional meaning. This makes food a promising material to be leveraged in the design of novel interactions. However, this richness also raises challenges for food-based design, as current technologies for capturing food experiences have limitedly accounted for their multisensory qualities. We present the design of FlavorDesigner app, a mobile application aimed to support the capture of multisensory food experiences and the crafting of personalized flavor cues to support their later recall. The app interface was evaluated through workshops with 12 participants. Findings outline richer understandings of capturing multisensory experiences, both live and remembered, vocabulary to inform conversations about them, rationale for our app design, and three implications for design and design research including evocative representations for capturing taste and smell; interactive, engaging and valid sensory evaluation scales; and new classes of technologies for food-based multisensory interactions.

CCS CONCEPTS **•Human-centered computing ~Interaction design ~Interaction design process and methods ~User centered design** •Human-centered computing ~Interaction design ~Interaction design process and methods ~Participatory design

Additional Keywords and Phrases: Human-food interaction, Design tools, Food Experiences, User Experience, Multisensory Design, Flavor, Smell, Taste, Texture, Memory

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1 INTRODUCTION

Francesca is tired. Today is their 45th wedding anniversary - the first she will be celebrating alone. She is holding a beautifully wrapped small box, delivered from the new shop in her town selling unique made-to-order gifts. This unexpected present is from her late husband with one simple note: "remember". So many shared experiences that she would love to relive. While she recalls details, their vibrancy is fading away with each year that passes. Gently she opens the box to find a delicate pod held by a small silver spoon. The pod is soft and white-cacao marbled, with purple flakes. As the pod bursts in her mouth, she is taken back 45 years in one bound to the Tuscany summer evening of her wedding day, sharing the heart shaped tiramisu cake with her husband. She could feel again the silky richness of the white mascarpone cream coating her mouth. Oh, and here it is: that tantalizing bitterness of the sprinkled cacao together with the sweetness of the almond biscotti after they have been dunked in the unmistakable caramel nutty flavor and apricot-like aroma of the vin santo. While tasting the dry lavender flakes in her mouth, she could almost smell the evening air filled with the intoxicating perfume of the blooming lavender fields over the Pisan hills. As Francesca closed her eyes she felt again the gentle evening breeze touching her face while carrying over that mandolin song together with people's chatter, laughter and her pure joy.

This vignette depicts an imagined near-future scenario [15,96] where users like Francesca and her husband can engage in novel food-based user experiences supported by 3D printing technologies for the delivery of personalized flavor-based memory cues. The growing body of work on Human-Food Interaction (HFI) has focused mostly on designing-around-food to support social experiences of food sharing, albeit less so on designing-with-food and its focus on design for novel user experiences explicitly integrating eating [42]. This less explored strand of interaction design research has brought to the foreground the bodily and emotional aspects associated with the act of eating, while focusing on novel design of technologies to stimulate or augment the senses, but also to support emotionally richer experiences including memory recall. By leveraging not just sight, hearing and touch, but also taste and smell, eating experiences are excellent candidates for the exploration of how multimodal sensory stimuli can be integrated in design. Here, we agree with Velasco and Obrist's [92,93] definition of *multisensory experiences* as designed experiences with rich sensory elements intended to stimulate multiple senses. However, most HFI research has focused mostly on unimodal rather than multisensory experiences and we know little of how such multisensory food experiences in general, and those of significant personal events may be *captured* and then used to *create flavor-based memory cues* to support later recall of such events. While visual and audio modalities are commonly used for both capturing experiences [56,80] and for cuing their recall, flavor as a material embedding taste, smell and touch stimuli has been less explored in interaction design [39,40,58], despite its ability to elicit strong emotional recall [46,62]. Indeed, prior work exploring relations between flavors and emotions [38], and flavors and memories [39] has shown the value of co-designing personalized flavors, and of 3D food printing technologies [39,40] to support emotional experiences and memory recall.

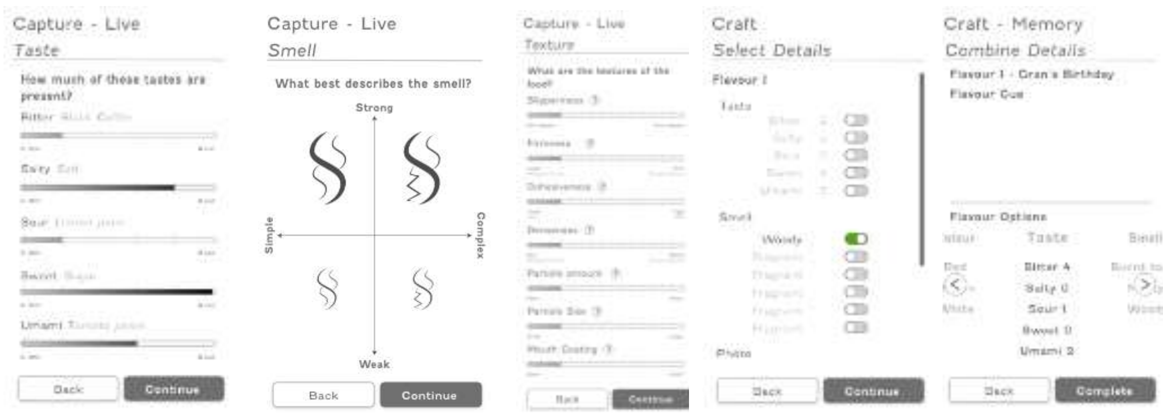

Figure 1 Two of the FlavorDesigner app's main functionalities of capturing live and remembered multisensory experiences through taste (left), smell (left-middle), and texture (middle); and of crafting flavors to cue recall by selecting memorable experiential aspects (right-middle), and integrating them in flavor-based memory cue (right)

However, such emerging work still relies strongly on designers' facilitating role, rather than being user-led. Addressing this limitation is particularly timely, given the growing interest in mass-personalization of products and services [60] from cards and clothes to potentially flavors, capturing the essence of precious memories that we may like to revisit for reminiscing later in life. We need however new tools to capture the richness of multisensory experiences, and for using such information to support users' design of flavor-based cues. For this, we can build also on the body of work in food sciences for the development of robust scales to assess multisensory experiences [14,17,28,34,59,89]. The value of such scales for informing the capturing of, and designing for multisensory experiences has been however limitedly explored in interaction design. To address these gaps, we aim to explore new ways to capture multisensory aspects of food experiences. For this, we report the interface design and initial exploration of the FlavorDesigner, a mobile application supporting the capturing of multisensory food experiences and the crafting of personalized flavor cues for later recall. To address this aim, we focused on the following research questions:

- How can users capture the various aspects of their multisensory experiences?
- How can users be supported to design their personalized flavor-based memory cues?
- What design implications and tools can support such capture and design for multisensory interactions?

The main contributions of this work include (i) in depth understandings of the different aspects for capturing multisensory experiences, both lived and remembered, and vocabulary to inform conversations about them, (ii) novel design implications and tools for capturing and designing for multisensory user experiences, and (iii) the interface design of FlavorDesigner app illustrating some of these implications and tools (Figure 1) (see supplementary material for the complete list of wireframes).

2 RELATED WORK

To support the design of the app we have drawn from prior work on conceptualizing user experience and its multisensorial aspects, as well as on how these aspects are also reflected in remembered experiences. We also reviewed HCI approaches and methods supporting design for multisensory experiences. Finally, we extended our related work by looking at food science research and in particular sensory evaluation, and their range of methods for capturing multisensory food-based experiences.

2.1 User Experience: Multisensory & Contextual Aspects of Lived and Remembered Episodic Events

This section outlines key aspects of user experience, both lived and remembered, while focusing on their content, and modalities for capturing such content. In terms of content of lived experiences, this is rich in sensory, emotional, and cognitive aspects, as well as situated and temporally framed [10,45]. Forlizzi and Battarbee's [32] framework for user experience can be extended to include also interaction with food. In this respect, previous work has emphasized the potential of food to support narrative experiences [12,26,43,93], as well as their emotional [37,48 or ephemeral qualities [28]. For instance, HFI research has shown that users can be sensitized to different food qualities such as the connection between bitter tastes and negative emotions [36], or to the temporal decay of taste experience in the mouth [28]. Awareness of these qualities provides new opportunities to interact with one's own body as well as others, for example through self- and co-regulation of emotions [39,48]. A more rigorous exploration of experiences' content involves categories such as event, time, place, emotions, thoughts, and perceptual/sensory aspects that have been advanced in memory research for capturing the structure of *episodic memories* (defined as those of everyday events that occurred at specific place and time, with duration shorter than 24 hours [57,70]). Thus, episodic memories are in fact remembered everyday experiences and when these involved interaction with technology, they can be also seen as user experiences. Indeed, both user experiences and episodic memories are discrete events [64] that share similar content categories including specific and rich perceptual or multisensory aspects, alongside contextual ones such as spatio-temporal and social aspects where the original event took place.

With regard to modalities of capturing their content, most lived experiences have been captured in audio-visual format for instance through lifelogging technologies, or textual format through self-reporting, albeit less attention has been paid to capturing other sensory aspects such as taste and smell. To this end, a range of technologies have been explored with respect to food-based experiences, such as 3D food printers [36,38]. The combination of food with visual media has been also explored through both traditional screens [93] and virtual reality [43]. Despite this potential of food as a resource for design, HFI research on designing with food has focused mostly on unimodal experiences using for instance chemical or electrical tastants for stimulating taste [68], or VR technology for augmenting it [65] in order to influence taste perception towards playful or healthy eating.

In contrast to unimodal experiences, design for multisensory ones usually involves 3D printing technologies targeting flavor stimulation [38,53] for both hedonic and emotional experiences. This is not surprising, given the extensive body of work in food science [24], psychology [30], and linguistics [52] showing the link between food and emotions, be them of present events or of remembered ones, i.e., emotional memories. In terms of episodic memories, most of their cues have been predominantly in audio-visual modalities such as photos [80] or videos [56], although emerging efforts aim to integrate emotional arousal within cues [73,84,87]. However, flavor-based cues have been limitedly explored in interaction design [39,40,58], despite the value of smell and taste for memory recall [46,62].

To summarize, user experience is a complex construct of key importance in interaction design, and the growing efforts to conceptualize it have converged towards a set of experiential aspects such as bodily, emotional and temporal ones. When we extend its temporal perspective from present to remembered user experiences, we can also draw from memory research to identify additional contextual aspects reflecting the structure of episodic memories. Despite these efforts to theoretically frame user experience, tools for capturing its multisensory situated richness are limited. For this, we now turn our attention to existing approaches and methods to design for multisensory user experiences.

2.2 Design Approaches and Methods for Multisensory User Experience

The third wave HCI with its focus on the body [59], somaesthetics [47], pleasure [45] and meaning [61] has led to a growing interest in designing for richer user experiences beyond mind-body dualism to support both users' [21,22,23,86] and designers' [1,79] awareness of bodily aspects while interacting with technology. This aligns with the somatic turn in interaction design leveraging "*self-inquiry [to provide] a rich experiential ground from which to understand and empathize with the experiences of others, the people for whom we design"* [58:55]. Such methods aim to support designers' sensitivity and awareness towards the body, in order to surface aspects of experience that might otherwise go unnoticed, for instance by bringing attention to bodily physiological responses [1,9] or posture [76]. From bodystorming [94] and embodied ideation [95] to magic machine workshops [44], new methods inspired by the somatic turn have been also developed for designing multisensory interactions. Some of these take the approach of breaking down complex multisensory experiences into their constituent parts to consider one sensory experience at a time [13,81]. These elements are then combined, to construct the target multisensory experience to be designed for [81]. For instance, experience map method [13] provides a framework for designers to move from an intended experience to concrete qualities of a product, through sensitizing questions challenging designers to thoroughly consider each sensory aspect and its potential to inform the design.

In contrast to this body of work on designing for multisensory experience more broadly, fewer efforts have focused on designing for food-based interaction experiences. In their framework for designing taste-based interactions [37], Obrist and colleagues have mapped the temporal, embodied, and affective experiences of the basic tastes and how they unfold in time [66]. While this framework targets taste, design methods focusing on flavors (which besides taste include also smell, texture, and temperature [62]) have been even less explored. Two noticeable exceptions are sensory probes [41], and material food probes [39]. Inspired by cultural probes, sensory probes [41] is a design method including a set of artifacts and activities. Some of these consist of recipe writing letters, body mapping booklet, and gameboard that pairs flavors with evocative images in order to sensitize users towards food experiences. Other probes such as food diary, camera, and sound recorder support the capture of eating activities and their context. Finally, a third set of probes i.e., eye mask, nose clip, ear plugs and gloves, are intended to provoke users to experience both sensory augmentation and deprivation. Through these artifacts, the sensory probes aim to capture rich multisensory flavor aspects, and have been leveraged in two studies for the co-design of multisensory flavor-based experiences to support rich user experiences such as emotional communication in intimate relationships [39], and recall of self-defining memories in older adults [40].

These two studies also employed material food probes, a design method consisting of co-designed personalized flavors, printable with 3D food printing technology [39]. Inspired by material probes [51] emphasizing sensorial exploration of probes' material properties such as shape, texture or color, and how these may inform design for multisensory experiences, material food probes have the added advantage of extending this exploration to the organic materiality of food and the different properties of flavor's multisensory aspects: taste, smell, texture, and temperature [62]. Findings indicate that material food probes support users' engagement in the co-design of personalized flavors as a creative and playful process resembling craft [39,40]. Moreover, by printing them in the home as part of end of day ritual of connecting with one's partner, gifted 3D printed flavors have been used to express love and communicate emotional support [39].

While most multisensory design methods tend to support designers and their creative practices [1,9,13,76,94,95] both sensory and material food probes target users, sensitizing them to the multisensory food experiences that integrate taste, smell, vision, sound, touch and even internal senses of digestion and metabolization. With their emphasis on capturing and co-designing personalized flavor cues, these probe methods extend Bartoshuk's conceptualization of *taste world* [66] towards *flavor design worlds* [40] to support users and designers work together for crafting such cues. However, we know less of how such crafting of flavor cues can be entirely user driven. This is important, as in terms of memory cues, these tend to be most commonly automatically generated and with limited input from users themselves, despite findings indicating the value of users crafting their cues for better recall and increased self-expression [23,74,77,78,85]. Moreover, while crafting memory cues can be beneficial across all age groups, they can be particularly valuable later in life when people can benefit from increased sensory stimulation [75]. In turn, such cued recall could strengthen one's sense of identity and personhood threatened by cognitive decline or dementia [75].

To conclude, despite increasing efforts to conceptualize user experience, tools for capturing its multisensory situated richness are limited. In turn, novel approaches and methods are being developed to better inform the design of multisensory user experience by predominantly supporting designers' awareness to their bodily and emotional experiences during the design process. In contrast, with some limited work on how user and researchers co-design flavors together for novel user experiences, there are even fewer tools supporting users (rather than designers) to capture their multisensory experiences and design for them, or as in this paper, to design flavor based cues for their recall. One additional body of work relevant here is that from food science and sensory evaluation with their specific methods for capturing multisensory food related experiences, as highlighted below.

2.3 Sensory Evaluation: Food Science Methods

Sensory evaluation in food science research [60] is concerned with how people respond to stimuli targeting each of the five senses, in particular those pertaining to food and its qualities, with the intention of creating more tasty food that consumers appreciate. Techniques developed in this field include both objective and subjective measurements of sensory aspects of food products, and of people's responses to them, respectively [17].

Objective measurement methods describe such products along their qualitative sensory aspects or attributes such as taste, texture, or smell, for instance through texture or flavor profiles in order to compare and discriminate food-based products based on sensory similarities and differences [88]. Objective measures also include quantitative sensory aspects, namely the intensity of each attribute [17]. While subjective measures can be used by non experts in order to assess consumers' preference for such products, objective measurements require expert skills involving trained panelists [88], often using a range of validates scales [60]. Given that cost of engaging experts, alternative methods have been proposed to be used by people with limited skills such as children to assess taste profiles [29], or non trained evaluators for instance through flash profiling by ranking products for one quality, sorting foods into groups defined by evaluator, or projective mapping of products on spatial axes [89]. They also focus on large sample of evaluators in order to identify statistical trends in order to manage sources of variance [17]. Examples of scales for assessing individual sensory aspects target for instance trigeminal, i.e., spiciness attribute [14], texture attribute [60] or smell descriptors [34]. However, even these methods tend to be text heavy with technical jargon and use scales with large number of points for fine tune assessment. They are also predominantly paper and pencil, with limited focus on alternative more engaging (digital) formats.

To summarize, the robust food science methods such as sensory evaluation scales offer interesting opportunity to become appropriated for capturing multisensory experiences along all five senses and in particular taste, smell and touch (texture and temperature) for interaction design. For this, we need to explore how such methods can be imported by making them accessible and engaging for non experts, both in terms of language and format, while maintaining their validity.

3 INTERFACE DESIGN OF FLAVORDESIGNER APP

The aim of the FlavorDesigner app is to capture both live and remembered multisensory experiences, and to support the crafting of personalized flavor cues for the later recall of these experiences. Previous findings suggested also an important aspect impacting the design of such flavor cues, namely the presence of food in the original experience [40]. If the food is present, then the making of the flavor cue usually tends to reproduce the key multisensory and contextual aspects of eating that food. However, if the food is not present, then the making of flavor cue for recalling that experience can benefit from scaffolding the process of associating this non food experience with a flavor based on similarities that matter to user. Thus, the three main functionalities of the FlavorDesigner app are (i) capture live or remembered multisensory experiences, (ii) create associations of non food-based experiences with flavors, and (iii) craft personalized flavor-based memory cues. The distinction between live and remembered experiences is that the former relate to present experiences or those which have just ended albeit users can still access their situatedness. In contrast, remembered experiences are those from more distant past, that users can no longer capture directly, but only through reconstructing them solely from memory.

3.1 Capture Live, or Remembered Multisensory Experiences

This functionality was informed by models of designing for multisensory experiences that suggest focusing separately on fragments of experience for each sensory pathway such as taste, smell, touch, vision and sound [13,81], flavor's components - highlighted in food science research - which include beside taste and smell also texture, and temperature [62], as well as models of episodic memories and their structure including besides sensory aspects, the emotional ones as well as the spatio-temporal and social context of original event [57,70]. In addition, information about the food itself: dish name, ingredients and cooking procedure are essential for the making of flavors to cue the memories of these events [40] so they were also elicited through our app.

We now outline the rationale for the interface design capturing each sensory aspects, particularly for taste, smell and texture, as design explorations of capturing such content have been limited. For the five basic tastes of bitter, salty, sour, sweet, and umami we decided to use one of the few taste scales from food science albeit developed to be used by children rather than experts [29]. These scales ask how much each of the five basic tastes is present in a food experience. Given that novice users experience difficulties with differentiating between some of the tastes such as bitter and sour [27], or are less familiar with the meaning of umami [40], we provided for each of the basic taste, a prototypical foodstuff illustrating it, as suggested by prior work: black coffee for bitter [18,72], salt for salty [29], lemon juice for sour [18,72], sugar for sweet [29] and tomato paste for umami [8] (Figure 2 left). For the visualization of the scale itself, we decided to explore two formats. One was the linear scale previously used in food science research [29] (Figure 2 left), while the other one was the radial scale which has been used in the prior HFI studies [38,39] supporting a holistic view of how basic tastes in a foodstuff contribute to its overall taste profile with some taste being dominant (Figure 2 center). We were particularly interested in finding out users' preferences for the scale format, and the value of the provided prototypical examples for each taste. To avoid repetition, we made the choice to use each of these formats only once for capturing either live or remembered experiences, hence in Figures 2, 3 and 4, the wireframes relate to both captured live, and remembered experiences.

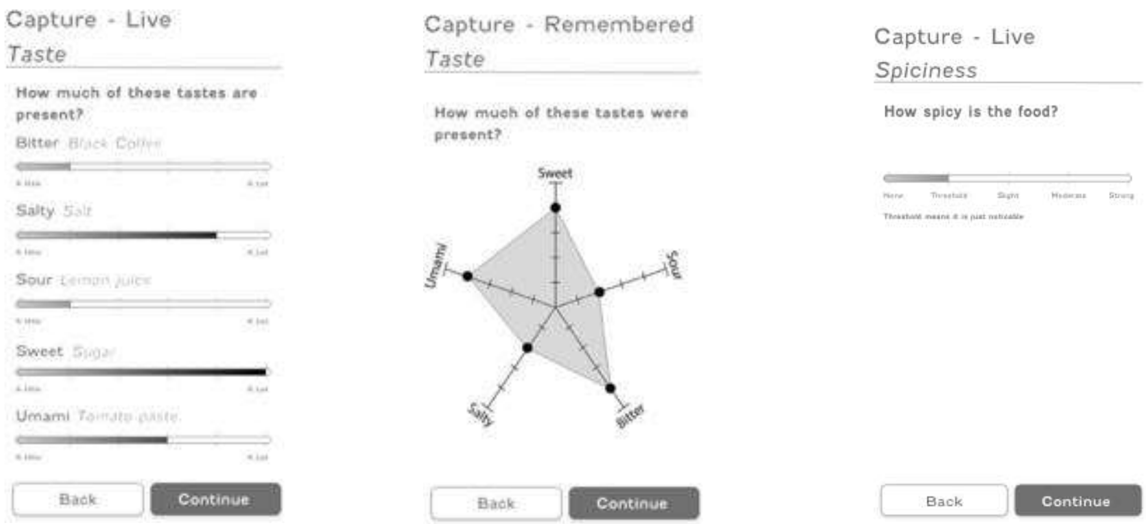

Figure 2 The FlavorDesigner app's functionality of capturing taste sensorial aspect on 6-point Likert scale through two different visualizations: horizontal sliders with anchor labels, and prototypical foodstuff for each basic taste (left), and radial sliders (center); spiciness sensorial aspect on 5-point Likert scale (right)

While not a basic taste, spiciness is a complex taste with haptic qualities, relevant in many cuisine. To capture this trigeminal experience, we used a valid 5-point Likert scale (i.e., none, threshold, light, moderate and strong) from sensory science [14] asking: "*how spicy is your food*?" (Figure 2 right).

Unlike the defined categories we have for taste, i.e., the five basic ones, there is no equivalent classification of smells; smells are more idiosyncratic and linked to their source. To capture individual smells we used smell descriptors of food additives [34] namely minty, coconut, fatty, musk, aniseed, piney, woody, almond, cinnamon, lemon, butter, garlic, cabbage, clove, vanilla, as they represent a range of smells relevant for both savory and sweet dishes (Figure 3 left). Apart from sources, smells also vary in intensity and just like tastes, can be combined to create complex smells in a dish, involving more than one individual smell which can be captured through more than one descriptor. In order to capture this richness of smells, we designed a bespoke two dimensional space based on smell intensity (weak vs strong) and complexity (simple vs complex). Figure 3 center shows four quadrants, where users can provide a visualization of their food smell in their most relevant one. For the visualization we provided two options: one of drawing the pattern of smell by tracing their finger across the screen, and one for selecting the pattern from the four that we designed to reflect evocative air movements: (a) wiggly and smooth, (b) straight and sharp, (c) jugged and sharper, and (d) rain drops (Figure 3 right). We were interested to explore if people selected pattern (a) for pleasant smells, pattern (b) for more neutral smells, pattern (c) for less pleasant smells like acrid, rotten, or burnt, and pattern (d) for diluted, ambiguous smells. For the first visualization, the pattern's size and color were predefined, while for the second one, users could chose them across the two provided sliders with the meaning of the color not being specified, while the size of the smell pattern being expected to be mapped to smell intensity. Each of these visualizations was used only once for capturing either live or remembered experiences.

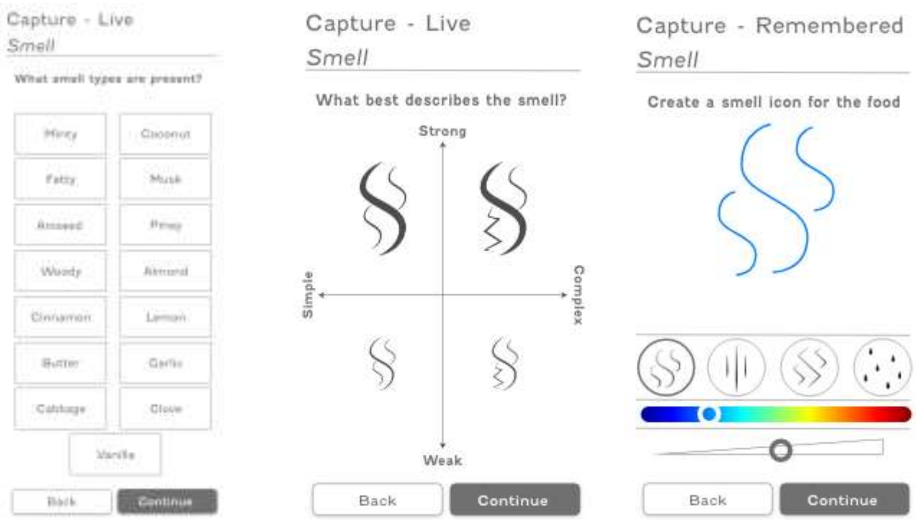

Figure 3 The FlavorDesigner app's functionality of capturing smells' sensorial aspects based on a set of individual smell descriptors for both sweet and savory dishes (left), two dimensional space for capturing both individual or simple and multiple or complex smells varying on the simple-complex axis (center), and free draw of the smell pattern with option to select one of four patterns: wiggly and smooth, straight and sharp, jugged and sharper, rain drops, together with their color and size (right).

To capture <u>texture,</u> we used much cited texture descriptors from sensory science [60] consisting of 15 attributes for texture of solid foodstuff: roughness, wetness, stickiness to lips, springiness, hardness, cohesiveness, fracturability, viscosity, denseness, crispness, juiciness, flinty/glassy, moisture absorption, cohesiveness of mass, tooth packing, and 7 attributes for texture of semisolid foodstuff: slipperiness, firmness, cohesiveness, denseness, particle amount, particle size, and mouth coating. These were measured on 16-point Likert scales with labels at each end, i.e., dry-wet for wetness attribute. A subset of these texture descriptors are shown in Figure 4 left. We also included from previous work [60], illustrative examples of foodstuff at each end of texture attributes, i.e., cracker vs water for wetness attribute. To sensitize participants to the distinction between solid and semisolids, we added one question from food science [83]: "*can you squash the food against the roof of your mouth without chewing it"*. To capture the <u>thermal</u> properties of food we employed a scale from thermal comfort studies [31], while using also the representation of a thermometer which we positioned vertically to match the metaphor "more is high" (Figure 4, left-center).

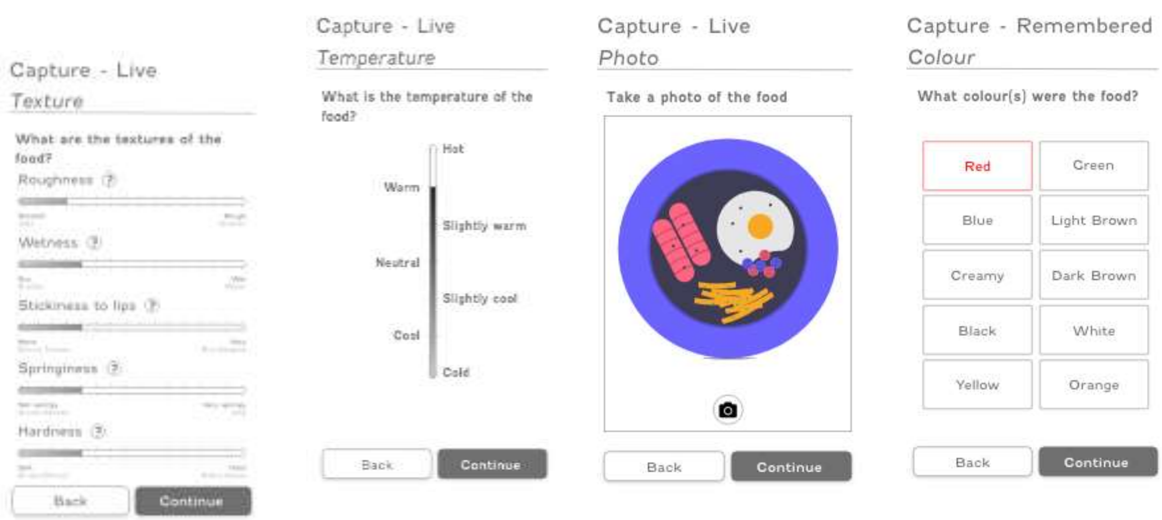

Figure 4 The FlavorDesigner app's functionality of capturing texture sensorial aspects based on texture descriptors of both solid and semisolid foodstuff on 16-point Likert scale with labels and prototypical foodstuff at each end (left), capturing temperature sensorial aspect through the image of a vertical thermometer (left-center), capturing visual sensorial aspect by taking a photo of the food for lived experiences (right-center), or selecting the food's dominant color(s) for remembered experiences (right)

In order to capture the visual aspect of the food, for live experiences, we provided the option of taking a photo (Figure 4 right-center) and for the remembered experiences to select the food colors from a list we provided that depicts everyday food color [41] (Figure 4 right). For lived experiences, participants were also given the option to make a short sound recording. In addition, participants were also prompted to enter in textual form details of the dish: its name, ingredients, main flavors, and cooking/ preparation process. Not at least, we also prompted recall of the main elements of episodic memory structure: feelings, people involved, place and time [50].

3.2 Create Associations of non Food-based Experiences with Flavors

This functionality supports creating associations between the non-food experience targeted to be remembered and flavors (remembered from previous food experiences or even imagined). Such associations are made with at least one of the main components of the episodic memory of the non-food experience: emotions, time, places or significant persons [50] (Figure 5 Memory qualities). The functionality supports associating each of these identified components to the most relevant food flavor that users can describe through ingredients, dishes name, flavors, smells and colors (Figure 5 Associated Flavors) Once completed, these details could be curated to create a flavor-based memory cue. The design of this functionality is inspired by the co-design process depicted in previous HFI research [38,39].

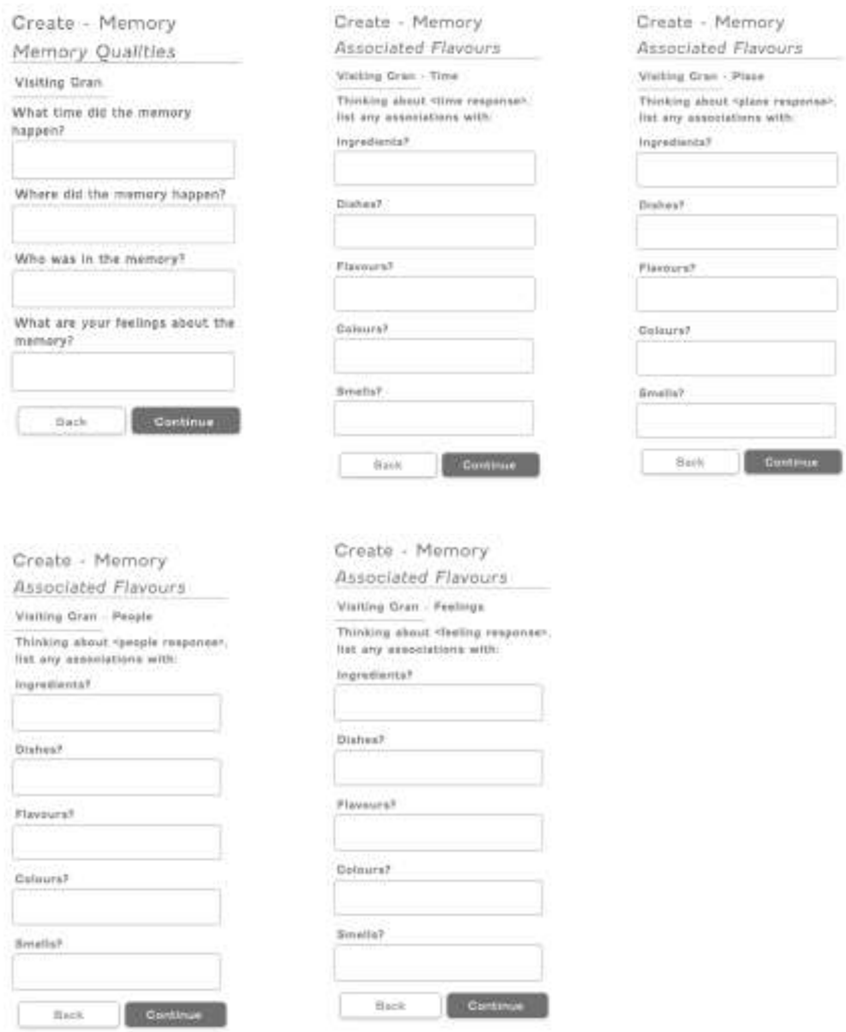

Figure 5 The FlavorDesigner app's functionality of creating associations of the non-food experience's main components on the one hand: time, place, people, emotions (top left), and associated flavors on the other hand, or foodstuff aspects: ingredients, dishes, flavors, smells and colors (top center, top right, and bottom)

3.3 Craft of Personalized Flavor-based Memory Cues

This functionality leverages data gathered through the two functionalities described above in order to support users to craft their flavor-based cues. It brings together each sensorial aspect of the original flavor experience, allowing users to select the most salient and unique ones. Then, users can integrate or combine them to create a distinctive and evocative multisensory flavor experience for cuing the recall of the target memory (Figure 6).

Figure 6 The FlavorDesigner app's functionality of crafting flavors to cue the recall of a target memory, i.e., Gran's Birthday, by browsing through all its captured sensorial aspects (top row) and iteratively selecting the most salient ones (bottom row), i.e., bitter

4 METHOD: EXPLORATION OF THE INTERFACE OF FLAVORDESIGNER APP

For the initial exploration of the FlavorDesigner app's interface design we employed online workshops and Wizard of Oz approach [19]. Workshop method was preferred in order to stimulate discussions about the app design. It allowed participants to reflect together on the proposed functionalities for capturing experiences and generating flavor-based cues, as well as how these functionalities can be improved. During the workshops, each participant was supported to express their voice while respecting their needs for reflection. Workshops took place online to protect both participants and researchers while adhering to the Covid-19 social distancing requirements.

The workshops included three stages (Figure 7): (i) brief introduction to the app and its main functionalities alongside use scenarios grounded in previous research findings; (ii) presentation of each functionality, through interaction with wireframes providing detailed descriptions of each functionality, followed by videos for explanations of these functionalities. These functionalities included capture experiences, both live and remembered ones, create association of non-food based experiences with food, and craft flavor-based cues for later recall of these experiences. For capture-live experiences, we prompted participants to think at their latest meal of the day, just before the workshop. For capture-remembered experiences, we asked them to think back at a significant past experience involving food, while for craft association of non-food based experiences with food, we asked them to think back at a significant past experience that did not involve food. The last stage of the workshop (iii) consisted of semi-structured group interviews to gather overall feedback on each functionality and app's interface design.

Given the novelty of the FlavorDesigner app and its limitedly explored functionalities, our efforts at this early stage of app development have focused on the design of the interface (rather than a fully functional app) which is best suited to be explored through Wizard of Oz approach. Thus in the second stage of the workshop, participants were instructed to interact with provided wireframes by entering the required data for *Capture* and *Create* functionalities, and by designing the flavor-based cue as prompted by the *Craft* functionality. Following data entry for each functionality, participants were presented a video regarding that functionality, and were invited to review and discuss each wireframe with a focus on the flow and clarity of interaction design. They were also asked to provide feedback on the value of the content and format of data being collected, together with any further suggestions for improving the interface design or alternative solutions. The workshops were audio recorded and fully transcribed. All content was then coded by the first author following thematic analysis [11] to identify emergent themes including aspects of the design that were successful and why, within each of the main functionalities, where the design did not achieve its aims, and how such limitations may be addressed. The codes have been revised through extensive conversations between the first two authors.

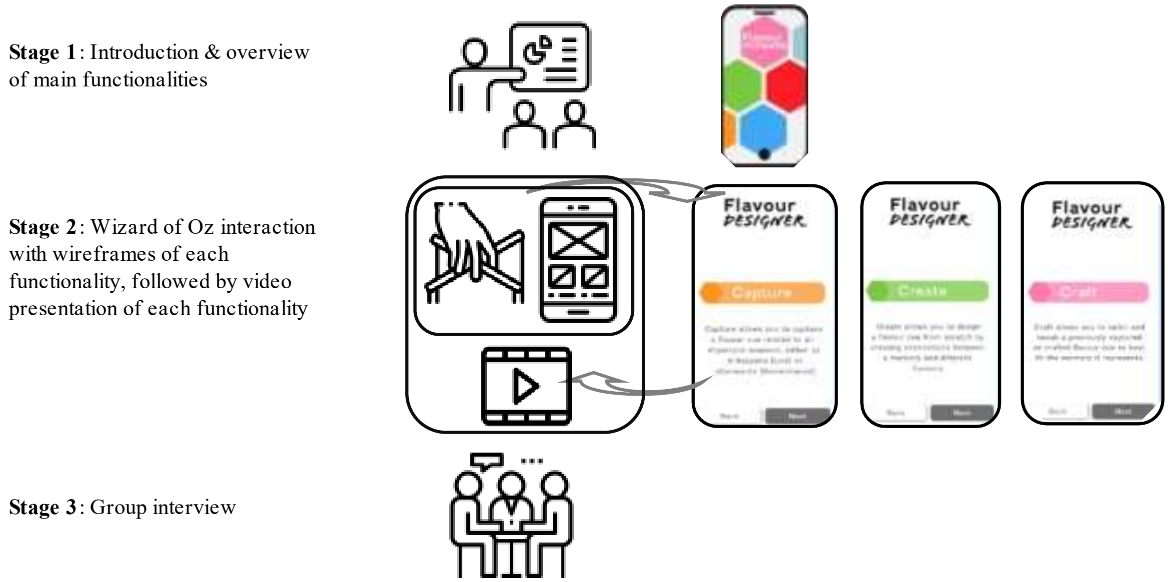

Figure 7 Overview of the three study stages: (1) Introduction and overview of main functionalities, (2) Wizard of Oz interaction with each main functionality's wireframes followed by its video, and (3) group interviews (Icons:@Uniconlabs – Flaticon, @Freepik – Flaticon, @Smashicons – Flaticon, @Becris – Flaticon)

4.1 Participants

We recruited 12 participants (8 female, 4 male), mean age: 35.5, age range: 26-65. Ten participants were white, and two with mixed or multiple ethnic backgrounds. Over half of them had postgraduate qualifications, and 5 had professional experience in app design. All participants were familiar with mobile apps, using them in their everyday life. Participants were recruited through adverts on social media describing the aim of the study as the exploration of a mobile app for capturing and designing experiences with food. The prevalence in our sample of educated professionals mirrors the characteristics of early adopters of novel food technologies previously shown [37]. The study took about 2 hours and each participant was rewarded with £10 online gift voucher.

5 FINDINGS

In general, participants felt that the language used throughout the app design was clear (n=8 participants) and that they could *"have an idea of what a flavor cue was […] there was just the right amount of information"* (P12). They also liked the visualizations: "*the way you've used a range of graphics, you know […] you've organized the information differently on each screen. And I think that's really helpful [and] quite engaging*" (P1). We now describe the key findings for each of the app's main functionalities highlighting how people perceive them, and what they found useful or more challenging, and why.

5.1 Capturing Multisensory Experiences

The capturing functionality was provided for both live and remembered multisensory experiences, and was generally perceived as *"simple [since it] seemed to flow as to inputting and building the experience"* (P4), and feeding well into the crafting of the cue: "*I like you have split it down to say you can record in the moment a flavor cue and I guess later on […] the app would ask me and I could put in pine and you might generate that up into the cue that I am relating to in that moment. And yeah, I think it's quite easy to understand the difference between them*" (P4). Although the capture functionality builds on users' familiarity with mobile phones broader practices, this rich capture of their multisensory experiences is perceived as new, requiring many of them to pause and think particularly about the sensorial aspects. For instance, with respect to taste, some participants engaged in online exploration of umami concept: "*umami is not a flavor,* *a taste that everybody knows. I mean, in the school, they don't teach you that. So, you eventually, maybe tell it with an example, you kind of like help*" (P3). All scales were provided with prototypical foodstuff to illustrate that attribute at the two ends, which was appreciated: "*I noticed them and I like them ... example foods, are very helpful"* (P5)*"* and *more such examples would be useful"* (P10). For capturing taste, either horizontal or radial arrangement of the Likert scales were presented. Participants preferred the radial arrangement as: "*it makes me feel like all the tastes are there to work with each other. So, by pulling them across and seeing how they relate, like sweet and sour, you can definitely tell what is more than the other. It's in combination.*" (P8, n=4), and that radial visualization was "*a bit more visual*" (P6, n=3). This is an interesting finding suggesting that at least within the same taste modality, different attributes can be captured separately or together, but given the option people tend to prefer their integration: "*I think because you get kind of a bit of a visual representation of where the flavors are leaning"* (P3). People also liked the simplicity of spiciness scale: "*I mentioned, how it liked about the spiciness [...] I like that there's a bar"* (P2).

For capturing smell, participants liked the matrix that described smell in terms of simple-complex and weak-strong axes (n=4): "*I really liked the smell matrix [,,,] I thought that was ingenious [...] so pastry is a weak taste"* (P8). However, while strong-weak dimension was clear for all participants, simple-complex dimension was not easily linked to individual or compound smells, which on reflection could have been a better wording: "*I did have to take a minute. I didn't get it straight away; I have to say. I think strong and simple, make total sense. The complex and weak; that I was a bit like, Oh, so and obviously with the banana, I was just like, um okay. And then in the end, I went for the simple, strong. But it just, I get it, I thought about it, but it didn't sort of like, I had to think about it, basically"* (P9). An alternative free drawing option was also offered for smell capture, which was received with mixed responses. While some participants found it challenging given the perceived ambiguity of the patterns: "*to create meaning with each of those patterns"* (P11, n=4), others (n=3) found this the most creative approach for sensory capture, ensuring that "*icon reflects, you know your kind of personal association*" (P2). Other participants added: "*instinctively, I feel I'd be able to [use free drawing] more than the slider. Free drawing [...] is what I'd go for. Because it is a bit more personal. I think we're trying to create a personal experience. I would like to be able to personalize it as much as possible"* (P10). In contrast to the matrix, the 4 provided patterns for smell icons were not easy to understand and discriminate their distinct meaning: "*I think they actually make sense like the icons in the context of the axis [...] But yeah, it takes a while maybe to notice the difference between the smooth line versus the like, sharp line [...] maybe just emphasizing, you know that [...] one is a curving, one is more like straight lines, is just probably quicker to spot the difference*" (P3). People also liked the provision of classifiers for odors, albeit they noted that it covers only a small set of smells and not the ones that they wanted to describe (n=7).

A common issue experienced in this functionality was the complexity of the texture scales (n=10). It was also less clear to participants how to deal with foodstuffs that contained multiple textures, or dishes which contained multiple foodstuffs, "*It's not just one dish, it is kind of Sunday roast, which has many different components to it. Do you just choose one of them?"* (P3).

For color description of remembered experiences (as the live ones could be photographed), some participants preferred picking from the provided color wheel as it was more specific (n=2), whilst others preferred choosing the color label from the table since it allowed for multiple selection and better supported selection of black, white and dark colors (n=5). The requirement for photographing the food during live experience capture was also suggested to be brought forward to avoid people having consumed the food before taking the photo (n=4). This point highlights the importance of further work on eating practices to understand how the capture and eating may interact with each other.

The final screen in the capture functionality was for reporting of experience details, which participants felt that was very important functionality: "*experience details part may be quite important. It was like my favorite page. And I feel like if we're using these cues, with memories, this is kind of important, but [...] it was the last slide. And we've done anything else. It felt like an afterthought*" (P5). Thus, some participants suggested that these details should be moved ahead of the flavor description (n=3): "*as you start to describe things, and you really think through those questions, if you may be more open to them, answering some of the other ones as well, because then you're thinking more deeply about the flavor, the texture, etc."* (P11). This suggestion indicates how experience details create user investment into the cue as well as sensitize them to think more deeply about the specifics of the experience by starting with the more general context and working towards the deconstruction of the multisensory aspects of the experience. Prompting the entry of emotional content was also suggested for enriching the experiential details (n=3).

5. 1.1 Benefits and Challenges of Sensory Scales

An important finding concerning the capture of multisensory experiences is participants' perception of the sensory evaluation scales. Some scales such as radial diagram of tastes, or spiciness one were particularly liked due to visual representation and simplicity: "*I'm happy. Yeah, I think it is clear. And sort of the layout of the screen with the headings and words, with the numbers next to them, how they've been scored was easy to understand what you were looking at, and how you could interact with the data. And I think, yeah, it's pretty clear where it came from as well. You know, you've got the name of the flavor cue. And yeah, for me, it was very clear and it was actually easy to use"* (P3).

In contrast, other scales such as the texture ones were problematic due to their complexity: large number of attributes including unfamiliar ones which were not easy to understand by untrained people: "*the particle ones, for me, they were quite confusing. Maybe because I don't come from a science background"*(P1), and large number of points on the Likert scale. P7 asked: *"the layperson [...] are they going to persevere through 15 different descriptors [in the texture scale]?"*. The texture scale used 17-point Likert scales, something that felt too fine-grained (n=7) and whilst the provided explanatory text was helpful, it did not fully overcome this challenge. One way to address this challenge is by sourcing simpler scale with consistently smaller number of points: "*I think having some kind of consistency would probably help because then you're thinking about everything in the same way [...] for example, we see here, there's a six point scale, and it's a five point scale, and a 17 point scale"* (P7). Such consistency can also ensure more accurate capture across different sensory aspects: "*so sometimes you rate the bitterness out of ten. But that [texture] section where you rate [...] smoothness, that's out of 17. So from a user, I can't really quickly judge the level in which I need to say, Oh, actually, the bitterness might be higher than the 10 that I've mentioned before"* (P8). Another suggestion for addressing the challenge of complex texture scales is to provide some minimal training: "*I feel like the way the question is asked is more suited towards like a gourmet, trying to analyze the flavor and the texture"* (P2). One potential suggestion to address this knowledge gap was to use further walkthroughs in the app: "*maybe there is almost like a second set of onboarding [...] that people can engage with, that walks them through those processes. A second more active step that you might take, and maybe that provides greater clarity when you're going through and creating or crafting or capturing"* (P11).

5.2 Creating Associations of non Food-based Experiences with Flavors

This functionality supported the association of non-food related memories to flavors, as an intermediate step towards crafting the flavor-based cues for the recall of these memories. Findings show that participants found that the process allowed them to produce many associations between such memories and flavors (n=5): "*we looked a lot at the capture [...] how would you summarize all of this data into [...] a snippet, so that you can go and revisit later. It was pretty clear, you know, all of the steps in the process. And yeah, I think the remember, and the create section, were particularly good"* (P6). In this respect, the process was found to be generative, prompting people to uncover flavors that may cue other memories than the targeted one. In this way the process was perhaps creative, but not constrained to achieve the target goal: *"because I was asked to think of a place, it led me to my hometown, I put all of these associations that I have to my hometown, which are seafood related. So, I feel like, "Oh, I started with this memory", but then I didn't select those food for them, for the cue. [Instead] there was a dish. But also not that dish in the circumstance, the context, there were other foods that also were in the memory. But they were not in that particular memory"* (P1). To address this unconstrained exploration of associations, some participants suggested to include prompts for the type of content they should identify (n=3), or that suggestions could be made, for example based on taste-emotion mappings (n=2).

5.3 Crafting Flavor Cues

This final main functionality supported participants to select the most salient aspects of captured multisensory experience or created by association with food, in order to refine the design of their flavor-based cue: "a *nice way to capture what was really important about that experience, like a nice little summary* (P3, n=4). Emphasizing the integration of captured data, another participant noted that this stage offers "a *good thing to just reflect on although you have put in all the sort of poignant aspect [...] the layout of the screen with the headings and words, with the numbers next to them, how they've been scored was easy to understand what you were looking at, and how you could interact them, with the data. And I think, it's pretty clear where [the data] came from as well"* (P5). Participants also considered whether the action of selecting saliency for aspects of the experience could be integrated into the capture or create stages (n=2).

In the study participants were told about prior research on flavor cues for experience, but they felt that the purpose or application of the cues was not sufficiently clear: *"it'd be good to have some kind of visual, [to] be able to envision it more, I think that would aid the process […] I think more ideas about how the flavor cue would be of value to me would make me carry on [using the app]"* (P12). This quote captures both how emphasizing the application could support understanding as well as motivation for capturing and designing the flavor cue.

Another interesting finding was increased awareness and sensitivity towards food, through the mere engagement in the workshop: "*what would stop me from using the app? I think somebody else mentioned earlier that it's hard to think about food so deeply just because we don't really do it. And so that might stop me halfway through. But then [as] I think more […] about how the flavor cue would be of value to me would make me carry on"* (P1).

6. IMPLICATIONS FOR DESIGN AND DESIGN RESEARCH

We start with three implications for the design, and design research that our findings informed. These include the importance of evocative representations for capturing taste and smell, interactive, of engaging and valid sensory evaluation scales, and for new classes of technologies for food-based multisensory interactions.

6.1 Evocative Representations for Capturing Smell and Taste

For the design of our app interface, and in particular representations of smell, we leveraged existing odor classifiers and novel evocative icons. Here we explored a range of representations from predefined icons as part of a two dimensions space or matrix, free and supported drawing tools with provided patterns, colors and sizes for users to choose from in order to describe smells. This approach was informed by prior work into visualizing taste experience [63] and tangible objects for describing experience which were designed not to have inherent meaning but to be used to create meaning by users [48]. The application of the smell iconography worked best alongside with the classifiers taken from literature [34]. This indicates that pairing together more exploratory and multimodal responses with validated scales may be a way of combining together the aesthetic and psychophysical descriptions of sensory experience that best support shared understandings [93] and user engagement. Such representations can be leveraged not only for multisensory user experience but for interaction design more broadly.

6.2 Interactive, Engaging, an Valid Sensory Evaluation Scales for Multisensory Interaction Design

Our findings also led to implications for design research through novel tools for capturing and assessing sensory experiences. These will sensitively integrate robust scales from sensory evaluation, with engaging interactivity features as illustrated in the design of our app interface. Our findings suggest users' desire for choice in describing their experiences, i.e., select from multiple labels or from a color wheel. However, they also highlighted that too fine choices or fine grained scales may be problematic. This suggests the importance of balancing broader set of choices with different levels of granularity so that users can select their preferred level. One solution is to increase the support for understanding complex terms, another is to reduce the overall complexity of scales whilst supporting more open-ended descriptions.

6.3 New Classes of Technologies for Food-based Multisensory Interactions

The FlavorDesigner app was designed within the context of creating flavor-based cues to support the recall of memories by building on prior work of codesigning and actually making such cues in the lab [39]. Inspired by our app, we can image other technologies leveraging multisensory food-based experiences. For this we can think for instance at creating memory-based meals for use in space travel [66], designing foodstuffs for use in playful experiences [2,3], supporting emotional experience with food [37,90], interpersonal emotional expression and coregulation [38], supporting rich craft practices with food [83] or how food can be used as a tool for exploring and understanding more about sustainability and ecological systems [25,54]. Each of these designs could be catered for through swapping out the experience details or in other words, changing the *target expression*. In this way the app can be used to support much wider adoption of food as a resource for interaction design by overcoming the barriers of designing for an individual's subjective experience, instead making this a feature of various interactive experiences where the subjective multisensory experience supports personally meaningful interactions. In particular, the crafting of flavor-based cues could further sensitize participants to their flavor experiences [39,40], and subsequently their sensory experiences [40]. Such design process however will be iterative and users should be encouraged to see it as such so that they can progress the created cue (or *sensory effect* [32]) closer to the intended experience (*sensory impression* [32]).

7 DISCUSSION

In the light of our findings, we now revisit the initial research questions. The first question focused on how can user capture the various aspects of their multisensory experiences. Study outcomes indicate that the capture functionality was by large easy to understand and engaging, but also challenged participants to pause and reflect, given their unfamiliarity with some of the sensory evaluation scales and their language. Our approach to capture the richness of multisensory experiences [13,81,92,93] from multiple theoretical perspectives was appreciated, with people liking the most the structure of episodic memories capturing events, place, time, people and feelings [57,70]. The sensory aspects and their evaluation tools from food science [14,17,28,34,59,89] were perceived as being easy to capture with, in some respects, but also challenging in others. In particular, they appreciated our efforts to increase the engagement and accessibility of sensory evaluation scales that we embedded within the app interface through intuitive visualizations and additional use of prototypical food examples to illustrate the ends of the scales. People also appreciated the interactivity option of drawing for instance smells, seen in itself like a form of crafting with further mnemonic potential. This echoes previous findings on the value of doodling for cuing memory recall [77], and how this may extend to free drawing of iconic visualization of sensory aspects for instance through stylized representations or icons of smells.

The description of smells through sources [34] received mixed responses when participants could not find a match for their target flavor. The space of sensory and contextual aspects that people were prompted to capture can be perceived as rich and potentially overwhelming, so visualizations providing means to integrate some of these aspects are much preferred, like for instance bringing the basic tastes together in a radial diagram instead of individual horizontal sliders. Interestingly, the most challenging sensory aspect was texture, most likely because of the complex scale that we used [60] featuring many unfamiliar texture attributes, which even with provided examples challenged participants' understanding. Together, these outcomes suggest the value of providing the option for capturing the breadth of individual fragments of multisensory experiences, but also coupled with giving people choice of tailoring this option so that they restrict the capture to what is needed at specific time and avoid the risk of participants becoming overwhelmed. In particular, a top down approach starting with the structure of episodic memory that capture predominantly contextual details, and then the sensory aspects seems to be preferred.

The second research question looks at how can users be supported to design their personalized flavor-based memory cues. Findings suggest that people engaged in the crafting of their flavor based cues, albeit did not fully grasp their value, despite our initial briefing on the rationale of the app design. Also challenging was identifying salient flavors to cue non food memories as participants generated many low saliency associations perceived by users as demotivating. Whilst many approaches to multisensory design emphasize completeness in considering each sensory perspective [13,42,78,81] these haven been generally aimed at designers whose training allows they to dispassionately assess the potential of different avenues in order to choose the most promising ones. In this app, users are not expected to have design expertise for recognizing salient associations. So an important implication here is extending the app to scaffold users' ability to curate and recognize salient associations. We recognize that creating such associations is likely the most challenging functionality and people may be encouraged to engage with it after some experience of crafting cues for food-based memories. This will allow developing a richer understanding of what salient flavor cue may mean for them.

The challenge of not fully grasping the value of flavor based cues also contrasts with people's enthusiastic engagement in the crafting of flavor-based cues as described in previous work [39,40,41]. These studies differ from ours in terms of their length which has been considerably larger involving for instance 2 week diary study with sensory probes which ensured participants' sensitizing to the bodily responses and food experiences. This suggests an interesting broader perspective that may be needed to support people engage in such new multisensory practices. Previous work has shown that users capturing their sensory experiences is a well-established practice albeit mostly through audio-visual modalities of mobile and lifelogging technologies [56,73,80,84,87]. In contrast, capturing the taste, smell and haptic aspects of multisensory experience is a less familiar practice, or so called proto-practice which users need time to appropriate as we have seen for instance with biosensing technologies [73]. Such appropriation however is likely to happen with the advent of food technologies and we would argue that it holds potential to open new classes of novel multisensory experiences that interaction design researchers will be provoked to explore. Such framing as proto-practices of users' capture of their multisensory experiences and crafting of flavor cues has methodological implications as people may benefit from engaging in longer studies to become sensitized towards these practices. Alternatively, if short workshops are still preferred, then it is important to explore more evocative vision scenarios that can allow people to bridge the gap from present to the near future when such new practices become established. Future and speculative design methods [98] may be leveraged in this case and embedded in multisensory approaches to design for HFI proto-practices.

This research question also invites reflection on how our design may impact people's every day practices. For this we note that while designing flavor-based memory cues requires efforts comparable to those for cooking a meal for a loved, the experience of consuming the cue differs significantly: flavor cues are intended to be precious and celebratory, used selectively, for carefully crafted emotional experiences in order to travel back in time to significant moments of one's life. While informed by the food eaten when the memory was encoded, their evocative power can be increased through injecting for instance stronger flavors or by embedding new contextual aspects not captured in the original food, such as flakes of dry lavender flowers from Tuscany hills like in our introductory vignette. So flavor cues are not proxy meals, but support significantly different experiences.

The third research question focuses on *what design implications and tools can support such capture and design for multisensory interactions.* Our findings support the value of our approach to leverage complementary theoretical perspectives of multisensory experience and memories from both interaction design [13,57,70,81,92,93], and beyond [14,17,28,34,59,89]. They also show the particular value of using the structure of episodic memories [57,70] together with the simple and accessible sensory evaluations tools [14,28,34] albeit less so [59]. Appropriating such methods from food research requires attention for trading the fine line between valid and accessible scales. Such appropriation also offers the tacit advantage of extending the understanding of multisensory aspects, both for us as researchers and for our participants. We argue that such scales will enrich our interaction design vocabulary of multisensory experiences, opening up for more nuanced conversations in this space. Indeed, a challenging aspect of working with flavor is the confusion between the scientific and colloquial use of terms. *Taste* for example is understood in sensory evaluation as relating to very defined experiences in the mouth based on chemical stimulation of the tongue [16], however in common parlance it can be used to denote what scientifically is described as the flavor experience (e.g. *a lovely chocolate-y taste*). One way of supporting the understanding of key terms is the use of vignettes to demonstrate in concrete and applied manner what something means or what something does. Examples of successful applications of vignettes to support the explication and communication of complex internal and subjective experience can be seen on their use for lived experiences of depression [76].

7.1 Limitations and Future Work

Our initial exploration of the FlavorDesigner app through Wizard of Oz matched the early stage of its design, while future work will look into implementing and evaluating the fully working prototype. Given our qualitative approach involving a small sample of participants, our findings are not intended to be generalizable, but rather to open up conversations about a potentially rich and less explored design space of food-based multisensory interactions not just for memory support but arguably for a broader range of application domains. We already mentioned in this respect the use of future and speculative design methods towards multisensory approaches to design for HFI proto-practices. For instance future work can focus on generative value of smell, taste, or flavor-based interfaces and employ for instance magic machines technique [21] with different stakeholders to explore novel applications and form factors of such interfaces. Future work can also leverage insights from sensory linguistics [97] and food science [14,83,88] to extend our vocabulary to talk about such multisensory interaction, like we have done in our introductory vignette.

8 CONCLUSION

This paper reports on the design and initial exploration of the FlavorDesigner app's interface, an app for supporting the capture and design for multisensory experiences with food. The app consists of three main functionalities: capture live or remembered multisensory experiences, create associations of non food-based experiences with flavors, and craft personalized flavor-based memory cues. The app was explored trough workshops with 12 users using Wizard of Oz approach. Findings described the experience of use for each functionality as well as users' overall feedback on the app. These led to three design implications such as evocative representations for capturing taste and smell; interactive, engaging and valid sensory evaluation scales, and new classes of technologies for food-based multisensory interactions.

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