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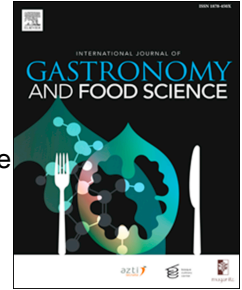
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Sketching the future of human-food interaction: Emerging directions for future practice

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## Author statement

We are very thankful to the reviewers for their feedback. We added a table in response to reviewers where we described the individual improvements we made based on the feedback, structured by the reviewers' comments.

We have also included a Word version with "track-changes" and a revised version without markup in order to make our changes easily visible and comparable.

Thank you again for the valuable feedback, we believe it helped to make an improved version of the work that will make for a great article for IJGFS.

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10th November, 2022

RUNNING HEAD: Sketching the Future of Human-Food Interaction

**Sketching the Future of Human-Food Interaction:**

**Emerging Directions for Future Practice**

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# 1 **Sketching the Future of Human-Food Interaction:**

## 2 **Emerging Directions for Future Practice**

### 5 **ABSTRACT**

6 There is an increasing interest in food within the Human-Computer Interaction (HCI) field  
7 with emerging interactive prototypes that augment, extend, and challenge the various ways  
8 in which people engage with food. The emerging subfield is defined as “Human-Food  
9 Interaction” (HFI). Given the rapid advancement of interactive technology that converges  
10 with a wide range of food settings, this article seeks a continuous scrutiny towards the field  
11 to ensure it advances in fruitful directions. In this article, we identify nine emerging themes  
12 building on the submissions presented by 19 researchers at an HFI workshop recently held  
13 at an international conference. Furthermore, we brought to light three potential design and  
14 research directions to inspire HFI futures, and, simultaneously, to build a foundation upon  
15 which HFI, gastronomy and food science communities can work together.

16 **Keywords:** Food, Interaction Design, Human-Computer Interaction, Human-Food  
17 Interaction

### 18 **1 INTRODUCTION**

19 Food is an essential part of life. From birth to death, we spend hours procuring, preparing,  
20 eating, digesting, and thinking of food (Rozin et al., 2003), and innovations in food practices  
21 have shaped our life experiences (Ulijaszek et al., 2012). The emergence of digital  
22 technology has taken food innovation to new heights, including significant changes to the

23 ways in which foods are produced, prepared, and consumed. The convergence between food  
24 and technology, producing novel engagements with food, has become a vital matter of  
25 interest in Human-Computer Interaction (HCI) research. Innovations are taking place in  
26 digital fabrication (Mizrahi et al., 2016), interactive eating (Mehta et al., 2018), and  
27 gustatory augmentation (Narumi et al., 2011), have combined to constitute an emerging  
28 subfield within HCI, which has been named “Human-Food Interaction” (HFI) (Altarriba  
29 Bertran & Wilde et al., 2019; Choi et al., 2014; Comber et al., 2014; Deng et al., 2021; Khot  
30 et al., 2019), denoting the “the interconnection between the self and food”(Choi et al., 2014).  
31 Subsequently, the various research has turned HFI into a flourishing area of study. The use  
32 of digital technology has underpinned a wide variety of implementations that have enriched  
33 food practices across bodily (Khot et al., 2017a), communal (Wang et al., 2020), societal  
34 (Barden et al., 2012), environmental (Liu et al., 2018), and planetary aspects (Obrist et al.,  
35 2019). At the same time, the heterogeneous nature of this emerging field challenges  
36 researchers and practitioners to critically engage with the community (Altarriba Bertran &  
37 Wilde et al., 2019). In this context, we call for continuous scrutiny towards the field to ensure  
38 it advances in fruitful directions.

39 While there have been various food research in the area of gastronomy, for example, food  
40 studies in relation to the arts (Youssef et al., 2018), the humanities (Hsu et al., 2022; Spence,  
41 2021), the natural sciences (Spence, 2022; Spence & Youssef, 2019), and the social sciences  
42 (Koerich & Müller, 2022; Plata et al., 2022). However, HFI and gastronomy have different  
43 cultures and practices of scientific enquiry and, so far, the two fields have limited synergy  
44 in a substantive way to develop a deep and common understanding of food. In this context,  
45 this article attempts to build a foundation upon which HFI, gastronomy and food science  
46 communities can work together. To support this collaboration, we examined 19 recent HFI  
47 works and identified nine emerging themes and a set of future directions that we hope can  
48 inspire food researchers and practitioners to collaborate to create preferable food futures.

## 49 2 BACKGROUND

50 Over the last couple of decades, there has been a notable increase in HFI research,  
51 highlighting the exciting possibilities for technology to impact our food practices and  
52 experiences (Altarriba Bertran & Wilde et al., 2019). To demonstrate new ways to interact  
53 with food, researchers have experimented with emerging technologies such as  
54 computational gastronomy (Zoran, 2019), food printing (Khot et al., 2017a; Sun et al.,  
55 2015), virtual reality (Arnold et al., 2018), capacitance sensing (Heller, 2021; Wang et al.,  
56 2018; Wang et al., 2020), robotics (Mehta et al., 2018), electrical muscle stimulation  
57 (Niijima & Ogawa, 2016), acoustic levitation (Vi et al., 2017; Vi et al., 2020), and shape-  
58 changing interfaces (Nishihara & Kakehi, 2021; Wang et al., 2017) to illustrate new ways  
59 of interacting with food. Also, gastrophysics researchers (Spence, 2017) and multisensory  
60 researchers (Spence & Piqueras-Fiszman, 2014; Velasco, 2020; Velasco et al., 2018a;  
61 Velasco et al., 2018b) have explored new ways for culinary practitioners and designers to  
62 use emerging technology to innovate with food design and enhance the associated dining  
63 experiences.

64 We contend that the “technological solutionism” (Morozov, 2013) found in some of the  
65 works we reviewed is only one of many ways in which we can bring together food and  
66 technology design. For example, Comber et al. (2012) proposed that HFI needs to pay  
67 greater attention to people and the ways in which they engage with food, rather than focusing  
68 on the efficiencies and novelties that new technologies offer; the authors also argued that  
69 due to the nuanced practices and experiences around food and technology, HFI has been  
70 evolving dynamically with the varied perspectives of understanding across transdisciplinary  
71 research fields, reflecting the diversity of ways people interact with food. For example, prior  
72 works from a range of fields, including anthropology (Holtzman, 2006; Mintz & Bois,  
73 2002), medical sciences (Kendrick, 2008; Scrinis, 2013; Willett & Stampfer, 2013),  
74 psychology (Bays, 2017; Connor & Armitage, 2002; Rogers et al., 2016), and sociology

75 (Schneider, 2018; Warde, 2016), have increasingly utilized food as a research vehicle to  
76 understand the beneficial impacts that the integration of food and technology can have on  
77 human health (McCurry, 2022), wellbeing (Block et al., 2011), social experiences (Chen et  
78 al., 2021), and planetary sustainability (Liu et al., 2018).

79 This transdisciplinary nature of HFI has motivated researchers in the field to initiate a  
80 wide range of articulations of the relationships between food, human, and technology, and  
81 of HFI's social and environmental impacts. For example, employing three themes – eat,  
82 cook, and grow – Choi et al. (2014) put forward a rich platter of perspectives and a variety  
83 of expertise from design, computing, and social studies to find ways to design technology  
84 toward engaging, healthy, socially inclusive, and environmentally sustainable food futures.  
85 Similarly, Khot et al. (2019) reviewed existing research in HFI and conceptualized a rich  
86 design space to guide further exploration. While these prior works represent initial attempts  
87 to conceptualize how we might understand and design HFI for a better future, they do not  
88 offer a systematically thorough revision of the current state of HFI. This poses a question:  
89 how do researchers and practitioners remain up to date with the state of HFI, so that they  
90 can continuously engage with and make sense of this emerging field?

91 In response, Altarriba Bertran & Wilde et al. (2019) developed a literature review tool  
92 and a conceptual model of the broad spectrum of HFI disciplines, methodologies, and  
93 research agendas. Based upon their examination of the state of HFI research, using a  
94 taxonomy they developed from a 260-publication dataset, the authors expressed their  
95 concern that the number of HFI research “contributions that fix, speed up, ease, or otherwise  
96 make interactions with food more efficient, clearly outweigh those that explore the social,  
97 playful, or cultural aspects of food practices.” In response to this concern, the authors called  
98 for more research that focuses on food practices and cultures “to ensure that advances in  
99 technology do not come at the cost of enriched, embodied engagement with and through  
100 food” (Altarriba Bertran & Wilde et al., 2019, p. 9). The authors also pointed out that their



101 dataset and analysis of the latest HFI research should be continuously updated, to ensure an  
102 ongoing meaning-making process within HFI. Likewise, in their review of existing HFI  
103 works, which focused on the use of computational technologies, exploration of human  
104 senses, and digital interactions in food experience design, Aguilar et al.'s (2019) concluded  
105 that “where everyday new discoveries appear, the challenges to be solved are constant,  
106 frequently challenging the researcher” (dos Santos Aguilar & Aguilar, 2019).

107 Additionally, a variety of HFI workshops, Special Interest Groups (SIGs), and events have  
108 made significant contributions to the field's understanding and visions of the future of food  
109 (Choi et al., 2009). For example, “Future of Food in the Digital Realm” SIG (Khot et al.,  
110 2017b) discussed food printing practices and envisioned a future of digital technology for  
111 food fabrication, while other workshops (Ferran Altarriba Bertran et al., 2019; Chisik et al.,  
112 2020; Davis et al., 2020; Dolejšová et al., 2020; Vannucci et al., 2018) reimagined future  
113 food practices and play that can nourish both people and the planet. Also, a “Manifesto on  
114 the interwoven Future of Computing and Food” (Obrist et al., 2018) was developed from  
115 work undertaken at an ACM Future of Computing Academy event.

116 Because of the rapid progression of HFI research and knowledge, the HFI community  
117 faces the challenge of maintaining the currency and completeness of its understanding of the  
118 state-of-the-art. With this challenge in mind, we concur with the call for an ongoing HFI  
119 meaning-making process (Altarriba Bertran & Wilde et al., 2019), and we call for  
120 continuous and constant scrutiny of HFI to ensure it advances in fruitful, societally desirable  
121 directions, and meanwhile, to look at what comes next. In response to these HFI imperatives,  
122 this article examines 19 recent HFI works to provide an update to the HFI community's  
123 current understanding of HFI work, and to identify emerging themes that indicate promising  
124 future directions for HFI research and inspire practitioners to venture down new paths.

### 125 3 METHOD

126 This article is based on the outcomes of a workshop (“The future of Human-Food  
127 Interaction”) we conducted at the Association for Computing Machinery CHI Conference  
128 on Human Factors in Computing Systems in 2021 (Deng et al., 2021). brought together  
129 experts with diverse opinions on the design of the experiential aspects of technology-enabled  
130 food engagements and offered a forum in which the research community and a broad range  
131 of practitioners could learn from each other. To encourage further HFI community-building,  
132 we invited a wide variety of submissions on HFI explorations and received 19 proposals<sup>1</sup>  
133 co-authored and submitted by practitioners, researchers, and theorists from several  
134 universities, research centers, and industry-based organizations across the world. The  
135 submission topics included theory, methods, technology, and applications from a variety of  
136 perspectives, including computer science, food science, HCI, psychology, design,  
137 multimedia and the digital arts, affective and social computing, data science, cyber-physical  
138 systems, machine translation, cognitive science, intelligent engineering, digital health,  
139 marketing, and communications. These submissions and the workshop discussions  
140 constitute the data that this article analyzes (Table 1). The workshop was conducted via  
141 videoconferencing, with the activities divided into two parts. In part one, submission lead  
142 authors made PechaKucha presentations of their content, then all workshop participants  
143 engaged in open discussion around the topics, ideas and research presented. In part two,  
144 breakout groups brainstormed the HFI space, challenges, and concepts, then showcased the  
145 outcomes of their activity to the whole workshop. We also discussed the future of HFI with  
146 specific attention given to how technology design can contribute to stimulating, sustainable,  
147 just, and socio-culturally rich food futures.

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<sup>1</sup> All submissions can be found on the workshop’s online collaboration platform here:  
[https://miro.com/app/board/o9JILLQmP0=?share\\_link\\_id=885890873005](https://miro.com/app/board/o9JILLQmP0=?share_link_id=885890873005).

148 We analyzed the workshop submissions and the workshop outputs to identify key themes.  
 149 We followed a reflexive thematic analysis process (Braun & Clarke, 2019), whereby we  
 150 progressively made sense of the workshop submissions emphasizing our “reflective and  
 151 thoughtful engagement” with our data and analytic process. While thematic analysis is quite  
 152 common in HFI research, its procedure is the subject of some debate. (Braun & Clarke,  
 153 2021). Instead of rigidly following a traditional “phase-approach” procedure (Braun &  
 154 Clarke, 2012), we believe that “quality reflexive thematic analysis is not about following  
 155 procedures ‘correctly’ (or about ‘accurate’ and ‘reliable’ coding, or achieving consensus  
 156 between coders)” (Braun & Clarke, 2019). First, three authors of this article independently  
 157 reviewed the workshop submissions to establish an overview of the data and identify  
 158 patterns of shared meaning (emerging themes) across the works reflecting the primary  
 159 design/research directions of future HFI. Using this initial list, two of the researchers  
 160 iteratively combined and synthesized the themes based on their commonalities and  
 161 differences. After three iterations, nine key themes emerged from the analysis: 1) food  
 162 perception, 2) blending interfaces, 3) food magic, 4) food play, 5) digital commensality, 6)  
 163 food tech for all, 7) healthy food choices, 8) sustainability, and 9) empowering R&D. These  
 164 themes were independently checked and confirmed by a third researcher.

#### 165 **4 THEMES**

166 This section sets out the 19 workshop submissions (WS) and their connections with the nine  
 167 HFI futures themes (Table 1), then defines each theme and outlines the workshop  
 168 submissions that exemplify that theme.

169 **Table 1: A summary of workshop submissions, authors, affiliations, and key themes**

WS	Submission Title	Author(s)	Affiliation(s)	Theme(s)
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1	Differences In Remembered Taste and Smell Sweetness in Food and Beverages Between Sweet-Liker Phenotypes.	Chi Thanh Vi, Rhiannon Armitage, Martin Yeomans	Sussex Ingestive Behaviour Group, School of Psychology, University of Sussex, UK.	<b>Food perception</b>
2	Motivating Research Intersecting Visual Analytics and Human-Food Interaction.	Michelle Dowling Timothy L. Stelter	School of Computing, Grand Valley State University, USA. Department of Computer Science, Virginia Tech, USA.	<b>Food perception; Blending interfaces; Empowering R&amp;D</b>
3	The Future of Food is on the (Capacitive) Table.	Florian Heller	Hasselt University–tUL–Flanders Make, Belgium.	<b>Blending interfaces</b>
4	Mind-Gut Computer Interaction: Research Areas and Opportunities.	Khalid Majrashi Alexandra L. Uitdenbogerd	Department of Information Technology, Institute of Public Administration, Saudi Arabia. School of Science (Computer Science), RMIT University, Australia.	<b>Blending interfaces</b>
5	Impossible Food Experiences in Virtual Reality.	Carlos Velasco Francisco Barbosa Escobar, Qian Janice Wang	Department of Marketing, BI Norwegian Business School, Oslo, Norway. Department of Food Science, Aarhus University, Aarhus, Denmark.	<b>Food magic</b>
6	Rendezfood – Interacting with Anthropomorphized Food.	Philip Weber, Thomas Ludwig	Cyber-Physical Systems, University of Siegen, Siegen, Germany.	<b>Food Magic, Empowering R&amp;D</b>
7	Gastroludology – Gastronomy Meets Ludology.	Yoram Chisik	Independent researcher.	<b>Food play, Food magic</b>
8	Socially Situated Human-Food Interaction.	Gijs Huisman Roelof Anne Jelle De Vries Mailin Lemke Maurizio Mancini	Delft University of Technology, the Netherlands. University of Twente, the Netherlands. Delft University of Technology, The Netherlands. Sapienza University of Rome, Italy.	<b>Digital commensality</b>
9	Designing To Support the Exchange of Food and Eating Practices Between Remote, Intergenerational Family Members.	Aswati Panicker, Kavya Basu, Chia-Fang Chung	Indiana University Bloomington, USA.	<b>Digital commensality</b>
10	Digital Commensality Helps Strangers Connect – A Qualitative Study.	Khawla Alhasan, Chee Siang Ang, Alexandra Covaci	University of Kent, UK.	<b>Digital commensality</b>

11	“My Mind Was Telling Me ‘Stay in Bed All Day... Only Get Up to Eat’”: Opportunities to Design Around Food from Eating Behaviors During the Pandemic.	Mario O. Parra, Jesus Favela	Ensenada Center for Scientific Research and Higher Education, Mexico	<b>Digital commensality</b>
		Luis A. Castro	Sonora Institute of Technology (ITSON), Mexico	
12	Investigation Of Human-Food Interaction (HFI) and Food Practices Behaviors in People with Intellectually Disability.	Shijing He	Cisco Systems, Inc., China	<b>Food tech for all</b>
13	Food Sharing and IoT in Community Building: The Case of Community Fridges.	Sarah Kiden, Joyce Yee, Angelika Strohmayer	School of Design, Northumbria University, Newcastle upon Tyne, UK.	<b>Food tech for all</b>
14	Ambience and Appraisal: Effect of VR and AR Generated Ambience on Consumers’ Food Evaluations and Food Choices.	Pennanen Kyösti, Vanhatalo Saara	VTT Technical Research Centre of Finland Ltd, Finland.	<b>Healthy food choices</b>
		Raisamo Roope	Tampere University, Finland	
		Sozer Nesli	VTT Technical Research Centre of Finland Ltd, Finland.	
15	Exploring Tradeoffs in The Design Space of Human-Centered Semi-Automated Food Journaling.	Xi Lu	Informatics, University of California Irvine, USA.	<b>Healthy food choices</b>
		Sruthi Ramabadran	Cognitive Sciences, University of California Irvine, USA.	
		Edison Thomaz	Electrical and Computer Engineering, University of Texas at Austin, USA.	
		Daniel A. Epstein	Informatics, University of California Irvine, USA.	
16	A Future Vision for Sustainable Human-Food-Interaction.	Philip Engelbutzeder	University of Siegen, Siegen, Germany.	<b>Sustainability</b>
17	Envirofy: A Real Time Tool to Support Eco-Friendly Food Purchases Online.	Gözel Shakeri	University of Glasgow, Scotland, UK.	<b>Sustainability</b>
		Claire McCallum	University of Northumbria, England, UK.	
18	The Future of Meat: Sentiment Analysis of Food Tweets.	Maija Kāle	Faculty of Computing, University of Latvia, Latvia.	<b>Sustainability</b>
		Matīss Rikter	The University of Tokyo, Japan.	
19	Virtual Farmer’s Market: Towards Virtualizing and Augmenting Food Testing.	Summer D. Jung	Center for Design Research, Stanford University, USA.	<b>Empowering R&amp;D</b>
		Chandrayee Basu	Independent researcher, USA.	

170

**171 4.1 Theme 1: Food perception**

172 The food perception theme relates to submissions that focus on understanding the  
173 mechanisms associated with how we perceive food in the way we do. The theme  
174 encompasses research into the multi-sensory nature of food experiences, and how those  
175 multi-sensory experiences can be studied and understood by using interactive technology,  
176 and research often draws upon other fields, such as sensory science, psychology, and  
177 neuroscience.

178 With respect to food perception, Vi et al. (WS1) investigated perceptions of the  
179 sweetness of foods and drinks among people of different sweet-liking types. Their findings  
180 suggested a correspondence between people's sweet-liking phenotypes and their memories  
181 of the perceived sweetness of foods and beverages. The authors pointed out that this study  
182 could potentially inform future designs of more personalized gustatory and olfactory  
183 interfaces. Complementing this work, Dowling and Stelter (WS2) proposed an under-  
184 explored area at the intersection between HFI and "Visual Analytics (VA)". The authors  
185 aimed to help users to communicate their food and eating experiences across cultures and  
186 languages via the interactive visualization of food items in the dataset. Using statistical  
187 analytic approaches, Dowling and Stelter's system allowed users to compare similarities  
188 amongst food items in terms of taste and mouthfeel attributes.

**189 4.2 Theme 2: Blending interfaces**

190 The blending interfaces theme relates to submissions that focused on interfaces that blend  
191 the real and the digital world, and it encompasses the exploration of how to make the edible  
192 computational and the computational edible.

193 With respect to blending interfaces, Heller (WS3) presented a new interaction space for  
194 food as an edible, tangible, ephemeral interface, by using muffins as part of the interactive  
195 medium that could be detected and identified on a capacitive touchscreen. The system  
196 enabled animated food recommendations and opened up new ways to arrange and serve  
197 food. Majrashi and Uitdenbogerd (WS4) proposed “Mind-Gut Computer Interaction  
198 (MGCI)”, whereby human mind-gut activities can be blended with external computing  
199 devices. The authors envisioned combining brain activities and human motility, secretion,  
200 nutrition delivery, and microbial balance with computation. The authors also presented four  
201 potential MGCI research opportunities: using ubiquitous, wearable, or mobile computing  
202 tools and systems to detect and record mind-gut activities; developing visualization tools to  
203 enhance the understanding of mind-gut communications; providing tailored food intake  
204 advice (to optimize mind-gut communications) based on an individual’s mind-gut activities  
205 data; and evaluating user interfaces and experiences.

### 206 **4.3 Theme 3: Food magic**

207 The food magic theme relates to submissions that focused on the creation of technology-  
208 enabled food experiences that go beyond the real and towards and towards the fantastical by  
209 defying the limitations of analog food practices and breaking the laws of physics. Food  
210 magic research focuses on allowing users to experience sensory experiences that would be  
211 impossible without the mediation of computation.

212 With respect to food magic, Velasco et al. (WS5) proposed a “reality-impossibility”  
213 model to guide future research into and design possibilities for “impossible food  
214 experiences” via virtual reality. This model aims to open new opportunities through breaking  
215 the laws of physics, and the authors envisioned “fantasy dining scenarios where the  
216 questions of where, when, who, and what to eat are all open to experimentation.” Weber and  
217 Ludwig (WS6) conceptualized another future possibility for a food magic experience:

218 “Rendezfood”. The “Rendezfood” Augmented Reality (AR) application enables diners to  
219 interact (“chat”) with “anthropomorphized” food in a human-like manner. Also, Chisik  
220 (WS7) proposed several possibilities for using multimedia for playful eating augmentations.

#### 221 **4.4 Theme 4: Food play**

222 The “food play” theme is concerned with submissions that focused on playful interactions  
223 with/through food, including the study and the design of novel artifacts, systems, and  
224 experiences that afford such playful interactions.

225 Specifically, Chisik (WS7) introduced the notion of “Gastroludology” and argued that  
226 exploiting “food affordances and properties” holds an inherent potential for play. The author  
227 also provided examples of a growing research interest in harnessing technology to engage  
228 and play with food. Examples of this interest include the use of image projection to alter the  
229 perceived quantity of food, applying electricity to the tongue to simulate taste sensations  
230 and create novel taste and texture experiences, and sharing virtual taste sensations to  
231 augment social eating and cooking experiences. Chisik suggested that future playful HFI  
232 designs could consider the development of games to engage people with the broader cultural  
233 and environmental aspects of food, and the design of food as electronic interface elements  
234 in applications and games.

#### 235 **4.5 Theme 5: Digital commensality**

236 The digital commensality theme refers to studies of eating together and the multi-faceted  
237 nature of social dining. It encompasses research that explores the social dimension of eating  
238 experiences and the design of technologies that intervenes with it.

239 For example, Huisman et al. (WS8) proposed an HFI approach that “considers food and  
240 the act of eating as being socially situated”, and “technology as a lens through which to view  
241 social eating, and develop artifacts that serve as mediators for social engagements around



242 food.” Panicker et al. (WS9) conducted a study on nuanced forms of long-distance  
243 communication and social connectedness in families and this study inspired the future  
244 design of systems that support healthy eating conversations by facilitating sharing behaviors  
245 among family members. Alhasan et al. (WS10) provided an initial account of how current  
246 digital platforms (e.g., AR) can offer an enhanced sense of commensality by facilitating  
247 “open-up”, “relaxed”, and “informal” communications while users eat. Parra et al. (WS11)  
248 reported on an eating behavior study that was conducted during the Covid-19 pandemic. The  
249 study’s aim was to inform the design of future interactive technologies to enrich eating  
250 experiences, including improving socialization while eating (e.g., turning solo home  
251 cooking into impromptu online social activities) as a way of alleviating negative feelings  
252 such as loneliness. The authors proposed the design of a virtual space in which people could  
253 gather around food (the food equivalent of “gather.town”) and which could be presented as  
254 different types of locations (e.g., virtual restaurants, pubs).

#### 255 **4.6 Theme 6: Food tech for all**

256 The “food tech for all” theme is concerned with submissions that focus on food-related  
257 inclusive design. This theme encompasses research into how technology can help to make  
258 food practices more inclusive, and how to design food-related technology that is inclusive  
259 and accessible.

260 With respect to food tech for all, He’s (WS12) research statement proposed that future  
261 HFI design should aim to improve the wellbeing and quality of life of people with  
262 intellectual disabilities by reducing public discrimination and prejudice in food practices.  
263 He called for the integration of ethnography with user-centric, inclusive, participatory, and  
264 collaborative design, and the consideration of deep engagement, interdisciplinarity,  
265 individuality, and practicality when designing technologies for populations with special  
266 needs. Taking a different perspective on the same goal of creating food technology for all,

267 Kiden et al. (WS13) investigated how a network of community fridges could use Internet of  
268 Things (IoT) technology to support social inclusion in culturally diverse neighborhoods.

#### 269 **4.7 Theme 7: Healthy food choices**

270 The “healthy food choices” theme relates to submissions that focused on the design and use  
271 of interactive technology to facilitate healthy eating choices.

272 With respect to healthy food choices, Kyösti et al. (WS14) reported on two experiments  
273 utilizing VR and AR technologies to investigate how multisensory ambience could affect  
274 dietary behaviors. The results of these experiments indicated that a “sunny day” and “nature”  
275 ambience was more likely to nudge participants toward healthier food choices (i.e., rye  
276 nacho and vegetable-based dishes). Experiments like these could inform the future  
277 development of technologies and consumer studies that aim to encourage/support healthier  
278 food choices. Similarly, Xi et al. (WS15) proposed a “speculative survey” of several concept  
279 designs of on-body diet tracers and suggested the use of wearable and intraoral sensors to  
280 explore users’ acceptance of different self-monitoring technologies for food journaling. The  
281 goal of these wearables and sensors would be to give users a better understanding of their  
282 eating patterns, thereby helping them to build healthier eating habits and manage their  
283 weight.

#### 284 **4.8 Theme 8: Sustainability**

285 The “sustainability” theme relates to submissions that focused on overcoming sustainability  
286 challenges associated with food. This theme encompasses research into how technology can  
287 support sustainable food lifestyles, as well as how food-technology innovations can be  
288 ecologically sound.

289 Specifically, Kāle and Rikter (WS18) reported on their analysis of food tweets to assess  
290 changes in the public mood and attitude toward meat consumption over the past nine years.

291 This report, according to the authors, could potentially “pave the way for, e.g., alternative  
292 proteins as well as vegetarian/vegan diets”. Engelbutzeder (WS16) called for future  
293 “sustainable HFI” research that addresses the urge for “a deep change in food systems”, and  
294 that highlights the “values, consumption and production practices, as well as politics  
295 allowing for deliberation and grassroots mobilization.” Shakeri and McCallum (WS17)  
296 argued that educating consumers about the environmental impact of their choices as they  
297 shop may be a powerful approach to encouraging eco-friendly food purchases. The authors  
298 presented Envirofy: a real-time e-commerce grocery tool (in the form of a browser  
299 extension) that allows shoppers to reduce their dietary carbon footprint by delivering  
300 “behavioral interventions” when they are making purchase decisions. A pilot test suggested  
301 that Envirofy could improve “relevant knowledge, skills and perceived consumer  
302 effectiveness across all participants” while reducing the CO<sub>2</sub> in their shopping basket by 14  
303 percent.

#### 304 **4.9 Theme 9: Empowering R&D**

305 The theme “empowering R&D” relates to submissions that focused on the mediums,  
306 methods, and processes that facilitate research and development in HFI. This theme  
307 encompasses research into technologies and methods that support food sector professionals  
308 (e.g., food markets, restaurants, and the hospitality industry) to develop digital alternatives  
309 that enrich customer experiences, through more personalized options, and help corporations  
310 cope with extreme situations, such as pandemics.

311 For example, Jung et al. (WS19) presented a study on “human-food-human interaction”,  
312 which investigated enabling people to try out and experience the food in a virtualized  
313 farmer’s market environment. Their study envisioned future virtual systems to bridge the  
314 vocabulary gap between food makers and food eaters. Weber and Ludwig’s “Rendezfood”  
315 (WS6), aimed to increase awareness and intensify customer loyalty in the catering industry

316 by creating an emotional connection between the customer and food products, highlighting  
317 future technological companions (e.g., AR) that enable augmentation and communication  
318 with food in a human-like manner.

## 319 **5 DISCUSSION: FUTURE DIRECTIONS**

320 HFI research has been predominantly a technology-centric endeavor, according to previous  
321 research (Altarriba Bertran & Wilde et al., 2019). Such techno-solutionist (Morozov, 2013)  
322 approaches may seem to contradict the goal of HFI research, which aims to emphasize the  
323 people and the ways they engage with food (Comber et al., 2014). In response, Alonso  
324 (2020) identified future opportunities focusing on the materiality and consumption of food.  
325 Furthermore, Velasco et al. (2021) summarized multiple areas for future development  
326 around multisensory inquiries, including eating, food attitude, social aspect, and ethical  
327 considerations. Our analysis of the work discussed at our workshop with HFI experts  
328 highlights a set of design and research directions that approach the human-food-technology  
329 interplay through a more diverse and holistic perspective. Furthermore, our themes  
330 demonstrated a more heterogeneous nature across various areas. From our critical reflection  
331 on the themes that emerged from the workshop, here we share four areas of HFI that might  
332 give rise to exciting future advancements in the field.

### 333 **5.1 Design for experiential augmentations via food's material affordances, integrated** 334 **mind-gut activities, and multisensory experiences**

335 Our themes (particularly food perceptions, blending interfaces, and magic food) revealed  
336 that designing for experiential augmentations is an exciting direction in which the HFI field  
337 can advance. While previous work has explored technologies for augmented eating, such as  
338 eating with mixed reality (Narumi et al., 2011) and digital taste (Ranasinghe et al., 2016),  
339 we identified a set of new approaches to designing experiential augmentations. For example,  
340 rather than focusing on technological novelty and efficiency, we propose the employment

341 of food and its affordances as a material and playground for interaction design. This  
342 direction requires us to consider the food physics (i.e., the physical properties of food  
343 materials) (Figura & Teixeira, 2007) and food's aesthetic, affective, sensual, and  
344 sociocultural qualities (e.g., (Deng et al., 2022; Obrist et al., 2014; Obrist et al., 2019)). We  
345 hope that this focus will reveal new ways to produce, serve, and engage with food. Another  
346 approach to experiential augmentation is integrating mind-gut activities within  
347 computational systems. Another approach to designing for experiential augmentations is to  
348 integrate mind-gut activities within computational systems. One possible design direction  
349 could be to consider the human gastrointestinal tract and the brain activities as synergistic  
350 parts of the computational systems, with the objective of enabling a more personal  
351 communication between the consumer and the creator and delivering more personalized  
352 services and experiences in real-time. Furthermore, incorporating multisensory experiences  
353 into food practices and contexts could offer a pathway to experiential augmentations for  
354 consumers. In this respect, possible design considerations include multimodal HFI through  
355 studying the sensorial phenomenon and developing multimedia devices and VR/AR  
356 applications for creating playful and magical food experiences. Overall, this direction could  
357 potentially lead the way to future advancements in hospitality, food markets and retail shops  
358 by enriching any product line and creating novel food experiences.

## 359 **5.2 Reinforce commensality and sociocultural bonds for communal responsibility**

360 Sociocultural engagement provides an opportunity to solidify food values and norms and  
361 strengthen communal ties (Batat et al., 2019), especially, our themes (particularly food play,  
362 digital commensality, and food tech for all) emphasized building up a more accessible,  
363 inclusive, and just food community for everyone. The future direction of reinforcing  
364 commensality and sociocultural bonds, inspired by our themes, suggests a multifaceted  
365 pathway. This could include designing technology-enabled remote eating (e.g., tele-dining  
366 installations), technology-mediated environments where diners can eat together (e.g.,

367 utilizing virtual and augmented reality), or developing Metaverse food communities that  
368 place a virtual layer over the physical world and help people to socialize over food. Our  
369 themes also point toward a research direction that incorporates inclusive, justice-focused,  
370 and participatory design approaches into technology developments, including the use of IoT  
371 and the use of open-source hardware to design more accessible food technology. This future  
372 direction for HFI design and research could inspire policy makers, social designers, and  
373 scientists to build a more engaging, just, and ethical community around food.

### 374 **5.3 Promote better food choices for health and environmental care**

375 Our themes also revealed the potential for HFI to raise awareness and empower design for  
376 healthy food choices and environmental care through technological interventions  
377 (particularly healthy food choices and sustainability). The themes suggested two future  
378 possibilities of designing technology to promote healthy food choices: the first being to  
379 facilitate nudging through multisensory design created through VR and AR; and the second  
380 being the use of bodily monitoring devices and on-body sensors to better understand users'  
381 eating patterns. Our themes also highlighted possible technology interventions (e.g.,  
382 utilizing social media to collect food-related data, and developing applications to track  
383 customers' behavior in relation to food practices) for improving food attitudes, food beliefs,  
384 and food knowledge. The insights gained from these interventions can then guide  
385 researchers in their design of novel systems that aim to vary people's food choices and  
386 support a more sustainable food future. Overall, we hope that this direction in HFI research  
387 and design will light the way for governments and food institutes who are looking for new  
388 ways to improve customers' understanding and awareness of their consumption and its  
389 impacts.

## 390 6 LIMITATIONS & FUTURE WORK

391 While we acknowledge the limitations of our work, these limitations also present  
392 opportunities for future work. We acknowledge that this article does not provide an *ultimate*  
393 *guide* to future HFI research, given that it is based upon the results of an examination of a  
394 limited number of submissions made at a single workshop. Our more modest goal is to offer  
395 a timely summary of what a group of HFI experts see as the future ways in which research  
396 and design might bring food, humans, and technology together to beneficially shape human  
397 food practices. The addition of the work and perspectives of other experts would allow for  
398 a more comprehensive understanding of the present state of HFI and provide richer insights  
399 into future HFI practices. We also acknowledge that HFI does not yet adequately cover some  
400 contemporary developments in food studies, including emerging research around: food  
401 provenance, authenticity and the use of blockchain (Cao et al., 2021; Foth, 2017; Teli et al.,  
402 2022); food waste (Berns et al., 2021; Farr-Wharton et al., 2014; Farr-Wharton et al., 2012);  
403 and green energy in food preparation (Kuznetsov et al., 2022). Also, it is necessarily to point  
404 out that our work is only a starting point and does not comprehensively address all aspects  
405 of contemporary food issues raised in previous studies, including agriculture and production  
406 challenges (Pawlak & Kołodziejczak, 2020), food policy and allocation issues (Alkaabneh  
407 et al., 2021), as well as hunger (Collier, 2008) and the climate crises (Downing et al., 1996).  
408 Our work provides only a starting point that needs to be developed and critiqued further by  
409 other scholars and practitioners across food, gastronomy, and HCI. With these gaps in mind,  
410 we intend to conduct future workshops, special interest groups, and seminars to continue the  
411 discussion of possible HFI futures, and to, thereby, facilitate an ongoing sense-making  
412 process (Altarriba Bertran & Wilde et al., 2019).

413 Finally, we acknowledge that our article originated from a group of researchers who are  
414 predominantly from institutions around the developed world (mostly the USA and Europe).  
415 Consequently, our results might be perceived as reflecting the biases inherent to our

416 “privileged” positions. For example, the future directions we identify might only be relevant  
417 to or in reach of those in similarly privileged positions. Furthermore, as contributors to, and  
418 convenors, coordinators, examiners, analysts, and communicators of the workshop content,  
419 processes and results, our inherent values, and our beliefs about the HFI field might have  
420 biased the selection and characterization of themes and future directions. Nevertheless, we  
421 believe that this article’s assessment provides a comprehensive foundation for future  
422 research that advances the HFI field. Our different roles in the workshop allowed us to  
423 develop an intimate knowledge of the submissions and an overarching view of the workshop  
424 outcomes as they unfolded. We believe this privileged position helped us to establish and  
425 communicate a deep and rich understanding of the emerging themes and future directions  
426 of HFI.

## 427 **7 CONCLUSION**

428 In conclusion, as the HFI field rapidly progresses and expands, overviews of its status can  
429 quickly become outdated. Contributions to knowledge and systems in the field also need to  
430 be constantly re-assessed with reference to what will no doubt be rapid changes in the field’s  
431 aims. In this context, we convened a workshop in which we received and examined 19 works  
432 by HFI experts. By analyzing these expert submissions along with the results of the  
433 workshop, we identified nine themes relating to the objectives of HFI research and design  
434 and three emerging future directions for HFI research and design. Ultimately, with our work,  
435 we hope to update the current understanding of HFI and inspire researchers and practitioners  
436 to venture down new paths.

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# Implications for gastronomy

In the manuscript, we call for continuous and constant scrutiny of HFI to ensure it shapes up in fruitful, societally desirable directions, and meanwhile, to look at what comes next – an ongoing meaning-making. To this end, we examined 19 latest works from HFI experts participating in a workshop to identify 9 themes within HFI and reflect on how technology design can contribute to the future of food experiences. We also discussed emerging future directions identified through our analysis. Ultimately, with our work, we hope to update the current understanding of HFI and inspire practitioners to venture down new paths in the future.

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## Conflicts of Interest Statement

We have no conflicts of interest to disclose, and the manuscript complies with the policies on ethical research practices.

Sincerely,

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