Mindful Eating Aspects as Bridging Concepts Represented through the MEDEC Cards: Towards a Design Framework for Mindful Eating Technologies

LALA GULUZADA, ADA University, Azerbaijan; Lancaster University, UK
CORINA SAS, Lancaster University, UK

Eating is complex, as is people's relationship to food, which significantly impacts wellbeing and health. Mindful eating interventions have been shown to be effective in addressing problematic eating, and mindful eating has also gained increasing interest as a research topic in HCI, albeit with limited grounding in health research, so that we know little about how HCI work could be informed by health research on mindful eating and its interventions. Such a theoretical foundation grounded in health research is crucial to ensure the design of safe and effective mindful eating technologies and interventions. To address this gap, we present an analysis of health research on mindful eating principles, measurement scales, and therapeutic interventions such as the MB-EAT program, which helped us identify the main aspects of mindful eating. Then, we conducted a scoping review on technologies targeting these aspects, from which we curated 16 design exemplars representing the breadth of these technologies and generated a new SmartPlate conceptual design. Then, we designed the Mindful Eating Design Critique (MEDEC) cards and reported workshops with 36 mindful eating practitioners who used the MEDEC cards to critique the set of design exemplars. Our main contributions include a solid theoretical foundation grounded in health research for the design of mindful eating technologies, the MEDEC cards as a novel critique tool consisting of 29 cards improved based on practitioners' feedback, and a design framework to further support research and development of mindful eating technologies.

CCS Concepts: • **Human-centered computing → HCI design and evaluation methods**.

Additional Key Words and Phrases: Mindful Eating, Mindful Eating Aspects, Bridging Concepts, Mindful Eating Technologies, Mindful Eating Interventions, MB-EAT, Design Exemplars, Design Cards, Design Space, Design Framework

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1 INTRODUCTION

Eating processes are both complex, satisfying a range of needs from basic ones of energy and nutrition, to those of comfort and belonging, and also flexible, as people may ignore internal hunger signals by overeating or undereating, especially in environments with increased availability of palatable food which is energy-dense and nutrient-poor [139]. As a result, mindless eating has become prevalent, particularly in Western contexts [18], contributing to an unhealthy relationship to food and the epidemic of obesity and eating disorders (EDs) [145]. Mindless eating has been linked to dysregulation of food intake and limited self-control, interoceptive awareness, or emotional regulation [139, 145].

To address these challenges, there has been increased health research indicating the role of mindful eating in reducing problematic eating behaviors, increased quality of food intake [111, 162], and general wellbeing [126, 162]. Much such research has also explored mindfulness-based interventions to support people who are overweight, those living with

Authors' addresses: Lala Guluzada, ADA University, Azerbaijan; and Lancaster University, UK, lguluzada@ada.edu.az; Corina Sas, Lancaster University, UK, c.sas@lancaster.ac.uk.

EDs, or diabetes [126, 162]. Among these, the Mindfulness-Based Eating Awareness Training (MB-EAT) program of interventions stands out for its specific focus on mindful eating and its tailored approach to addressing disordered eating patterns, making it particularly effective for individuals struggling with issues like binge eating and emotional eating [92, 139, 141, 142, 144, 145]. Despite the emerging HCI interest in mindful eating technologies, little is known about how, or which aspects of mindful eating, have been considered for the design of these technologies. Part of such work has been conducted in Human-Food Interaction (HFI) research, which focuses broadly on "*the interconnection between the self and food*" [47] (p.4), with a strong focus on digital commensality for solo or shared meals [8, 43, 196]. An earlier review of 270 HFI papers [12] used six lenses of food source, produce, track, eat, and speculate, showing the emphasis on a technology-centric approach to HFI research focused on system functionalities, rather than a human-centric approach focused on users' experience of technology. This emphasis appears consistent across all lenses, with the exception of the eat lens, where previous work has focused mostly on sensory stimulation for taste perception. This review does not highlight the HFI's work on healthy eating or mindful eating. Another review of HFI research [128] echoed these six lenses by outlining four main themes of growing, cooking, eating, and disposal of food, as well as the topics of healthy eating and mindful eating under the theme of eating. For healthy eating, the review identified mobile apps for food journaling, smart tableware for monitoring food intake, and persuasive games. Authors also highlighted users' challenge of disconnecting from screen-based interaction during meal times, and argued that mindful eating technologies should be designed around this challenge, informed by a richer understanding of the interplay between eating behavior and consumption of screen-based media.

A more recent review of HFI research focused particularly on eating experiences [81] and highlighted the sensory, emotional, cognitive, and social aspects of eating, as well as application domains. Their findings showed emphasis on augmenting sensory stimulation of taste and flavor for more pleasurable experiences, and on healthy eating as the most common application domain. The review [81] also showed that most research on healthy eating focused on supporting eating more healthy food, less caloric-dense food, or eating the right way through persuasive, gamified interfaces, self-tracking, or smart tableware. Their findings indicate that self-tracking technologies such as mobile apps aim to support users' body awareness during eating [60, 93, 187], while AR/VR focused on users' awareness of digestion and metabolization to foster slow chewing for good digestion [17]. The systematic review also showed that slow eating had been targeted by smart tableware such as cutlery or cups to track the eating speed or eating rate to provide real-time feedback, for instance, through traffic-light LEDs [96, 133, 134, 170]. However, besides the emphasis on HFI research on supporting healthy eating, bodily awareness, and slow eating, this review indicates a limited focus on technologies explicitly designed for mindful eating.

As shown above, this emerging HFI work on eating experiences focuses mostly on healthy eating through different types of technologies, most common being mobile apps, AR/VR, or smart tableware. Such research has also touched on some aspects of mindful eating, such as slow chewing, slow eating rate, or small portions, while other aspects, such as avoiding multitasking, have been less investigated. Moreover, such exploration has been *fragmented*, as aspects such as the ones above were often explored in isolation, and with insufficient integration, while even less research has explored how a given technology may support more than a few mindful eating aspects. Not least, the design of such HFI technologies targeting only some aspects of mindful eating has been limitedly informed by health research on mindful eating. We argue that such grounding is much needed and crucial to ensure the future design of safe and effective mindful eating technologies.

However, bridging the gap between theory and practice in design research is not trivial [49, 51, 188, 218] given the need to translate abstract theories into knowledge that can be easily understood by those involved in design, irrespective of their expertise, or stage of the design process. Such translational work has led to the exploration of intermediate-level knowledge from translational resources [49] to bridging concepts [51] or strong concepts [106]. Besides the exploration of design knowledge for bridging the gap between theory and practice, HCI work has also focused on design tools for bridging this gap, including tools such as personas, scenarios, toolkits, or design cards. Cards in particular offer specific benefits as an effective translational design tool that could communicate abstract concepts effectively through text and visual components [174, 177], being accessible and engaging [177].

For translational work in health domain, HCI research has focused for instance on translating acceptance theories to generate the Technology Acceptance Toolkit (TAC) consisting of cards, personas and scenarios to support design for long term acceptance of health technologies [177], the translation of the principles of slow design to generate cards for designing mindful use of everyday products [88], or behavior change theories to develop Behavior Change Design (BCD) cards to support the theoretical informed design of behavior change technologies [138]. However, similar translational work for the design of mindful eating technologies remains limited.

To address this gap, we took a three-pronged approach. First, we explored health research on mindful eating, including mindful eating principles, scales, and the most effective interventions, such as the MB-EAT program, to identify the theoretically and empirically informed main aspects of mindful eating. These aspects, as bridging concepts, could better underpin the design of mindful eating technologies. Second, we explored the current technologies targeting these mindful eating aspects through a scoping review to identify different types of such technologies, their theoretical underpinnings, development stages, stakeholders, and the specific aspects targeted by different technologies. From these, we curated a set of 16 design exemplars to represent the breadth of eight different types of technologies, which we looked closely at in the third study. To achieve this, we have also developed MEDEC cards to communicate the bridging concepts reflecting the main aspects of mindful eating, which we explored together with the design exemplars through a study with 36 mindful eating practitioners. This study asked the experts to critique these design exemplars using the MEDEC cards, and in particular, if, and how, the set of main mindful eating aspects has been properly accounted for in the design of eight types of technologies: mobile apps, wearables, smart tableware, AR/VR, robots, conversational agents, 3D food printing, and image analysis. Practitioners also provided feedback on the MEDEC cards themselves, which we used to slightly revise the cards as the final set. While the co-design of wellbeing and health technologies could benefit from the involvement of various stakeholders, from end users or patients to designers or health experts, the initial intended audience for the MEDEC cards is mindful eating experts, and future work will explore their value for other stakeholders, such as designers and end users interested in these technologies. The cards have been developed over several months of iterative design activities.

While a commonly accepted definition of mindful eating is still awaited, our working definition is the following: *mindful eating is present moment awareness of eating experiences through slowly savoring the food and non-judgmental acceptance of these experiences* [184, 229]. Our work's overarching aim is to identify and address the conceptual fragmentation of mindful eating research in HCI and beyond, by articulating the underlying main aspects of mindful eating, and informing how these aspects can be represented to inform the design of future mindful eating technologies. For this, we focused on the following research questions, each building on the previous one(s), while remaining connected through the *set of main aspects of mindful eating*, which RQ1 identifies, RQ3 captures through MEDEC cards, and RQ2 explores how such aspects are supported or hindered by different types of technologies targeting them. RQ3 also evaluates the MEDEC cards as a novel design critique tool for mindful eating technologies.

- RQ1: Which are the main mindful eating aspects informed by health research?

- RQ2: How have these main aspects of mindful eating been supported or hindered by existing technologies targeting them?
- RQ3: What is the value of the MEDEC cards as a tool to communicate and represent the mindful eating aspects and to critique design exemplars of technologies targeting them?

Our contribution is threefold: (i) a solid theoretical foundation grounded in health research for the design of mindful eating technologies, (ii) MEDEC cards as a novel design tool for mindful eating technologies, and (iii) a design framework for mindful eating technologies structured around three types of systems to direct, alter, and guide experience, and three types of input: user-entered data, tracked movement, and tracked food. Note: The final set of the MEDEC cards is freely available to download in a digital version from the Appendix (Figures 7, 8, 9, and 10). Optionally, a professionally produced printed deck can be ordered through the ***Mindful Eating Lab website***[1].

2 HEALTH RESEARCH REVIEW: IDENTIFICATION OF MINDFUL EATING ASPECTS

Designing mindful eating technologies can benefit from a stronger theoretical underpinning, in which we review health research on mindful eating and examine five widely used scales and effective interventions, such as MB-EAT.

2.1 Mindful Eating: Definitions and Principles

Despite growing interest, mindful eating lacks a universally accepted definition [42, 76, 199, 208], though its multifaceted nature is widely acknowledged [236]. For example, mindful eating was defined as "*non-judgmental awareness of physical and emotional sensations while eating or in a food-related environment*" [73], while Nelson highlighted the importance of the sensory aspects of the food, such as sight, smell, taste, texture, or sound, while being fully present by eating slowly in a non-distracting environment, without multitasking [184]. Central to mindful eating is also tuning into the body, and listening to internal bodily signals of hunger and satiety, while being aware of triggers for eating, including thoughts and feelings, to prevent overeating [229]. These definitions include common aspects such as avoidance of distraction, sensory awareness of food, body awareness of hunger and satiety, problematic relationship to food, and non-judgmental attitude towards eating.

To organize these aspects, another useful lens to conceptualize mindful eating is through the mindfulness concept itself [234], which can be applied to eating experiences [73, 235]. Thus, mindful eating would also align with the *two-factor mindfulness model* involving (i) attention to the present moment, and (ii) non-judgmental acceptance [28]. This involves focusing on eating experiences [118], and approaching related thoughts and feelings without judgment [73], particularly those linked to cravings [235]. Monroe's five principles of mindful eating [171] further outline its core dimensions: (i) savoring food through bodily awareness and without judgment [79, 120, 247], (ii) recognizing hunger and satiety cues [39, 100], (iii) using external cues to support bodily awareness [159] such as (iv) eating slowly through smaller bites [205, 259], and (v) minimizing distractions while eating [29]. These core aspects aligned well with those reflected in the definitions of mindful eating, emphasizing also the importance of savoring food through sensory awareness, and eating slowly through small bites.

2.2 Five Mindful Eating Scales: Overview and Analysis

To further explore the key aspects of mindful eating, we also draw from mindful eating measurement scales. A body of research on mindful eating, aiming to operationalize the construct into its main dimensions, has focused on measurement

[1]https://mindful-eating-lab.com

scales. Over the last fifteen years, five such scales have been rigorously developed through similar approaches: a large set of questions generated from mindful eating literature was included in surveys, completed by large samples of participants, whose factor analysis led to the identification of main dimensions, facets, or aspects of mindful eating. Most commonly used such scales, which also meet the psychometric properties of validity and reliability are: Mindful Eating Questionnaire (MEQ) [73], Mindful Eating Scale (MES) [110], Mindful Eating Behavior Questionnaire (MEBQ) [251], Mindful Eating Inventory (MEI) [199], and Four Facet Mindful Eating Scale (FFaMES) [41] briefly described below.

The Mindful Eating Questionnaire (MEQ) [73] consists of 28 items reflecting five dimensions: awareness (of food sensations), emotional response (eating in response to negative emotions), external cues (eating in response to environmental cues such as food adverts), distraction (focus on other activities while eating), and disinhibition (inability to stop eating even when full). Further studies indicated its reliability and validity for all but the external cues subscale [16]. The MEQ was critiqued for its failure to capture a non-judgmental attitude, and for inclusion of the behavior disinhibition subscale [73]. To address these limitations, Hulbert-Williams and colleagues developed the Mindful Eating Scale (MES) [110] consisting of 28 items reflecting six dimensions: awareness (sensory awareness during eating), acceptance (non-judgmental acceptance of eating experiences), non-reactivity (not reacting impulsively while eating), act with awareness (full attention during eating), routine (degree of habitual/ mindless eating), and unstructured eating (eating in inconsistent or unplanned ways). Authors provided initial validation [110] and further research supported the reliability [160, 161] and validity of all subscales but unstructured eating and routine eating ones [160]. These two latter subscales have been critiqued for capturing aspects beyond the scope of the mindfulness construct [41, 235]. To address this issue, the following three scales were developed. The Mindful Eating Behavior Questionnaire (MEBQ) [251] includes 17 items within four subscales: focused eating, hunger, and satiety cues, eating with awareness, and eating without distraction. The scale shows initial validity [251] with further research indicating its reliability and validity, albeit limited power for the distraction subscale [160].

Mindful Eating Inventory (MEI) [199], which consists of 30 items within seven subscales: awareness of senses while eating, focused attention on eating, eating in response to awareness of fullness, awareness of eating triggers and motives, non-reactive stance (not reacting impulsively to urges while eating), accepting and non-attached attitude towards one's own eating experience, and interconnectedness (considering source and journey of food). Carrière and colleagues critiqued the MEI scale for its limited focus on craving [41], and developed the fifth scale: the FFaMES, for which they reported initial validity and reliability [41]. This scale comprises 29 items within four subscales: internal awareness, external awareness, nonreactance (the ability to maintain a mental distance from impulsive reactions to eat), and non-judgment.

To summarize, although these mindful eating scales vary in numbers and combinations of aspects reflected in their subscales, their specific items indicate six mindful eating aspects broadly consistent with those reflected in mindful eating definitions and mindful eating principles. The key additions provided by the scales include an attitude of gratitude towards food and an emphasis on avoiding distractions to support focused attention on food. The latter is particularly important, as it contrasts with previous arguments that mindful eating technologies should be designed to accommodate screen-based media consumption during mindful eating [128]. From the identified six main mindful eating aspects, two of these are reflected in the subscales of four scales: (i) avoidance of distractions and focused attention on eating (MEQ Distraction, MES Act with awareness, MEBQ Eating with awareness, and Eating without distraction, and MEI Focused attention); and (ii) savoring food through sensory awareness (MEQ Awareness, MES Awareness, MEBQ Focused eating, and MES Awareness of senses while eating). Other three main aspects are reflected in the subscales from three of the scales: (iii) body awareness of hunger and satiety (MEQ Disinhibition, MEBQ Hunger and satiety cues, MEI Eating in response to awareness of fullness), (iv) problematic relationship to food such as triggering negative emotions and thoughts (MEQ Emotional response, MEI Awareness of eating triggers and motives, External cues triggering eating, FFaMES Internal awareness, External awareness), and (v) non-judgmental attitude towards eating (MES Acceptance, Non-reactivity, MEI Acceptive attitude, Non-reactive stance, Non-attached attitude), FFaMES (Nonjudgment, Nonreactance). Finally, the last main aspect is reflected in only one scale: (vi) gratitude for food (MEI Interconnectedness).

2.3 Mindful Eating Interventions

We now describe the three mindful eating interventions: MB-EAT [145], intuitive eating [238], and MEAL [35], which are among the most studied and clinically applied ones, targeting problematic eating and/or eating disorders. These mindful eating interventions draw from both mindfulness-based and mindfulness-informed approaches. The former encompasses programs like mindfulness-based stress reduction [89] or mindfulness-based cognitive therapy [222], while the latter includes therapies such as acceptance-based approaches [105], and dialectical behavior therapy [85].

Systematic reviews and meta-analyses highlighted the significant impact of mindfulness-based interventions on improving eating behaviors and emotional wellbeing for individuals with obesity or overweight conditions [207], as well as increased awareness of internal cues and reduced binge eating across various weight categories [248]. Studies also show potential for long-term weight loss and wellbeing, particularly for those with obesity or EDs [86], and reduced binge and emotional eating [211]. Reviews also underscore the effectiveness of mindfulness meditation in reducing binge eating and emotional eating for people with EDs [125], and systematic reviews confirm significant benefits in emotional and binge eating for those impacted by problematic eating behaviors, both with and without clinical diagnoses [254]. A scoping review by Carriere et al. [42] focused on mindful eating interventions for people with obesity, showing that formal interventions emphasizing attention to eating and a non-judgmental attitude are most effective for weight management and reducing problematic eating. However, the effectiveness of these interventions can be difficult to assess due to the integration of various components from different approaches [192]. Mindfulness-based interventions also show potential for those with limited self-control over behaviors like problematic eating [248], but only a few are specifically designed to target eating habits.

2.3.1 MB-EAT Program. The MB-EAT program of interventions, initially developed for people with binge eating disorders (BED) [142, 143, 145], was further extended to support more broadly people living with obesity conditions [141]. Clinical trials demonstrate its effectiveness in regulating eating for people living with BEDs and for those without such a diagnosis [86, 145, 169]. Theoretically informed by significant work on the role of mindfulness for self-regulation [121], of interoceptive awareness in addressing dysregulation disorders [69, 220], and of food intake regulation in addressing obesity [206], the MB-EAT program supports self-regulation of eating behaviors, rather than imposing dietary recommendations requiring effortful self-control which challenges people with problematic eating [144].

The MB-EAT program integrates mindfulness meditation [119] with guided eating meditations to cultivate *inner wisdom* interoceptive awareness of bodily cues for hunger and satiety, enabling balanced responses to these signals and avoiding under- or overeating [144]. It also emphasizes focused attention to prevent mindless eating [145], and sensory experience of food, highlighting how taste intensity diminishes after a few bites due to habituation [30, 144], fostering mindful taste awareness and slow savoring of smaller portions. Slow eating, particularly through deliberate chewing [171], has been linked to reduced intake rates, increased satiation, and decreased obesity risk [14, 101, 102, 184, 189].

Table 1. Components of most common and effective mindful eating interventions, namely Mindfulness-Based Eating Awareness Training (MB-EAT), Intuitive Eating (IE), and Mindful Eating and Active Living (MEAL).

MB-EAT	IE	MEAL
Cultivating mindfulness	Reject the diet mentality	**Education**
Cultivating mindfulness	Honor your hunger	Behavioral health
Being non-judgemental	Make peace with food	Nutrition
Inner and outer wisdom	Challenge the food police	Mindfulness
Cultivating mindful eating	Feel your fullness	**Exposure**
Mindful attention and awareness of eating	Discover the satisfaction factor	The taste test
Savoring and enjoying food	Cope with your emotions without using food	**Experiental**
Awareness of sensory-specific satiety/taste satisfaction	Respect your body	Dine and discuss
Mindful food choices/ liking and health	Exercise - feel the difference	
Bodily awareness	Honor your health - gentle nutrition	
Non-judgemental awareness of eating		
Cultivating emotional balance		
Awereness of emotions		
Accepting emotions		
Cultivating self-acceptance		
Acceptance of body		
Acceptance of self		
Self empowerment		

Interoceptive awareness also involves distinguishing physical hunger from emotional hunger triggered by stress, anxiety, or boredom, which often leads to mindless eating [144]. The program addresses habitual thought patterns around emotional eating, encouraging non-judgmental awareness of these thoughts and emotions, coupled with self-compassion, to reduce impulsive responses [144, 145]. A non-judgmental attitude extends to body acceptance [144]. In addition to inner wisdom, MB-EAT promotes *outer wisdom*, equipping participants with knowledge about nutrition, calorie balance, portion sizes, and healthy food options to support informed decision-making [142, 143].

2.3.2 Intuitive Eating (IE). IE is underpinned by ten principles [248] highlighted in Table 1. At its core, IE intervention promotes a balanced relationship to food, the body, and physical activity, focusing on responding to natural hunger and fullness cues without dietary restrictions [238]. It encourages eating for nourishment and satisfaction, addressing emotions without food, respecting the body regardless of size, and engaging in physical activity for health and enjoyment rather than weight loss [238]. This intervention shares similarities with mindful eating. For example, Gast et al. [80] framed mindful eating as an IE component emphasizing intrinsic eating and anti-dieting, while Framson et al. [73] positioned mindful eating as encompassing IE, extending beyond it with additional aspects of non-judgmental awareness of physical and emotional sensations. Mathieu [166] also highlights overlapping principles, as well as the inclusion of meditation practices in mindful eating that are not shared by IE. Although research on IE interventions is still in the early stages and primarily correlational [20, 36, 149], initial findings are encouraging. Current evidences indicate consistent inverse associations between IE measures and indicators of poor psychological health, such as depression, anxiety, and disordered eating [56, 124, 242, 248].

2.3.3 Mindful Eating and Active Living (MEAL). MEAL is another mindfulness-based intervention that includes MB-EAT components, including taste awareness, relationship to food, and food choices to support healthier eating. It is a family-based mindfulness intervention developed to address pediatric overweight and obesity while improving healthy lifestyle habits via cooking classes [35] (Table 1). The three-week program consists of weekly two-hour sessions focused on cooking and education [24].

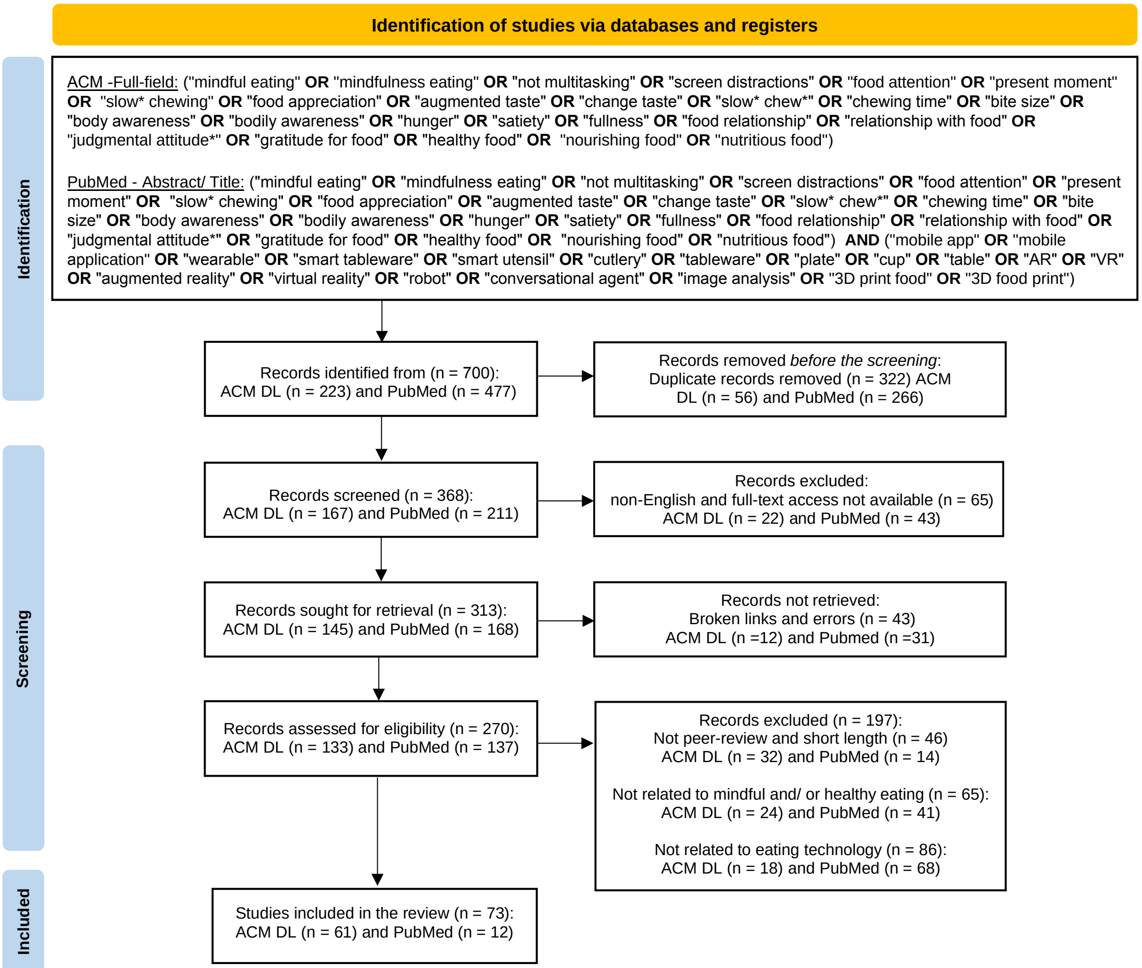
To summarize, while these three interventions: MB-EAT, IE, and MEAL share some principles [242] or components as shown in Table 1, they also differ in terms of their evaluated effectiveness [87, 204]. While several systematic reviews [248] examined MB-EAT interventions for binged eating, EDs, obesity, and related behaviors showed positive impact on reducing maladaptive behavior [125], and on managing emotional eating [125], other interventions, such as IE [20] and MEAL [35] have been less explored so that we have yet limited evidence of their effectiveness. Therefore, MB-EAT stands out due to its strong theoretical and empirical evidence of effectiveness, which led us to prefer it as the main intervention informing the design of the MEDEC cards. Thus, we identified that, except for gratitude for food, the MB-EAT program also focuses on the remaining five of the main aspects of mindful eating, as reflected also in the mindful eating scales: avoidance of distractions and focused attention on eating, savoring food, body awareness of hunger and satiety, relationship to food, and non-judgmental attitude towards eating. Moreover, the MB-EAT extends the latter towards non-judgmental acceptance of one's body, while targeting also the aspect of slowly savoring food, as reflected in mindful eating principles, and the new aspect of healthy eating.

To conclude, our theoretically-informed exploration draws from three main sources, and at each step, we extended and revised the list of mindful eating aspects. Thus, from mindful eating definitions and principles, we identified 5 initial aspects: avoidance of distraction, sensory awareness of food, body awareness of hunger and satiety, problematic relationship to food, and non-judgmental attitude towards food. As we moved from definitions to mindful eating validated scales, we identified 6 aspects: avoidance of distractions and focused attention, savoring food through sensory awareness, body awareness of hunger and satiety, problematic relationship to food, such as triggering negative emotions and thoughts, non-judgmental attitude towards eating, and gratitude for food. Finally, from mindful eating interventions, 7 aspects emerged: avoidance of distractions and focused attention on eating, savoring food, body awareness of hunger and satiety, relationship to food, non-judgmental attitude towards eating, non-judgmental acceptance of one's body, and healthy eating. We further integrated all these aspects by grouping small bites (bite size), chewing slowly (chewing thoroughly), and a small portion size (modest portion size) under "slowly savoring food", and the sensory aspects are under "savoring food". We also separated the non-judgmental acceptance of eating from the non-judgmental acceptance of one's body. While most of the main aspects of mindful eating were identified across the three sources, a few were unique to one source, such as "gratitude for food" from scales and "healthy eating" from interventions.

3 SCOPING REVIEW: TECHNOLOGIES TARGETING MINDFUL EATING ASPECTS

Our review of health research led to the identification of the following main aspects of mindful eating: avoidance of distractions and focused attention, savoring food through slow chewing and smaller bites, body awareness of hunger and satiety, relationship to food, non-judgmental attitude, gratitude for food, and healthy eating. To better understand the current design space of technologies targeting these main aspects of mindful eating, we conducted a scoping review of 73 identified papers. Unlike traditional reviews that critically assess evidence, this approach offers a comprehensive overview of prior studies, making it ideal for initial exploration [175].

Fig. 1. PRISMA diagram describes the three-stage process of identifying, screening, and selecting papers for the scoping review.



3.1 Identifying and Selecting Articles

The search was conducted sequentially on two databases, starting with the ACM DL[2] (Association for Computing Machinery Digital Library), and followed by the search on the PubMed (Public Medline)[3], and an updated search on the ACM DL to ensure that the latest papers are also included. We selected the former as it offers comprehensive coverage of computing and information technology literature, being also the main database for HCI-related research and reviews [58], and the latter to capture relevant interdisciplinary or health research not covered in ACM DL. We conducted searches on these databases from July to September 2024, starting with the ACM DL, for which we used search terms to identify mindful eating. Fig. 1 shows the PRISMA diagram of the three-stage process of identifying, screening, and selecting the papers, together with the search terms.

[2] dl.acm.org
[3] pubmed.ncbi.nlm.nih.gov

From the 61 papers from ACM DL, we identified seven types of technologies targeting mindful eating: mobile apps, wearables, smart tableware, AR/VR, robots, conversational agents, and 3D printing food (robots and conversational agents were found through the second search on the ACM DL). Then, for PubMed, in addition to the previous search terms on mindful eating aspects, we also used technology-related ones.

Inclusion/ exclusion criteria. From the initially identified 700 papers: in ACM DL (N=223), and subsequently in PubMed (N=477), we excluded duplicates (N=322). During screening from each database set, we excluded articles not written in English or without full-text access/ availability (N=65) (N=22 from ACM DL) and (N=43 from PubMed), or not accessible due to technical issues) (N=12 from ACM DL) and (N=31 from PubMed). The remaining 270 articles (N=133 from ACM DL) and (N=137 from PubMEd) were screened for eligibility based on title and abstracts, excluding those without peer review, or with short length such as magazine articles, awards, columns, commentaries, correspondences, courses, doctoral consortia, editorials, keynotes, or opinion papers (N=32 from ACM DL) and (N=14 from PubMed). The remaining papers (N=42 from ACM DL) and (N=109 from PubMed) were screened based on full text, and we further excluded those that did not directly engage with mindful eating and/or healthy eating (N=24 from ACM DL) and (N=41 from PubMEd), or eating technologies (N=86) (N=18 from ACM DL) and (N=68 from PubMEd). This left 73 papers (N=61 from ACM DL) and (N=12 from PubMed) to be included in the analysis (all preceded by an asterisk in the reference list). The outcomes of each step were carefully discussed by both authors to ensure consistent use of the criteria.

Coding process. Informed by our research questions, we iteratively developed the coding scheme, which consists of six main codes: technology type, theoretical underpinning, technology development stage, stakeholders, and mindful eating aspects (Table 2). Similar main codes (except for the latter) have been used in previous HCI reviews [64, 214, 245]. For technology code, the subcodes include the seven types of technologies and their combinations as identified through the ACM DL papers: mobile apps, smart tableware, wearables, AR/VR, 3D printing food, robots, and conversational agents, as well as an additional technology identified from the PubMed papers: image analysis.

For mindful eating aspects, we used deductively generated codes from mindful eating principles, scales, and interventions reviewed in Section 2, which also supported the identification of the main aspects of mindful eating. These codes included: avoidance of distractions [73, 110, 120, 159, 199, 251], sensory awareness of food through savoring food [30, 73, 110, 144, 199, 251], slowly savoring through slow chewing or small bites [171], body awareness of hunger and satiety [144, 199, 251], awareness of emotional eating reflecting relationship to food [41, 73, 144, 199, 233], non-judgmental attitude towards eating, and one's body [40, 110, 120, 144, 145, 199, 201], gratitude for food [120, 199], and healthy eating [142, 143]. The subcodes within each main code were also iteratively revised, following the second author's independent coding of ten papers. This process helped clarify the definitions of a small subset of codes.

3.2 Scoping Review Findings

We now present the scoping review findings focusing on technology type, their theoretical underpinnings, development stage, and stakeholders, followed by specific mindful eating aspects targeted by these technologies (Table 2).

Technologies. Findings indicate various types of technologies targeting mindful eating aspects most common ones being mobile apps [65, 91, 158], wearables [185], smart tableware [129], and AR/VR [181], followed by robots [78], conversational agents [194, 195, 223], image analysis [117], and 3D-printing food paired with mobile app [148], as well as other integrated technologies such as mobile app with smart tableware [122, 134], or mobile app with wearable [133].

Theoretical underpinnings. With regard to theoretical underpinning, findings indicate that less than 15% of papers provide definitions for mindful eating, and that less than 4% provide mention theories in their related work such as motivational interviewing [223], behavioral theory [176, 183], or the five-color diet theory [37], which these are used to inform the design of technologies. Findings also indicate a small number of 6 papers which leveraged interventions such as those for mindfulness [61, 65, 155], MB-EAT [185, 194], or intuitive eating [228] to inform the design of technologies for mindful eating. In contrast, the majority of papers (over 84%) do not define mindful eating, nor do not mention theories or relevant interventions to inform their technology design.

Development stage. With respect to *development stage*, findings indicate that most papers focus on technology evaluation, with most of them (over 80%) presenting research prototypes evaluated in the lab (43%) and in the wild (17%). Such evaluation commonly includes measures such as behavioral ones, i.e., slow eating, or portion size. Many papers (over 70%) also focus on design of technologies, including requirements gathering studies (11%) [21, 70, 104, 183, 193, 228], or design workshops (2.7%) [130, 137].

Stakeholders. Most of the reviewed research was conducted with non-clinical populations to either design or evaluate such technologies (over 60%), less so with clinical populations (26%). We noticed the small but growing body of work focusing on clinical conditions such as mobile apps for EDs [21] or robot-assisted feeding systems for people living with motor impairments to support their slow eating [104, 116, 179]. Surprisingly, findings show limited engagement of eating experts (less than 6%). This may reflect the emphasis of such technologies being developed for wellness rather than for the clinical domain.

Table 2. Distribution of main codes and their frequencies: technology type, theoretical underpinnings, development stage, stakeholders, and main mindful eating aspects targeted by these technologies. Some papers fit multiple subcodes within one main code.

Code	Frequency		Code	Frequency	
Technologies			**Healthy eating**		
Mobile app	21	28.8%	Less healthy snacks/foods	30	50%
Wearable	12	16.4%	Nutrition intake	29	48.3%
Smart tableware	10	13.6%	Healthy snacks/ foods	4	6.7%
AR/VR	10	13.6%	**Slowly eating**		
Robots	5	7%	Eating speed	20	33.3%
Conversational agents	4	5.5%	Portion size	19	31.7%
Image analysis	1	1.4%	Chewing speed	14	23.3%
3D printing food + Mobile app	1	1.4%	**Savoring food**		
Mobile app + Smart tableware	3	4.1%	Non-altered taste perception	12	20%
Mobile app + Wearable	2	2.7%	Altered taste perception	2	3.3%
Unspecified	4	5.5%	**Bodily awareness**		
Theoretical underpinnings			Hunger/satiety	8	13.3%
Mindful eating definition	10	13.7%	Digestion	3	4.1%
Theories	4	5.5%	**Relationship to food**		
Mindfulness intervention	3	4.3%	Problematic relationship to food	11	15%
MB-EAT intervention	2	2.7%	Dieting and calorie tracking	6	8.2%
Intuitive eating intervention	1	1.4%	**Non multitasking**		
Unspecified	62	84.8%	Eating during screen consumption	2	3.3%
Development stage			**Non-judgmental attitude**		
Evaluation	60	82%	Non-judgmental body acceptance	2	3.3%
Design	51	70%	**Gratitude**		
Stakeholders			Gratitude for food	1	1.7%
Non-clinical population	47	60.3%			
Clinical population	26	33.3%			
Eating experts	5	6.4%			

Mindful eating aspects. We now present the findings on the *main mindful eating aspects* that the reviewed papers and their technologies addressed, which we organized in decreasing order of the code frequencies, so from the most common to the least explored ones: healthy eating, slowly eating (including eating speed, chewing speed, and portion size), savoring food, bodily awareness, relationship to food, non multitasking, non-judgmental attitude, and gratitude.

- *Healthy eating*. An important finding is the types of food that these technologies present or suggest, with half of the papers indicating less healthy food items, such as cookies or crackers, while less than 7% of papers indicate healthy food items such as fruits or nuts. Findings also highlight the emphasis on healthy nutrition, with almost 48.3% of papers supporting psychoeducation through technologies such as mobile apps [6, 65, 70, 130, 153, 156, 215, 221], smart tableware [122, 151], integrated systems [122, 178], wearables [53, 172], interactive games [37], and conversational agents [38, 194, 223]. Examples include Food4Thought, an app offering lightweight daily food challenges [65], and design exemplars combining smart tableware with apps for balanced eating [122, 178]. Other technologies include wearables that capture eating context [172] and conversational agents [38, 194, 195, 223] or robots [78] that provide personalized nutrition advice.
- *Slowly eating*. Findings indicate diverse technologies focusing on eating behavior from wearables [132, 133, 185] and smart tableware [257] to mobile apps [135], conversational agents [38], AR/VR [17, 180, 212], or 3D printing food [148] (Fig. 4). Among these, most papers focused on eating speed, or chewing speed, which is seen as essential for healthy eating. The distinction is that technologies targeting chewing speed involve sensors for capturing users' chewing movements, whereas those targeting eating speed tend to capture the rate of food volume being consumed. The latter are most common (over 33%) and include smart tableware [55, 101, 256] or AR/VR systems [17, 231] for encouraging *slow eating*. For example, smart tableware with sensors detecting food pick up gesture and its amount while eating [257], or the AR game "*Feed the Food Monsters!*" integrates EMG sensors and head-mounted displays, allowing co-diners to view the game projected on each other's torsos to promote proper chewing time to aid digestion [17]. Technologies focused on *slow chewing* capture eating gestures, or chewing movements, to provide real-time feedback if the chewing speed is above a set threshold. For instance, wearables, such as necklace-like sensors on masticatory muscles [27, 133] or ear-worn sensors [46, 152, 172], are used to detect chewing or swallowing actions and deliver real-time, rewarding, and punitive feedback in haptic, visual, or auditory modalities.

  Arguing for the importance of limiting the amount of food to be eaten, 19 papers focus on *portion size* through smart tableware [45, 55, 123, 134, 255, 257], mobile apps for food journaling [6, 65, 70, 156, 221], wearables for detecting the food in the spoon [27, 115, 185], or tableware such as SSpoon which changes its shape to support slow eating without reducing pleasure, by detecting hand gestures and weight of each bite [45]. Other technologies include AR/VR to alter the food volume by augmenting it through real-time shape deformation [180, 181, 212], image analysis [117] to estimate food volume in the bowl from 2D images, or 3D printing food to alter food texture [148].
- *Savoring food*. Findings indicate various technologies for supporting savoring of food, such as mobile apps, conversational agents, smart tableware, or AR/VR, promoting awareness of the sensory experience of eating or drinking. For example, conversational agents like the Digital Sommelier encourage savoring wine using visual and tactile cues [194, 195], while the FlavourFrame app visualizes subjective tasting experiences [13]. Other technologies include smart tableware delivering electronic stimuli to enhance taste [203], AR/VR to modify food appearance [181, 182, 186], or auditory feedback to augment food texture by using the cross-model effect

[44, 137, 165]. In addition to supporting such sensory awareness, other technologies aim to alter the perception of taste. For instance, multisensory interfaces manipulate texture and taste through visual or auditory cues during mastication [114, 135].

- *Bodily awareness.* Findings indicate various technologies focused on bodily aspects related to external and internal senses, such as smart tableware, mobile apps, wearables, AR/VR, 3D printing food, and conversational agents. Most work in this space has targeted *awareness of hunger or & satiety.* For instance, work has focused on altering perceived hunger and fullness cues by modifying portion size using AR/VR [180, 212], using 3D printing food to enhance texture and satiety [148], wearable sensors to non-invasively detect hunger and satiety states by analyzing physiological signals (e.g., blood volume pulse) [113], mobile games to cultivate awareness on how everyday eating behavior impacts gut health [197], or conversational agent to prompt with bodily signals of hunger and satiety [194, 195]. Research has also examined how internal senses of digestion can support detection and regulation of stress or anxiety [244].
- *Relationship to food.* Findings indicate the challenge of mobile apps as they may negatively impact users' problematic relationship to food [22, 57, 84, 167, 191, 246]. Such challenges relate to technologies such as food-tracking apps, in particular, which promote diet culture. These shortcomings may harm users by reinforcing unhealthy behaviors or perpetuating unrealistic standards [191]. Other technologies include AR/VR simulating the consumption of food/drinks in social contexts to explore the link [31, 183, 193], as well as mobile apps [22, 57, 91, 130, 153, 191], and wearables [172, 244] to improve the relationship to food and prevent emotional eating for people with problematic eating.
- *Non-multitasking.* Surprisingly, only two papers targeted multitasking through screen consumption during eating. For instance, SWAN spoon is a smart tableware that uses vibration and tilts based on the user's gaze to a screen to discourage screen use during eating [129]. While designed to refocus attention on food, such devices may inadvertently distract from mindful eating by shifting the focus to the spoon itself rather than on the act of eating. Additionally, Khot et al. [127] examined how screens affect eating behaviors, noting that they impact hunger awareness, enhance the taste of bland food, alter eating focus, and change chewing speed, with screens often perceived as pleasant dining companions.
- *Non-judgmental attitude.* Despite its importance, our findings indicate a limited focus on a non-judgmental attitude. A noticeable exception is immersive VR environments designed to encourage body acceptance through customizable avatars and controlled simulations [176], or a mobile app for psychoeducation [3].
- *Gratitude.* Another aspect of mindful eating involves gratitude for the food, its source, and providers [98]. Despite its importance, limited attention has been given to supporting such awareness. A noticeable exception is Gratifood, a kiosk-based system that aims to help restaurant diners recognize the effort behind food and encourages them to share gratitude, benefiting unseen workers [62].

In summary, while much previous work has focused on the design and evaluation of a range of technologies, including mobile apps, wearables, and smart tableware, as well as 3D printing food, their theoretical underpinnings are rather limited. This is reflected in the limited operationalization of mindful eating definitions and the limited use of interventions such as those for mindfulness and mindful eating to inform the design of these technologies. Most of these technologies have also been explored with limited input from eating experts or among clinical populations.

With respect to the mindful eating aspects, our review shows the emphasis on healthy eating and slow eating, while aspects such as non-multitasking, non-judgmental attitude, or gratitude for food have received surprisingly limited

Table 3. Distribution of reported technologies and their specific mindful eating aspects intended to support

TECH TYPE	(no/ 73) and (%)		MINDFUL EATING ASPECTS									
			Healthy eating	Slowly eating			Savoring food	Bodily awareness	Relationship with eating	Non multitasking	Non-judgmental attitude	Gratitude
				Eating speed	Portion size	Chewing speed						
Mobile app	21	29%	10		3		1	1	6		1	1
Wearable	12	16.4%	2	5	3	6		1	2			
Smart tableware	10	13.7%	4	5	4	3	3			1		
AR/ VR	10	13.7%	5	3	3	1	6	3	3		1	
Robots	5	7%		3								
Conversational agents	4	13.7%	3				2	2				
Image analysis	1	13.7%			1							
3D Printing food + Mobile app	1	13.7%		1	1	1	1	1				
Mobile app + Smart tableware	3	13.7%	2	1	2	1						
Mobile app + Wearable	2	13.7%	1	2	2	2						
Unspecified	4	13.7%	2									

attention. Mobile apps primarily supported healthy eating, wearables targeted slowly eating, AR/VR: savoring food and bodily awareness, mobile apps and AR/VR: relationship to food, and only a limited number of technologies targeted non multitasking through smart tableware, non judgmental attitude thorough AR/VR, and gratitude through mobile apps (Table 3).

4 BRIDGING THEORY AND PRACTICE: MINDFUL EATING MAIN ASPECTS AS INTERMEDIATE KNOWLEDGE

This section positions the main mindful eating aspects as bridging concepts, describes the design of the MEDEC cards, and the design exemplars. For this, we begin with a brief review of previous work on design knowledge and tools that bridge theory and practice. The theory-practice gap in design research [49, 51, 188, 218] has motivated the development of intermediate-level knowledge that bridges abstract theory and concrete practice. Bridging concepts [51] are particularly effective, comprising three components: (i) theoretical grounding, (ii) design exemplars, and (iii) design articulations as functionalities within exemplars.

We position the main aspects of mindful eating, which we identified above from health research, as bridging concepts. These main aspects demonstrate strong (i) theoretical grounding through mindful eating principles, validated measurement scales, and evidence-based interventions. We now leverage our scoping review from which we curated a set of (ii) 16 design exemplars, aligned with the second component of bridging concepts. As shown in Section 4.4, these exemplars represent each type of technology from the scoping review, and the main mindful eating aspects they each reflect. As presented in Section 5, the MEDEC cards aim to represent and communicate the main aspects of mindful eating. In addition, the design exemplars are intended to situate and illustrate these main aspects within specific technologies of different types, which we identified from the scoping review. Not at least, we also run Workshops with 36 mindful eating experts using the MEDEC cards to critique these exemplars, to generate (iii) design articulations (Section 7.3), completing the third component of bridging concepts.

4.1 Design Process of the MEDEC Cards

Previous work indicated the value of design cards as translational tools that operationalize abstract theories into accessible, informed design knowledge [32, 49, 109, 188]. Their physical form particularly enables manipulation during design activities [109, 188]. We developed the MEDEC cards as design critique cards, a common HCI evaluation approach [7] to support stakeholder critique of mindful eating technologies, as well as to inform their future design.

Our MEDEC card set consists of 28 cards (Fig. 3) developed through three iterative refinements over several months. We translated mindful eating aspects, identified from valid measurement scales and health research, into textual and visual card content: labels, group names, sensitizing questions, icons, colors, and shapes (Fig. 2).

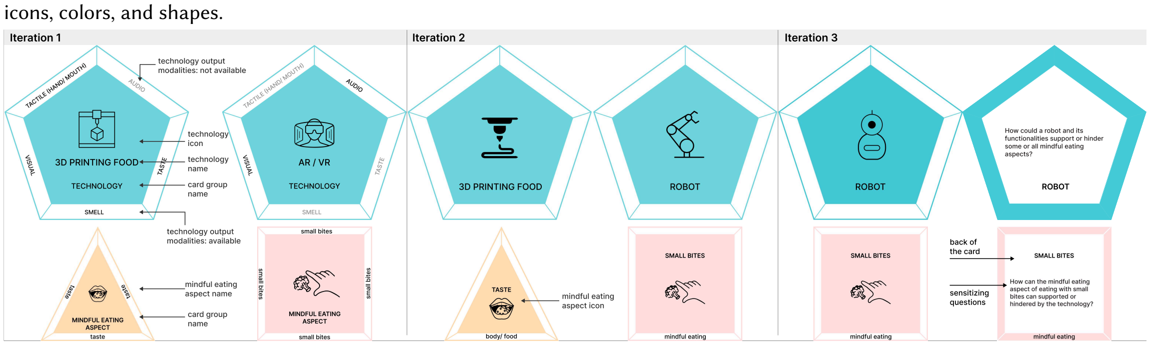
The MEDEC cards were designed, and explored iteratively, with the first version (Fig 2: Iteration 1), being used by 21 expert practitioners to critique design exemplars from the five types of technologies identified through the first search on the ACM DL: mobile apps, smart tableware, 3D-printed food, wearables, and AR/VR. Then, in light of the feedback from these 21 expert practitioners, the MEDEC cards were revised (Fig 2, Iteration 2, some icons and labels), and the revised set was further used by additional 15 expert practitioners to critique design exemplars for three new types of technologies: conversational agents and robots (identified through the second search on the ACM DL), and image analysis (identified through the search on the PubMed), To these exemplars, we also included the most common technology exemplars: mobile app, as well as our own generated conceptual design: the SmartPlate. Finally, in the light of the feedback from these 15 expert practitioners, the cards were slightly revised to their final version (Fig 2, Iteration 3).

Iteration 1: Established the information architecture with icons and brief descriptions for clarity. We selected blue for technology cards (associated with competence and security [4]) and warm colors like yellow for body/food cards (associated with sustenance [226] (Fig. 2, Iteration 1).

Iteration 2: Refined icons (e.g., AR/VR, 3D food printing) and removed redundant elements: sensory modality descriptions on pentagon shaped technology cards (as most technologies use limited output modalities), the "Technology" label (conveyed through shape and color), and repositioned mindful eating aspect labels from edges to card centers (Fig. 2, Iteration 2).

Iteration 3: Added sensitizing questions on card backs [138, 177], improved color accessibility using validation tools [1], and redesigned icons like the Robots card with anthropomorphized representations instead of robotic arms (Fig. 2, Iteration 3).

Fig. 2. Three main iterations of the MEDEC cards and their textual and visual content: labels, group names, sensitizing questions, icons, colors, and shapes.



4.1.1 Select the Definitions, Principles, Scales, and Interventions for Mindful Eating from Health Research. For the theoretical underpinnings of the MEDEC cards, we selected from health research the following three main sources already described in the previous section namely the principles of mindful eating [171], five valid measurement scales: MEQ [73], MES [110], Mindful Eating Behavior Questionnaire, MEBQ [251], MEI [199], and FFaMES [41], and the most effective intervention for mindful eating namely MB-EAT [142, 143, 145].

4.1.2 Identify the Main Aspects of Mindful Eating from Health Research. Also, as shown in the previous section, our analysis of mindful eating definitions, principles, scales, and interventions from health research has led to the progressive identification of the main mindful eating aspects. We further avoided duplication and ensured the use of consistent terms, particularly from measurement scales. To organize the identified main aspects of mindful eating, we use the two-factor mindfulness model, which includes attention to the present moment and a non-judgmental attitude [28], which we applied to the eating experience. Thus, attention to the present moment relates to aspects such as focused attention on eating and avoidance of distractions, savoring food through sensory awareness, and slowly eating, bodily awareness of hunger and satiety, awareness of emotions and thoughts associated with emotional eating, healthy food, and gratitude for food. The second factor of non-judgmental acceptance of eating and one's body. The set of these eight main aspects and their provenance from mindful eating definitions, principles, scales, and interventions is summarized below:

(1) avoidance of distraction [73, 184, 251], and focused attention on eating [110, 145, 184, 199, 251]
(2) savoring food [144, 171] through sensory awareness of food [30, 73, 110, 144, 184, 251]
(3) slowly eating through slowly chewing [144, 171, 184], and small bites [144, 171]
(4) body awareness of hunger and satiety [73, 144, 171, 199, 229, 251]
(5) relationship to food [41, 73, 144, 199, 229]
(6) healthy food [142, 143]
(7) gratitude for food [199]
(8) non-judgmental acceptance of eating [41, 73, 110, 144, 145, 171, 199], and one's body [144]

4.1.3 Identify the Breadth of Technologies Targeting Mindful Eating Aspects from Scoping Review. The scoping review from ACM DL led to the identification of seven types of technologies targeting mindful eating: mobile apps, wearables, smart tableware, AR/VR, robots, conversational agents, and 3D printing food. The first four of these were also identified by reviewing papers from the PubMed database, from which we found an additional type of technology: image analysis. Although these technologies feature with different frequencies within our corpus of papers, for a comprehensive set of technology cards, we decided to include them all, as both common and less explored technologies could support (or hinder) mindful eating aspects in different ways. Thus, we designed 8 technology cards. We also note that technology cards are generative [218], and that future work could extend them with novel technology types, explored to support mindful eating. To note, among the 16 design exemplars identified from the scoping review, only 8 have been evaluated, either in the lab or in the wild, while the remaining exemplars consisted of conceptual designs, similar to the SmartPlate designed by us.

4.2 The MEDEC Cards Textual Content: Labels and Sensitizing Questions

The MEDEC cards function as translational tools that operationalize abstract concepts for accessible design use [94, 174, 177, 188, 252]. The 28-card deck captures eight mindful eating aspects and eight technology types. Following defined card design practices [94, 138, 252], each card includes keywords, titles, and sensitizing questions [66, 107, 177] for quick communication. The eight technology cards represent one card per technology type identified in our scoping review. The 20 mindful eating aspect cards each represent one aspect or option within multi-option aspects. Single option aspects include: Non-multitasking, Savoring food, Relationship to food, Healthy food, Gratitude for food, Non-judgmental, and Relationship with body. Multi-option aspects include slow eating (3 cards: Chewing slowly, Small bites, Small portion size) and bodily awareness (2 cards: Satiety/fullness, Hunger). For savoring sensory modalities, we designed 8 cards covering basic senses (Sight, Sound, Smell, Taste), haptic submodalities (Texture, Temperature), and internal senses (Metabolization, Digestion) [24, 71, 81, 173]. Sensitizing questions on each card prompt exploration of technology aspect relationships: how technologies may support or hinder mindful eating aspects (Fig. 2).

4.3 The MEDEC Cards Visual Content: Icons, Color, Shape

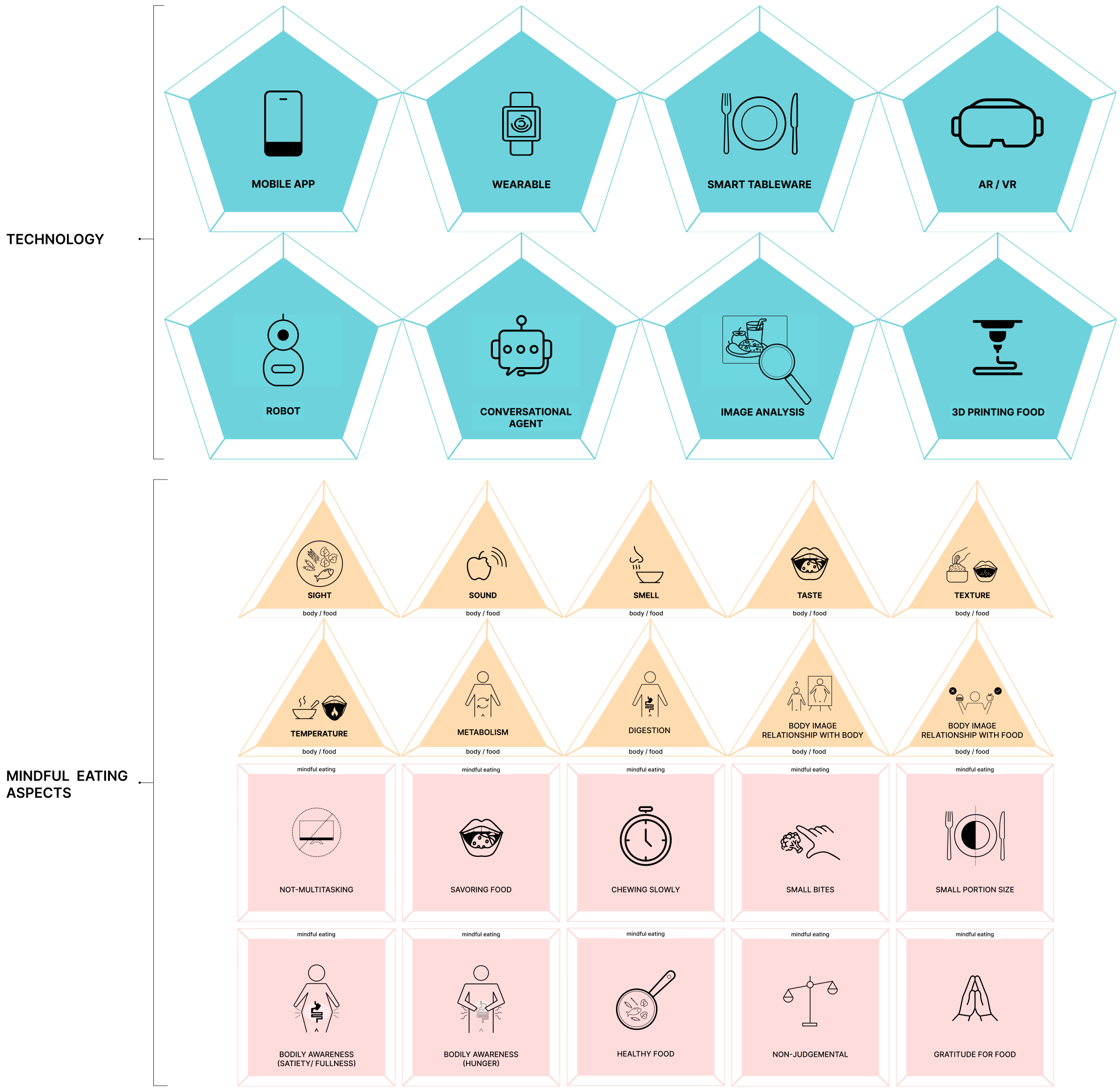
Each card includes visual content *icons, colors,* and *shapes* inspired by previous design cards [26, 67, 109, 112, 138, 177, 216]. We created a visual mood board from top-rated mindful eating apps [90] such as Habio and MEAL, which informed our use of minimalist icons rather than realistic photos (Fig. 2). Following established practices showing that colors support card differentiation and memorability [9, 66, 138, 177, 188], we used blue for technology cards (a cold color echoing previous design rationale [177, 188]), pink for bodily sensory aspect cards, and yellow for remaining mindful eating aspect cards. Shapes further support differentiation and physical manipulation [109, 188]: pentagons for technology cards, triangles for bodily sensory aspects, and squares for other mindful eating aspects. This design, inspired by hexagonal cards facilitating relationship exploration [26], emphasizes technology as the central point around which mindful eating aspects are considered. Equal side lengths for triangular and square cards enable them to connect when placed together, creating unique configurations for each technology being critiqued.

4.4 Design Exemplars Situating the Main Mindful Eating Aspects within Specific Technologies: Curation and Communication

Both bridging concepts [51] and design critique [7] require design exemplars [23, 218], which we defined as design knowledge about technological artifacts and their functionalities [218], which can be communicated in text, visual, or prototype form and are commonly used to stimulate reflection on artifacts [218]. In prototype form, design exemplars gain additional inspirational power since they can be more easily understood and envisaged [218]. Therefore, we curated the set of design exemplars, ensuring that they cover the breadth of the eight identified types of technologies, while targeting the breadth of the mindful eating aspects.

Curation of Design Exemplars. From the reviewed work, we curated a set of 16 design exemplars (to which we added a 17th one, SmartPlate, generated by us and later described), at least one exemplar from each type of technology, and more for some types with complementary functionalities (Fig. 4) (full descriptions are available in the Appendix A.3, Figures 11, 12, and 13). Design exemplars were also chosen for their potential to support or hinder different aspects of mindful eating. The latter was included to stretch the design space and challenge our and practitioners' assumptions about how mindful eating can be technologically supported. Such a role is served well by what Dix and colleagues called Bad Ideas, which are less desirable design ideas that provoke creative and critical thinking, with the potential to be transformed into good ideas [59]. Design spaces commonly include dimensions defined by aspects to which examples can be mapped [249], and toolkit creators can develop a set of examples that explore various positions within this space [108, 146, 163]. Findings from the scoping review also indicated that the 16 design exemplars selected by us target an average of 2.5 mindful eating aspects (range 1-6), while the rest of the reviewed technologies target an average of 1.6

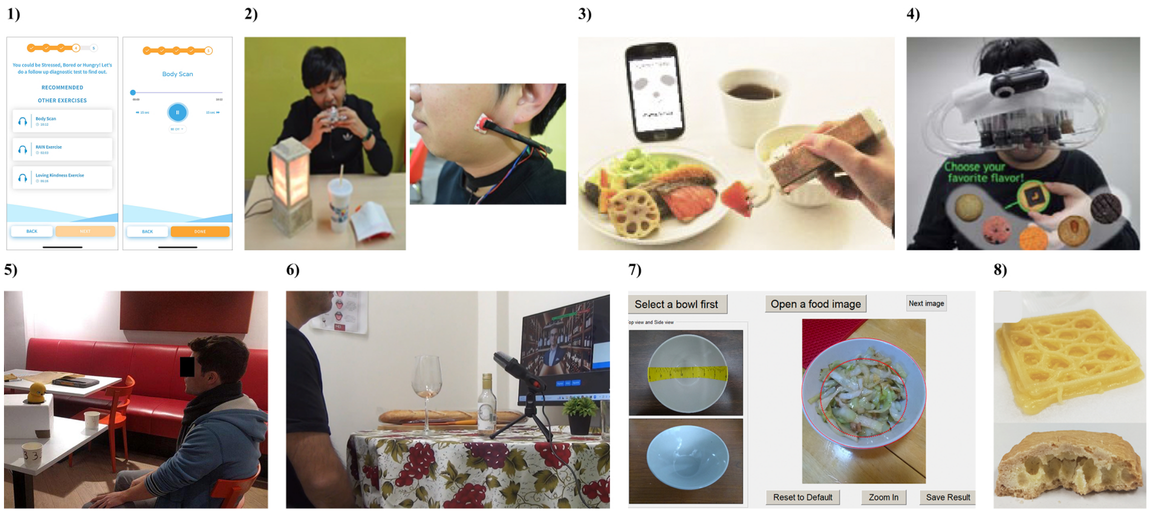
Fig. 3. The MEDEC card set is divided into three categories: Technology (8 cards, blue color); Mindful Eating Aspects, which includes bodily sensations and perception (10 cards, yellow color); and its aspects (10 cards, pink color).



mindful eating aspects (range 2-4). Besides individually reflecting more mindful eating aspects, we also ensured that collectively, our curated set targets the full set of mindful eating aspects.

Given the nascency of these technologies in HCI, some exploratory technologies were indeed purposefully designed as technology-driven provocations, such as SWAN [129]. Our curated corpus of exemplars is not intended to be exhaustive, nor entirely representative of every single technology we have reviewed, but sufficiently broad to cover each type of technology from the scoping review, to support reflection and comparative critique.

Fig. 4. Visual depictions of design exemplars targeting aspects of mindful eating: (1) mobile app [3], (2) wearables [133], (3) smart tableware [122], (4) AR/VR [182], (5) robot [78], (6) conversational agent [195], (7) image analysis [117], and, (8) 3D printing food [148]. © Copyright held by the author(s) and used with permission.



From mobile app technologies, we selected 1 exemplar, namely the Eat Right Now app [3], as one of the top-rated apps with a rich set of functionalities supporting psychoeducation and guided mindful eating. From smart tableware technologies, we selected 4 exemplars with complementary functionalities and forms, namely smart tray [134], smart fork [122, 123], smart cup [123], to which we added SmartPlate as our generated example of smart tableware. They also vary in their modality of real-time feedback on eating speed, healthy eating, or focused attention on the screen. For instance, the Ecomeal tray provides punitive light feedback for uneven eating rate [134], the SWAN spoon delivers punitive haptic feedback for gazing at the screen [129], and Educatableware provides rewarding gamified audio feedback for eating healthy food [123], while Sensing fork integrates movement, and color detection sensors, with a smartphone game to provide a real-time reward through a character who eats dumplings of the same color as the food consumed by the user [122] (full descriptions are available in the Appendix A.3, Fig. 12).

From wearable technologies, we selected 1 exemplar: Slowee, which provides real-time feedback, as vibrations on a wristband, if the chewing speed exceeds the set threshold, or as blue ambient light as a reward for slow chewing, or yellow light as feedback for normal speed [133].

From AR/VR technologies, we selected 3 exemplars, which alter aspects of food or plating to alter the perception of food. Augmented cookie superimposes larger food volume on actual food items [181], Meta cookie superimposes food images and scents over actual food items [182], while Calibra table alters the perception of plate size, through LED light plate placed beneath a transparent tabletop to detect the plate's position and to project the light around the food supporting users' perception of larger food portions [212] (full descriptions are available in the Appendix A.3, Fig. 11).

From conversational agents, we selected 4 exemplars, targeting mindful eating [38, 194, 195, 223] by supporting the savoring of food or liquid items, healthy eating, or tracking of meals. Thus, a digital sommelier uses expert input to guide wine tasting [195], while CATE uses artificial speech for savoring tea along with snacks as well as healthy food preparation [194]. TAMICA leverages motivational interviewing to explore barriers to healthy eating [223], while a

Personalized chatbot replicates human-like conversations for tracking meal data [38] (full descriptions are available in the Appendix A.3, Fig. 13).

For robot papers that target assistive feeding for users with mobility impairments, or dining partners such as the design exemplar we chose: Artificial commensal companion [78]. This is a toy-sized robot, which influences food choice through non-verbal head movement, gaze, and vocalizations (i.e., rewarding happy sounds, and nods if healthy food is selected) [78]. Finally, we selected 1 exemplar for image analysis, which predicts food volume to inform about the portion size [117], and 1 exemplar for 3D printing food, which augments satiety through texture [148]. While most of these design exemplars reflect only one of the eight types of technologies, 3 integrate two types of technologies, namely Slowee [133], integrating wearable and ambient technologies, Sensing fork [122] and Ecomeal tray [134] integrating smart tableware and mobile apps [122, 134] offering the benefits of more technological affordances. In addition to the above design exemplars curated from previous work, we also generated a 17th design exemplar: SmartPlate. This smart tableware uses lights to encourage savoring each bite through slow eating, as lights lit up, one after another, on the perimeter of the plate. SmartPlate differs from existing smart tableware technologies, such as spoon, fork [129], cup [123], tray [134], or Slowee [133], in that it does not provide real time rewarding or punitive feedback based on tracked eating or chewing speed, as instead, it guides user's slow chewing (full descriptions are available in the Appendix A.3, Figures 11, 12, and 13).

Communication of Design Exemplars. Aligned with Bardzell's suggestion [23], we started by generating clear descriptions of the curated design exemplars. This was not trivial, given the wealth of findings on people's limited understanding of technologies [131, 168, 217], be they end users or domain experts such as ours. To adequately communicate the design exemplars, we draw from the concept of brief descriptions [218], Ropohl's technology functionality grid theory of socio-technical systems [209] that frames technologies as a transformation of inputs: matter, energy, or information, into outputs through actions such as processing, transporting, or storing. The design exemplars have been used to inform the communication of complex technologies to non-experts through brief descriptions that are simple, condensed, and versatile, in complementary modalities [243], which findings showed to support non-experts' technological literacy.

5 WORKSHOPS WITH MINDFUL EATING PRACTITIONERS

5.1 Positionality and Reflexivity

Using workshops as a qualitative research method, we recognize that data collection is influenced by other perspectives and subject to bias [72]. Acknowledging our positionality is crucial, particularly in HCI health research [190], to understand how our views shape the research process. The first author specializes in HCI and mindful eating technologies, while the second author focuses on HCI, HFI, eating experiences, mindfulness, as well as mental health technologies, and both have personal interests in mindfulness and healthy eating. The first author primarily uses quantitative methods, while the second author is experienced in both qualitative and quantitative approaches. This combination provides a fresh perspective and critical engagement throughout the data analysis. The first author conducted the interviews and shared the most WEIRD (Western, Educated, Industrialized, Rich, and Democratic) characteristics [150] with our practitioners, minimizing potential power imbalances.

5.2 Rationale and Aim

Our findings demonstrate mindful eating aspects as bridging concepts [51] strongly grounded in health research. Our scoping review curated design exemplars representing identified technology types targeting these aspects, despite their surprisingly limited theoretical foundation in mindful eating research. Such grounding is essential for critiquing current technologies and informing future design of safe and effective mindful eating interventions. Thus, we designed the MEDEC cards as a design critique tool for stakeholders to evaluate technologies targeting mindful eating aspects.

We conducted workshops with 36 mindful eating practitioners to explore the MEDEC cards' value as critique tools. Design critique effectively evaluates emerging technologies [7] and has been used with domain experts [224], designers [63, 103], and end users [74, 164]. Given the limited theoretical foundation of mindful eating technologies shown in our scoping review, practitioners are best positioned to judge how well these technologies support or hinder mindful eating aspects through their extended practice experience. Expert-led critique provides valuable contextual and applied understanding that complements theoretical models [23, 198] and is particularly beneficial for critically evaluating health technologies regarding validity and practical applicability [48, 50]. As this HCI domain matures through foundational work like ours, other stakeholders, such as designers and end users, could employ the MEDEC cards for designing and evaluating novel mindful eating technologies.

As a foundational step, we engaged practitioners to (i) understand the cards, (ii) identify challenges, and (iii) suggest improvements for clearer communication to non-experts such as designers and end users. While domain expert critique of technologies remains underexplored compared to designer-led approaches, their input is crucial for emerging sensitive technologies in health domains [177].

5.3 Participants

We now describe the recruitment process, the expertise of mindful eating practitioners, and their demographics.

Recruitment and Sample Size. We recruited 36 mindful eating practitioners through convenience and snowball sampling from LinkedIn using the keywords: "mindful eating" AND (practitioner OR therapist OR psychologist OR nutritionist OR dietitian OR coach). Inclusion criteria were: (i) at least one year of experience as mindful eating practitioners (therapists, psychologists, nutritionists, dietitians, or coaches), (ii) from any country, and (iii) English language professional profiles. This approach, consistent with HCI health research [34, 64, 77, 157], brings together complementary expertise: psychotherapists and psychologists offer insights into behavioral patterns, problematic eating, and mental health impacts on eating; coaches provide understanding of interoceptive awareness and guided mindful eating meditation; while nutritionists and dietitians contribute knowledge of healthy eating behaviors and dietary needs. HCI healthcare workshops with domain experts typically involve around 5 practitioners [19, 34, 157], with few studies exceeding 20 participants.

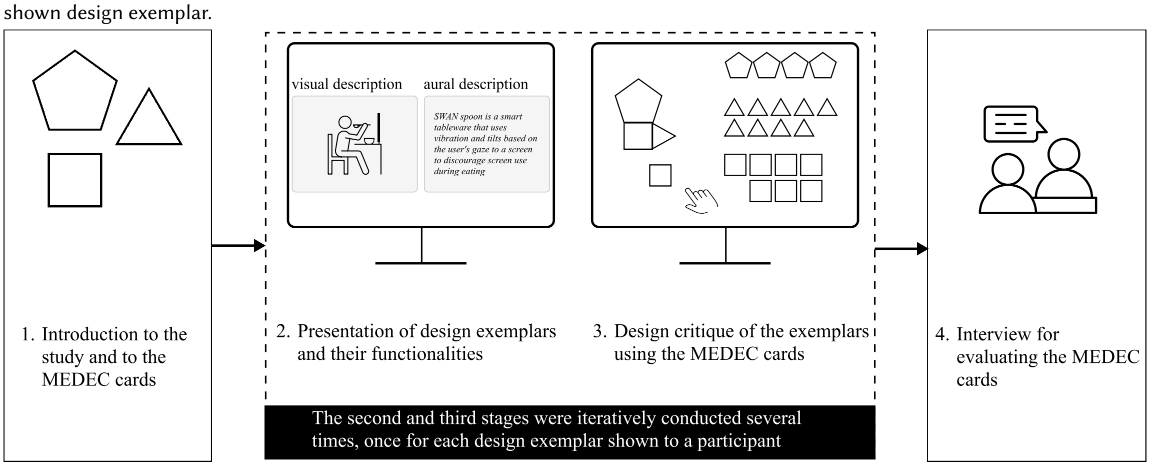
Practitioners' Expertise. As shown in Table 5, all participants hold university degrees: 20 Master's, 11 Bachelor's, and 5 PhDs. Participants average 10 years of mindful eating practice (range: 2-29 years) and include 15 dietitians (12 registered), 9 nutritionists (3 registered), 4 therapists, 3 mindfulness coaches, 2 mindful eating coaches, and 2 psychologists. All use guided mindful eating meditation, with some employing structured interventions including MB-EAT (19), MB-SR (10), ME-CL (1), and Intuitive Eating (1). Expertise indicators include certified training in these interventions and scholarly work on mindful eating or mindfulness (4).

Practitioners' Demographics. The sample included 34 female and 2 male participants (none non-binary), with an average age of 44 years (range 26-62), reflecting documented feminization of mental health professions [210]. Seventeen participants have experience with mobile apps for mindfulness meditation (Insight Timer, Plum Village, Headspace, Meditopia, Oxford Mindfulness), mindful eating (Eat Right Now), health (Apple Health, MyFitnessPal, Noom, Recovery Record), and communication (WhatsApp, Voxer). To mitigate WEIRD population bias in HCI research [150], we recruited all responding practitioners regardless of country, yielding participants from Western (31) and non-Western contexts (5) (Table 5).

5.4 Workshop Procedure

We conducted individual workshops with 36 expert practitioners. The study received Institutional Ethics approval, and participants received USD 100 Amazon vouchers. As shown in Fig. 5, workshops consisted of four parts: (1) study introduction and MEDEC card presentation, (2) presentation of 6-7 design exemplars and their functionalities, (3) design critique sessions for each exemplar, and (4) final interview for MEDEC card feedback, which is explained in detail below.

Fig. 5. Study procedure consists of design critique workshops, which include: (1) introduction to the study and the MEDEC cards, (2) presentation of design exemplars and their functionalities, (3) design critique sessions of each design exemplar using the MEDEC cards, and (4) an interview for evaluating the MEDEC cards. The second and third stages were iteratively conducted, once for each shown design exemplar.



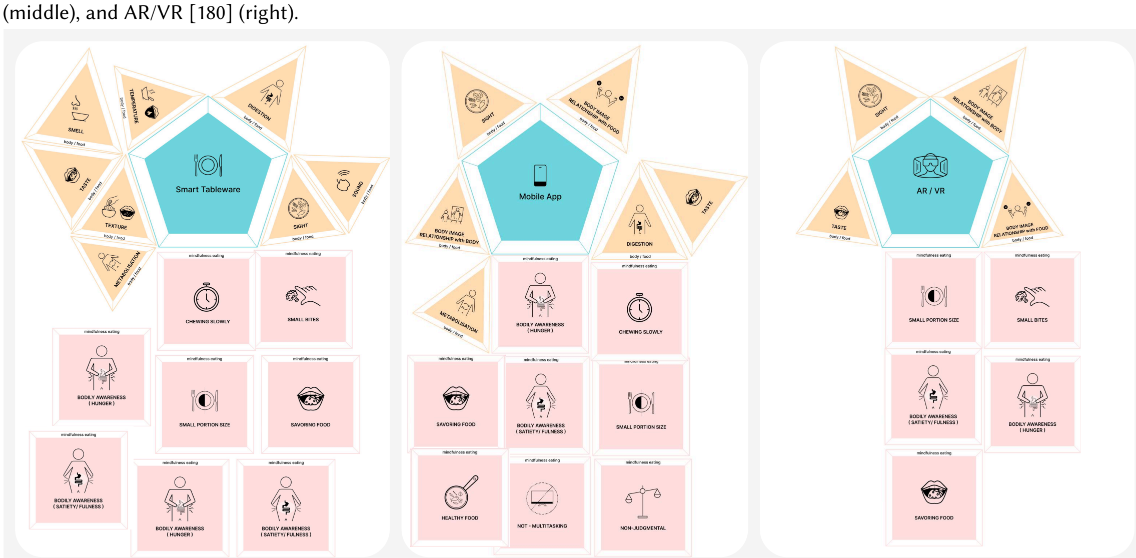
Study Aim and Presentation of the MEDEC Cards. We introduced the workshop aim, gathering practitioners' insights on whether and how technologies support or hinder mindful eating aspects, then presented the MEDEC cards through brief visual and aural descriptions of each card group and individual card.

Presentation of Design Exemplars. We introduced participants to 6 or 7 design exemplars through visual and aural descriptions of main functionalities, communicated clearly and succinctly with limited technical jargon (Table 6). This range allowed sufficient practice across multiple technology types without overwhelming participants within the 2-hour session, as confirmed through monitoring engagement of the first 2 participants.

Selection of 6-7 exemplars from the total 17 (Table 2) ensured: (i) each participant saw exemplars from at least three different technology types: mobile apps (1), wearables (1), smart tableware (5), AR/VR (3), robots (1), conversational agents (4), 3D food printing (1), and image analysis (1); (ii) for technology types with multiple exemplars (smart tableware, AR/VR, conversational agents), specific exemplars were randomly selected so participants saw 3 smart tableware, 2 AR/VR, or 2 conversational agent exemplars; and (iii) all participants saw the mobile app exemplar and our SmartPlate tableware design. This latter decision leveraged practitioners' experience with mobile apps, the most common mindful eating technology used by nearly half of our sample, and gathered feedback on our SmartPlate design, which addresses multiple mindful eating aspects.

Practitioners' Critique of Design Exemplars. Studies were conducted via Microsoft Teams and Miro in a quiet university room, facilitated by the first author. We created virtual design boards for each practitioner, one per design exemplar, populated with that exemplar and the MEDEC cards (Fig. 5). After introducing each design exemplar, participants joined its corresponding Miro board for a facilitated critique session. Participants first selected the technology card matching the exemplar's type, then reflected on mindful eating cards to identify which aspects the exemplar supported or hindered, dragging and dropping relevant cards around the technology card while describing their insights. Figure 6 shows three completed boards. We facilitated reflection through sensitizing questions such as "*how does this mobile app support or hinder mindful eating?*"; "*how does it support or hinder healthy eating*"; or "*how does it cultivate awareness of the taste experience?*". For each exemplar, practitioners suggested improvements and generated novel design ideas.

Fig. 6. Screenshots of practitioners using the cards during the design critique workshops in Miro, along with their reviews of the provided technology exemplars. The design exemplars include the SmartPlate concept (left), the Eat Right Now mobile app [3] (middle), and AR/VR [180] (right).



Interviews. The study concluded with interviews eliciting practitioners' feedback on the MEDEC cards: what they appreciated most and potential improvements. Following previous HCI card research [9, 188], we used this feedback to revise the cards as described in the Discussion (Section 7). We also explored less supported mindful eating aspects, novel technologies' potential to address identified challenges, and practitioners' views on feasibility and contexts for using these design exemplars in their practice.

5.5 Data Analysis

The workshops and interviews were audio-recorded, anonymized, and fully transcribed. Their analysis involved hybrid coding [68], integrating deductive and inductive codes. The former were informed by previous work, which we reviewed, such as mindful eating aspects, types of technologies, and how specific technologies support or hinder mindful eating aspects. The inductive codes generated from the workshops and interview data included how and why mindful eating aspects are supported or hindered, and specific technology functionalities supporting or hindering them. The codes were iteratively revised over a few months through weekly meetings, leading to over 1000 codes generated using Atlas/ti software for qualitative analysis [75]. The codes' frequencies presented in the Findings section are descriptive. In addition to interviews, we also analysed the card configurations on each Miro board. Thus, for each participant and each design exemplar they critiqued, we counted all mindful eating aspects cards that they selected as being supported or hindered by that exemplar.

6 FINDINGS

This section is organized around the eight technology types for which we highlight how their design exemplars support, or hinder, main mindful eating aspects, along with experts' suggestions for exemplars' improvement. The illustrating quotes below are assigned to practitioners, not only by number, but also by their occupation, such as psychotherapist (PT), psychologist (P), mindfulness coach (MC), mindful eating coach (MEC), dietitian (D), or nutritionist (N) (Table 5).

6.1 Practitioners' Feedback on Design Exemplars

6.1.1 ***Mobile Apps***. Findings indicate practitioners' appreciation of the *Eat Right Now*, a top-rated mindful eating app [91], as most of them noted its support for three mindful eating aspects: bodily awareness, non-judgmental attitude, and healthy eating. With respect to bodily awareness, practitioners liked the app's use of scales for users to check for hunger and satiety cues (30/36): "*text prompts and Likert scales to rate hunger before eating is quite powerful, which cultivates awareness around eating*" (P12-N). They also liked the app's support for non judgmental attitude (27/36) and healthy eating (27/36): "*using these scale to reflect on bodily awareness, will support non judgment aspect, because most of the time they [clients] struggle to separate hunger from external triggers [...], it supports healthy eating because creates awareness*" (P16-MEC). With regard to the app's potential to hinder mindful eating, practitioners mentioned the non multitasking aspect, due to sharing of attention between the app's interface and the eating experience (7/36): "*it might distract from attention from the food to the screen*" (P17-D). Few practitioners emphasized the importance of personalization interventions for users (4/36): "*I liked the way that app provides tools like craving, check in, or stress test, which I also ask my clients to do before or after eating. But, I wonder if this app offers specific mindful eating sessions for emotional eaters or someone with binge eating. Because, in my sessions, I use different tools for each client based on their needs*" (P13-N).

Key takeaways. Practitioners appreciated mobile apps' providing text- or speech-based psychoeducation on healthy or mindful eating, as well as guided mindful eating meditation, although the personalization of such interventions could be better supported. They also expressed concerns regarding screen-based interaction, which may hinder the non multitasking aspect, and bodily awareness during eating experiences.

6.1.2 ***Smart Tableware***. *Ecomeal Tray.* Findings indicate appreciation for the *Ecomeal tray*, albeit from less than 20% of practitioners, who noted its support for the following mindful eating aspects: non multitasking, chewing slowly, small portion size, bodily awareness, and healthy eating, while highlighting also tensions between them. With respect to non multitasking (5/8), the Ecomeal Tray's feedback was found potentially supportive due to bringing attention back to the meal (5/8): "*although light-based feedback creates negative reinforcement while supporting not multitasking, it might facilitate short mindful eating moment*" (P2-N). With respect to chewing slowly (7/8), small portion size (4/8), and bodily awareness (4/8), they noted: "*again it's negative reinforcement, but feedback might also support chewing slowly and portion size aspects, which could indirectly support bodily cues of hunger or fullness*" (P2-N). However, practitioners also emphasized that the given feedback modality hinders small portion size (5/8) and non-judgmental attitude (7/8); as such, real-time punitive feedback may be triggering for individuals with EDs (4/8): "*this could definitely trigger eating disorders and creates judgment. There are always different reasons why somebody might need more food than on other days, or a different meal [...] they need to trust their body cues to understand what a portion is for them, and to know when it's enough for them*" (P17-D). Practitioners also suggested ways to address such challenge by technologies support the shift of focus from portion size to recognizing satiety as a lived experience: "*beyond nutritionist guidance, users could be trained on recognizing satiety and adjusting portion sizes to ensure satisfaction*" (P21-MC), and by providing for instance audio feedback on hunger levels, thus reinforcing the importance of tuning into bodily cues.

EducaTableware Fork and Cup. Findings indicate practitioners' limited appreciation for the *Educatableware fork*, and three of them critiqued it for hindering the following mindful eating aspects: non multitasking (2/3), bodily awareness (2/3), chewing slowly (1/3), small portion size (1/3) and small bite (2/3) like in this illustrative quote: "*it develops an automaticity, just because something beeps, [it doesn't mean] that you're going to develop good food behavior, it is forcing to continue to eat mindlessly without slowing down or chewing properly [...] I don't see any value in this for mindful eating, it distracts attention from body to external trigger*" (P5-N). Practitioners suggested improvements, such as a utensil that tracks nutritional content (3/3): "*it might track, afterwards, and provide feedback on which food you ate, and might also track the speed to indicate how quickly you reach the next bite. At the end of the eating episode, the person can see the nutritional facts and the rate at which they reach for the food*" (P10-P), or check-ins on hunger and fullness (3/3): "*prompting questions to check in with hunger and fullness*" (P6-D).

Educatableware cup. Findings also indicate a similar critique for the Educatableware cup, for hindering mindful eating aspects, mentioned however by 6-8 participants: non-judgmental attitude (8/13), and non multitasking (6/13), which in turn hinders bodily awareness of hunger/ fullness cues (6/13): "*it might be fun for kids to drink with this cup, [but] because of distracting attention, [it] doesn't support bodily signals. It's encouraging overconsumption like -I'm gonna drink beyond how much I want to drink because the sound is really fun; in the long term, it might create judgment towards self and the food*" (P20-D). Practitioners suggested a smart water bottle with visual feedback for hydration goals and color changes to encourage slower drinking.

SWAN Spoon. Findings indicate practitioners' critique of the *SWAN spoon* for hindering mindful eating aspects of: non multitasking, non judgmental attitude, small bites, chewing slowly, small portion size, and bodily awareness. With respect to not multitasking, they mentioned the challenge of sharing attention between the screen and the food (8/12), which impacts small bites (8/12), chewing slowly (8/12), and small portion size (5/12): "*it's one of the challenges of my clients that external distractions negatively impact their eating habits, causing them to lose awareness of hunger and fullness. I always suggest having your food where you're not distracted [...] I didn't find sharing attention between the screen and the food helpful, even though [mindful eating was] reinforced with feedback*" (P21-MC). They also mentioned the hindering of non-judgmental aspect (8/12): "*I think there may be judgment if it's [SWAN spoon] vibrating on the person, says "oh, it's not supposed to vibrate'. That means I was distracted. It might bring up that recurring thought that I'm not doing it right [also] the spoon's haptic feedback is potentially frustrating, and could be perceived as a punishment rather than a gentle nudge*" (P18-D).

Participants also emphasized the potential hindrance of internal bodily aspects (8/12): "*to some extent, it hinders bodily awareness, like hunger and fullness, and also the metabolism and digestion, because he's sitting in front of the screen and eating mindlessly, but shouldn't't"* (P6-D). To address these challenges, practitioners emphasized the importance of non multitasking (7/12): "*I always suggest that when you eat, try to dedicate your full attention to the food you're eating. It's nourishing your body, mind, and awareness*" (P7-N), as well as non judgmental support bodily awareness (8/12): "*not* *meant to punish or blame, but to support awareness through subtle and gentle nudge with kindness [...] if we can bring it back to the present moment with kindness, they'll eat more mindfully and tune into the body and sensations*" (P18-D).

Sensing Fork. Findings indicate practitioners' appreciation for the *Sensing fork* as supporting the following mindful eating aspects: savoring food (5/8), and small portion size (4/8): "*it might teach kids to savor the food, because it's paired with the game, and each small portion is a dumpling on the game* (P10-D)". Practitioners also expressed criticism for hindering mindful eating aspects of: non judgmental attitude, non multitasking, bodily awareness, and healthy eating. With respect to non multitasking (6/8): "*it's putting a screen in front of their face, which is a negative of mindful eating*" (P10-P). With respect to non multitasking (6/8) and bodily awareness (5/8), the gamification feature was particularly critiqued: "*they're trying to complete the game while gazing at the screen versus checking in with their hunger and fullness*" (P10-P). With respect to healthy eating, they highlighted that color alone is not necessarily an indicator of healthy eating (4/8): "*it doesn't support healthy eating, because strawberries and meat are red, and too much sugary fruit will have a reverse effect*" (P15-D). Practitioners made suggestions for technology features to support reflection through psychoeducation "*instead of game, if this app could provide some scales, or prompts for reflecting, such as how "do you feel now?" or "do you have any thoughts now?" which might be better support for mindfulness around the food*" (P9-D).

SmartPlate. Findings show that most practitioners appreciated the *SmartPlate* for how it support mindful eating aspects, namely chewing slowly (33/36), small bites (32/36), small portion size (29/36), and savoring food (31/36): "*one light for per bite encourages chewing slowly, with small bites and portions, eventually savoring the food*" (P15-D). They also value SmartPlate potential for bodily awareness of hunger/fullness cues (32/36): "*light intervals also help them to recognize hunger and fullness levels*" (P18-D), as well as awareness of digestion (5/36): "*it has the potential to bring significant benefits [...] clearly communicate the advantages of eating slowly, such as improved digestion and potential relief from conditions like irritable bowel syndrome. Digestion begins in the mouth, and many people experience bloating or poor digestion because they rush through meals, barely chewing their food. By encouraging slower eating, this tool could help address these issues*" (P12-N). It is also mentioned (11/36): "*I think it's very effective because it provides a gentle reminder to keep bringing attention back, rather than giving judgmental feedback to tell you to focus on the light*" (P13-N).

Practitioners also expressed concerns for how SmartPlate may impact non judgmental attitude particularly for vulnerable users (6/36): "*if they've experienced an eating disorder, they may not be able to sense in their body the interoception, and the lights can be judgmental for them [...] encouraging them to slow down might feel guilty, if they can't*" (P21-MC). To further improve SmartPlate design participants suggested including lights for pausing to promote presence with the meal (9/36): "*instead of having several lights around the edge all on at once, they should come on sequentially at set intervals, like one light per bite [...] there should also be lights that serve as gentle reminders to pause, like a subtle nudge to put your fork down while chewing slowly and taking mindful bites*" (P20-D).

Key takeaways. Practitioners highlighted tensions among some of the mindful eating aspects and how these are supported or hindered by smart tableware exemplars. Such tensions concern mostly (i) non multitasking aspect, challenged by technology features designed around screen consumption during mindful eating, and its potential negative impact on bodily awareness as users share attention with the screen rather than focusing exclusively on bodily experience of eating, and (ii) non judgmental aspect, challenged by real time gamified punitive feedback on chewing speed, and its impact on bodily awareness as any external prompts can take attention away from tuning into one's own body. More importantly, this tension does not concern all smart tableware technologies, as participants noted about the SmartPlate exemplar as supporting focused attention on the meal. Our expert practitioners also made suggestions for supporting bodily awareness through measurement scales and reflective questions, as well as through purposeful design for pauses during eating, and the use of gentle guidance for slow, thorough chewing rather than real-time feedback or punitive feedback.

6.1.3 ***Wearables****.* *Slowee.* Similar to tableware exemplars, findings on wearables indicate the same range of hindered mindful eating aspects. Thus, practitioners critiqued the *Slowee* for hindering non judgmental attitude (16/21), non multitasking (10/21), bodily awareness (9/21), chewing slowly (9/21), small bites and small portion size (9/21). In particular, they highlighted how the explicit feedback on chewing speed can be detrimental for non judgmental aspect and that such feedback offers limited support for slowing down: "*I don't think this will be helpful for chewing slowly, small bites, or small portion size, because when people are operating in these kinds of behaviors, it's impulses and they know how fast they're eating, which creates judgment*" (P14-MC). Participants also highlighted that technologies such as exemplars that rely heavily on external cues for bodily awareness risk distracting people from mindful eating, and could hinder the focus of attention on one's internal bodily cues: "*getting information externally about something, with these sensors and light on the table distracts from mindful eating. If it's truly mindfulness, we need to be reading those bodily cues internally*" (P18-D). Practitioners' suggestions for improving such technologies include support for the connected rhythms of breathing and chewing (4/21), emphasizing how intervals between bites can be extended by refocusing on breathing: "*breathing cues help set a rhythm and a pace for the chewing, which reminds of the need to tune in with bodily signals, and savoring your food*" (P14-MC).

Key takeaways. Practitioners reported that wearable design exemplars could hinder mindful eating due to sensors' real-time feedback on eating speed, which attracts attention away from internal bodily awareness, and may lead to a judgmental attitude. Instead, they suggested shifting toward subtle, breath-based cues that encourage internal focus rather than external monitoring.

6.1.4 ***Augmented Reality and Virtual Reality****.* *Augmented Cookie.* Findings indicate *augmented cookie's* limited support for mindful eating, and practitioners' strong critique for its potential to hinder aspects, particularly non judgmental attitude (5/6), small bites (2/6), small portion size (4/6), bodily awareness of food (2/6). Its impact on the latter two aspects is indicated in this illustrative quote: "*this approach to mindful eating relies heavily on visual trickery, which may mislead people about how much they've eaten, without engaging their bodily senses. While it could potentially help people with eating disorders to control portion size, it does so dishonestly by distorting perception, rather than fostering true mindfulness*" (P3-D). The impact on non judgmental attitude and small bites emphasized in this illustrative quote: "*it might help them to eat more slowly with small portions initially, but it's deception, which will create a judgment towards oneself and the food in the long term*" (P3-D).

Metacookie. Practitioners expressed similar critiques regarding the *Metacookie* exemplar for hindering non judgmental attitude (6/9), bodily awareness of food experience such as taste, smell (6/9), chewing slowly (4/9), small portion size and small bites (4/9), savoring food (2/9), to which they also added non multitasking (2/9). This illustrative quote highlights the exemplar's impact on the first two aspects, particularly for more vulnerable users: due to concerns about deception: "*this is completely contrary to mindful eating. It is not realistic: an illusion in perception, [which] can mislead people with problematic eating [...] emotional eaters are already not aware of the taste or smell of food, because they're eating on autopilot*" (P1-D). With regard to non multitasking and small portion size, it is also emphasized "*unnatural eating process with this thing on your head, probably not applicable for daily life [...] with different smells or colors, it might create an urge to eat more*" (P11-N).

CalibraTable. Practitioners appreciated the potential of *CalibraTable* exemplar to support healthy eating (6/11): "*they might eat more healthier food as they perceived the plate as bigger*" (P7-N). They also noted its potential support for the aspect of small portion size (7/11): "*using Delboeuf illusion for altering portion size could be beneficial, as early in the intervention it's challenging for people to control their portion size, which might potentially increase bodily awareness for hunger or fullness, but, it still creates judgment towards food*" (P21-MC). As indicated in this quote, practitioners also expressed concerns about how this exemplar may hinder mindful eating aspects and a non-judgmental attitude: " *they used unhealthy foods on a small plate and healthy foods on a large plate. I believe it would have been more effective to show that nutrient-rich foods can fill a small plate. They changed the types of food, but the size of the plate doesn't influence people's desire to eat nutrient-rich foods. Therefore, I think this is misleading and may lead to judgments about the food*" (P9-D). Practitioners also provided suggestions for subtle visual or audio feedback to support the small portion aspect (3/11): "*the plate could change color or emit gentle audio feedback when users are near the end of their desired portion, which could increase bodily awareness*" (P1-D).

Key takeaways. Practitioners indicated that while AR/VR design exemplars could occasionally support a small portion size, in the long run, they are particularly problematic for mindful eating since altering food's portion size, appearance, or smell hinders bodily awareness of the eating experience and non-judgmental attitude. Instead, they suggested subtle and timely limited feedback to increase bodily awareness.

6.1.5 ***3D Food Printing****.* A key finding is practitioners' appreciation for the *FoodFab 3D food printing* and its perceived support for several mindful eating aspects: non multitasking (5/8), chewing slowly (5/8), small bites (4/8), and small portion size (5/8), savoring food (3/8). Its impact on non multitasking aspect is indicated in this illustrative quote: "*I believe it will encourage savoring food, and exploring different textures will bring attention back to the food itself, so they might not have time to think or do something else*" (P4-P). Participants particularly appreciated the customization of texture, as a key aspect of food that can direct people's attention to the meal as well as bodily cues: "*different textures and densities impact the chewing time, that's valuable for people to learn to eat with small bites and portion sizes. If they really do chew the bite for 45 seconds, this in turn could also increase bodily awareness*" (P20-D). Regarding mindful eating aspects which may be hindered, practitioners mentioned non judgmental aspect, because of the alteration in food's texture (3/8): "*it is really fascinating to me, but I'm also concerned that while it cultivates awareness of the food and their own eating behavior, it might slightly alter their perception of the food. I feel like there's a sense of deception, which could lead to judgment*" (P4-P).

Key takeaways. Practitioners appreciated 3D printed food for supporting mindful eating in terms of increased attention, slower chewing, small bites, and portion awareness through texture personalization. They also mention that 3D printing food technologies could potentially alter the perception of food due to unfamiliar foods or textures being experienced.

6.1.6 ***Conversational Agents****. TAMICA.* Practitioners' strongly appreciated *TAMICA*'s motivational interviewing functionality [223] to help users explore barriers to healthy eating. They perceived such conversations as beneficial in supporting most of the mindful eating aspects by deepening users' understanding of them: chewing slowly (4/8), small portion size and small bites (4/8), savoring food (4/8), bodily awareness of hunger or fullness (6/8), healthy eating (6/8) and non judgmental attitude (2/8): "*if the user prompts the chatbot with questions related to mindful eating aspects such as -how to better experience food sensations- then the chatbot might respond in ways that support those aspects. So it could potentially support all sensory aspects, depending on the interaction*" (P32-NC). Such increased understanding can also apply to bodily awareness, particularly internal sensation of digestion (4/8): "*if someone's got acid reflux or they're constipated, it might ask [TAMICA] what they're having for their meals, can you suggest to me what else I could do to help my digestion or improve these gut symptoms?*" (P22-D).

Digital sommelier. They also liked *Digital sommelier's* functionality [195] of the virtual agent guiding wine tasting session, and its potential to support many of the mindful eating aspects: savoring food (7/8), chewing slowly, small bites and small portion size (5/8), and bodily awareness: "*it would support many of sensory aspects, including sight, sound, smell, taste, and texture and temperature would apply in terms of smaller sips. Some people just gulp down drinks, but this encourages drinking slowly. Savoring the flavor definitely applies, and while you don't chew, you can still drink slowly and mindfully*" (P30-T). In addition, they also identified its potential hindrance of aspects namely non judgmental attitude (7/8), healthy eating (4/8), non multitasking (4/8) and gratitude (2/8): "*I don't think that alcohol is related to gratitude and not a healthy drink [...] since users are interacting with a screen, which might be slightly distracting. It's more a matter of timing—using it during a mindful eating session might be contradictory if the goal is to reduce screen-based distractions*" (P28-D). With regards to non multitasking, it is emphasized: "*if we were to improve it for more mindful eating, perhaps we could reduce screen time or provide audio guidance instead. That way, users can focus on the sensory experience without needing to look at the screen continuously. This could enhance mindfulness and reduce distractions*" (P28-D).

CATE: mindful eating/ cooking. Findings confirm participants' similar views for *CATE* exemplar aimed to support savoring tea and preparation of healthy food, in terms of its potential to support the aspects of savoring food (7/7), small bites, small portion size (7/7), and healthy eating (7/7):

"*it seems to provide helpful prompts, a soothing environment, and helps the user to have a mindful drinking experience, which eventually supports small portions, bites, and savoring food. Guiding through healthy food preparation also supports healthy eating*" (P25-N). Similar to the Digital sommelier exemplar, the CATE exemplar is also perceived as it might hinder the non-multitasking (2/7) aspect of mindful eating, and consequently, bodily awareness one (5/7): "*my only concern is, although it provides gentle guidance for drinking or eating, its screen-based environment, which might not allow them to listen to bodily cues*" (P25-N).

Personalized chatbot for nutritional coaching. Practitioners identified two mindful eating aspects supported by this design exemplar, namely small portion size (3/7), and healthy eating (3/7), albeit it can also hinder: non judgmental attitude (6/36) and bodily awareness (6/36): "*it would definitely help with portion size and healthy eating, but focusing mainly on calories and recommendations based on algorithms, it might ignore individual differences and mindfulness of the eating experience. It could take away from mindful eating by promoting a rigid or judgmental approach*" (P27-D). Some practitioners outlined potential hindrance for the gratitude for food aspect (2/7): "*it's easy to forget that food is more than fuel and that gratitude can't be tracked in calories*" (P31-D). To address this challenge, practitioners suggested such technologies that *instead of focusing on calories, the system could prompt users to add variety, and balance, for example: "can you add a vegetable?", "is your plate colorful?", or "are you missing a protein source?". It could also include prompts encouraging users to enjoy their meal mindfully, like "how do you feel during and after eating?" or "take time to notice your fullness"* (P27-D).

Key takeaways. Conversational agents received positive feedback for providing text- or speech-based psychoeducation and guided mindful eating interventions, particularly through effective speech interactions. However, as screen-based technologies, they may hinder non multitasking, and bodily awareness during eating experiences, and offer limited support for personalization of mindful eating interventions.

6.1.7 ***Robots.*** Practitioners mentioned three aspects of mindful eating in relation to the *artificial commensal companion, a toy robot* exemplar, each aspect hindered by it: non judgmental attitude (15/15), non multitasking (12/15), and healthy eating (12/15): "*it labels food choices as 'right' or 'wrong', which could trigger shame or stress, especially for people trying to rebuild a healthy relationship to food. It is overly directive and potentially guilt-inducing [...] it might support the idea of* *healthier eating, but I don't think it's worth the emotional cost. There are better, more compassionate ways to encourage behavior change*" (P23-MEC). To improve such technologies, several participants suggested (4/15): "*instead of judging the choice, the robot could encourage users to eat even "less healthy" food mindfully, in moderation. Support curiosity and awareness over labeling, and be more of a non-judgmental companion, perhaps asking reflective questions instead of reacting negatively*" (P29-T).

Key takeaways. Practitioners indicated that robot-based companions may undermine mindful eating when they adopt directive or judgmental feedback, and should instead support a non-judgmental, reflective, and supportive approach that fosters compassionate awareness rather than labeling food.

6.1.8 ***Image Analysis.*** Findings indicate practitioners' ambivalent view towards the *image analysis* exemplar pertaining to two mindful eating aspects, which it can support, but also hinder. These aspects are a non-judgmental attitude (12/15), and a small portion size (12/15) as illustrated in this quote: "*I'd say it could support awareness of portion sizes. However, as a practitioner, I'm cautious about relying on portion size measurement because people eat very differently in terms of quality and quantity. Portion control can be tricky and potentially harmful, especially for those with disordered eating, so it's important to be certain that users don't have such conditions. Also, focusing too much on portion size might make people feel judged, which is counterproductive. It's often not the amount, but the quality of the food that matters most. For example, eating a large portion of lettuce might fill a plate but provide very little energy or nutrients, leading to hunger shortly after. So, portion size alone isn't always a good indicator of healthy eating*" (P30-T). To address such challenges, practitioners mentioned that image analysis-based technologies could be improved by offering also nutritional information (6/36): "*if, alongside calories, it also considers protein and fiber content, emphasizing foods higher in both, then it would be more helpful. Just focusing on food volume can feel meaningless at times*" (P24-D).

Key takeaways. Practitioners outlined image analysis as potentially supporting portion awareness but hindering non judgmental attitude, recommending the inclusion of additional nutritional information to better promote mindful eating.

6.2 Practitioners' Feedback on the MEDEC Cards

The workshops concluded with interviews for capturing practitioners' feedback on the cards, and how they may be improved, as well as the perceived feasibility of the critiqued technologies for their mindful eating practice.

6.2.1 Appreciation of the MEDEC Cards. Participants made use of all cards in their critique sessions, albeit the most frequently selected cards (over 100 times) across all exemplars include the 3 cards on slow eating: slow chewing, small bites, and small portion sizes, the 2 cards on bodily awareness of hunger and satiety, and the one card on non-judgmental acceptance. The next commonly used cards (73-84 times) include non multitasking, savoring food, relationship to the food, and with the body, sensory experiences, and healthy food. The least used cards (8-22 times) include gratitude for food, digestion, and metabolization.

An important outcome on their use is the perceived value of the MEDEC cards for communicating well the mindful eating aspects through textual and visual content, as mentioned by 29 practitioners: "*the cards are very self-explanatory and easy to understand; even without someone explaining them, it's clear what each card represents, making them intuitive and accessible*" (P6-D). This indicates the value of cards as translational tools [49] or vehicles for materializing abstract concepts, such as (e.g., non-judgmental, or non-multitasking [239]. Findings further indicate that the cards provide a comprehensive and tangible overview of main mindful eating aspects, as reported by "*having all the different factors visually and tangibly laid out, encouraged breaking down complex ideas into manageable parts, making it easier to piece* *everything together*" (P8-RN). As this illustrative quote suggests, such an overview is important to support easy grasping of the multiple aspects of mindful eating, echoing previous findings on the value of cards' physicality [109, 188].

In addition to labels as textual content, our findings also confirm the benefit of sensitizing questions: "*having probing questions was helpful for brainstorming*" (P7-N), similar to previous work on design cards, albeit for domains other than mindful eating [138, 177]. Besides mindful eating cards, participants also appreciated the technology cards, as well as design exemplars, particularly the less familiar ones "*I never heard about printing food, but it encouraged me to think about its possibilities*" (P7-N).

In addition to textual content, the visual content reflected in icons, cards' colors, and shapes was also appreciated. Most participants (31/36) mentioned icons as supporting their understanding: "*icons convey the ideas that they [the cards] intended to represent, very clearly*" (P18-D), as well as colors and shapes to help supporting the ability to differentiate them at a glance: "*it's very good to categorize them with different colors and shapes, so you don't have to be confused by them*" (P3-RD). These outcomes further confirm previous ones on good practices for designing cards using icons [109, 138], colors [9, 66, 138, 177, 188], and shapes [26, 109, 188] to support their glanceability, differentiation, and manipulation [94, 138, 154, 252].

Key takeaways. The MEDEC cards were highly appreciated for their ability to communicate main mindful eating aspects while engaging in technology critique and ideation of new design ideas. They valued the cards' clear textual labels, sensitizing questions, and intuitive visual design (icons, colors, shapes), which together make mindful eating aspects tangible, easily understandable, and engaging.

6.2.2 Suggestions for Improving the MEDEC Cards. Besides the positive feedback described above, 19 participants also suggested some small, albeit important changes to improve the cards, concerning mostly the sensitive language for labeling 4 of the mindful eating aspects, increased clarity for labeling the other 3 cards, the removal of the metabolization card, the generation of two new cards, "pausing briefly during eating", and "balanced relationship to food", increased the cohesiveness of the grouping of 4 cards, and better supported manipulation by changing the cards' shapes. All these changes are also supported by findings from health research, as further detailed.

Using More Sensitive Language for 4 Cards on Amount of Food, and Eating Speed. About one-fifth of participants suggested revising the labels of mindful eating aspects related to the amount of food and eating speed. For the former, they focused on the two cards: "small portion size" (7/36), and "small bites" (5/36): "*I don't like "small bites" or "small portion size" because they sound judgmental and can suggest a dieting mindset*" (P13-N). They suggested terms such as "adapted" or "modest" for both portion size and size of bites. Regarding eating speed, participants mentioned being concerned about the label: "chewing slowly" (4/36), and proposed instead "chewing thoroughly" or "chewing completely": "*chewing completely means not too slow or fast, but until your body signals it's ready to swallow*" (P13-N). Thus, to account for these valuable suggestions for more sensitive labeling, we have revised them for these three mindful eating aspects from "chewing slowly", "small portion size", and "small bites" to "chewing thoroughly", "modest portion size", and "bite size", respectively. These revised labels will better support design with, and for, vulnerable users such as those living with problematic eating or eating disorders. The fourth mentioned label to be more sensitively renamed is "healthy food" for which practitioners (4/36): "*I think healthy is a loaded word, and I think nourishing food is less loaded, because it's nourishing your body and soul, and less problematic with eating disordered people*" (P13-N). They also suggested more sensitive labels, such as "healthy eating", or "nurturing food", or "nourishing food". Thus, we revised the label of the "healthy food" card to "nourishing food".

Increasing Clarity of Labeling 3 Cards: Non Multitasking, Non-Judgmental, and Relationship to Food. Participants also suggested improving the clarity of the labels of the other 3 cards. Thus, five practitioners suggested revising the label of "non multitasking" card (5/36): “*I wouldn’t put it negatively, because when you say not multitasking, mindfulness is what you do, it’s not what you don’t do. So it’s not really mindful to say not to multitask. It’s more mindful to say presence with the meal*” (P5-N). Besides presence with the meal, other suggestions include "focused eating", "attentive eating", or "eating with awareness". These suggestions are important, and they align with health research on mindful eating, emphasizing both the focused attention on eating [110, 145, 184, 199, 251], and avoidance of distraction [73, 184, 251]. This outcome indicates that our initial label "non multitasking" does not explicitly cover "focused attention on eating", while practitioners’ suggested labels do appear to cover them both. Therefore, we changed the "non multitasking" card to the "presence with the meal" card. This new label has the benefit of being framed as a promotion goal of focusing one’s attention on a meal, rather than as an avoidance goal of not multitasking, a benefit supported by research on goal motivation both in health [232], and HCI [10, 258].

The next label to be improved is "non judgmental", mentioned by 3 practitioners: “*I wouldn’t say non judgmental, I’d say self acceptance. Because it’s what we encourage with mindfulness, and you end up doing things in a non-judgmental way, because it’s an attitude towards the food and self*” (P18-D). This outcome is significant, aligning also with health research on mindful eating emphasizing both the non-judgmental attitude towards eating [41, 73, 110, 144, 145, 171, 199], and towards one’s body [144]. This further supports the improvement of the "non judgmental" label by specifying the "acceptance" as a noun to which the non-judgmental adjective applies, as well as the two aspects to which the non-judgmental acceptance applies, namely, to the eating experience, particularly a problematic one, and to one’s body. Moreover, about the former, practitioners also mentioned its importance for non reacting to cravings: “*whenever someone has cravings, these impulsive thoughts appear, but I introduce things like what it would feel like to be compassionate and not react to those urges, just slow down by taking a few deep breaths while waiting for them to disappear*” (P18-D). This quote illustrates the connection between the non-judgmental acceptance of such negative emotions and cravings, but also the mental distance for not impulsively engaging with and reacting to them. Such a connection is also reflected in health research on mindful eating [200], as well as mindful eating scales MEI [199], MES [110], and FFaMES [40]. Thus, we revised the "non-judgmental" card by splitting it into two cards: non-judgmental acceptance of eating-related emotions, thoughts, and experiences; and non-reactance to them" , and "non judgmental acceptance of one’s body". In addition, as the latter label captures a more nuanced meaning of the "relationship with the body" card, we also used it as the revised version of the "relationship with the body" card.

Regarding the "relationship with food", 4 participants mentioned the negative aspect of such a relationship, for which some used the term emotional eating: *"emotional eaters have a lack of interoception, which leads them to suppress these feelings. I’d suggest adding a card on emotional eating*” (P11-N). Other practitioners used more sensitive language to reflect it, such as less balanced eating: “*most people use food as a tool to reflect on, or suppress their emotions, which creates an imbalance towards the food*” (P18-D). Also related to the relationship to food, practitioners (24/36) mentioned how mindful eating could support a healthier relationship to food, which involves enjoying less healthy food, in moderation and without guilt: “*often, we eat foods like donuts or chips quickly because we feel guilty, but if we slow down and eat them mindfully, we can enjoy them just as much as soup, avocado, or broccoli*” (P32-T). These outcomes also align with health research on awareness of emotional eating as a core aspect reflected in the MB-EAT program [41, 73, 144, 199, 229]. Thus, to account for the problematic quality of one’s relationship to food, we chose to rename it using sensitive language as "unbalanced relationship to food", a term also reported in health research on mindful eating [24]. In addition, we also created a new card: "balanced relationship to food", also reflected in mindful eating interventions [139, 140, 142].

Removing Metabolization Card. The rationale for this choice is that this card was the least used one, and participants' feedback on it indicates less differentiation from the Digestion card (10/36): "*it's a later stage of digestion and a difficult concept, like breaking down or synthesizing [...] I'd prefer using the digestion card rather than metabolization*" (P8-N).

Designing New Card on Pausing Briefly during Eating. Finally, we designed a new card, also related to slow eating, since a quarter of practitioners emphasized the value of "pausing briefly during eating", for slowing down the eating (9/36): "*pausing between bites would allow to assessing bodily signals, which prevents over consumption*" (P20-D). This is an important outcome, also supported by previous research on principles of mindful eating [171], as well as mindful eating interventions such as MB-EAT [144]. Thus, we added a new card, "pausing briefly during eating".

Ensuring More Cohesive Grouping of 4 Cards. Our set of mindful eating cards included a subset pertaining to sensory aspects that impact savoring of food: sight, sound, smell, taste, texture, temperature, metabolization, and digestion, as well as the two body image cards. However, almost one third of participants (11/36) mentioned that the latter two are not sensory modalities, so they may be removed from this group: "*yellow triangles are more about food sensations, and biological and physiological, whereas body image cards are more subjective, and perception based*" (P25-N). This finding also aligns with those from health research on mindful eating and the value of sensory awareness of food [30, 73, 110, 144, 184, 251], as well as bodily awareness of hunger and satiety [73, 144, 171, 199, 229, 251]. Moreover, practitioners also outlined that hunger, satiety, as well as digestion and metabolization represent internal bodily sensations (6/36): "*these aren't just physiological processes, but also linked to internal bodily state, enabling self-regulation and energy balance through sensory and metabolic awareness*" (P22-D). This quote illustrates the value of differentiating these as internal sensory experiences from the external ones, such as sight or taste. Thus, for a more cohesive grouping of orange-colored cards, we renamed these as "awareness of bodily sensations" such as sight or taste, under which we differentiated internal bodily sensations, namely hunger, satiety, digestion, and metabolization.

Ensuring Easier Manipulation by Changing Cards' Shapes. Finally, participants (7/36) also provided feedback on the impact of the cards' shapes on their manipulation. Our decision of different shapes was grounded in placing technology cards at the centre of the critique, by positioning the relevant mindful eating aspects cards alongside their edges. However, during the workshops, more than five cards were used to critique each technology, and therefore, the five edges of these pentagon-shaped cards become a constraint: "*I like them, and it helps visually, because you're kind of creating a puzzle, almost of connecting different things, as a tangible item to help people stay grounded and focused. But, maybe because of my age, slightly worried in case I was not able to connect their edges [...] might be better to replace it with a square or rectangular to prevent self judgment*" (P18-D). Thus, although practitioners appreciated these different shapes, they suggested using one regular shape for all cards, while preserving the three grouping colors. Thus, we changed all cards' shapes to rectangles, while keeping blue color for technology cards, yellow color for bodily awareness cards, and pink color for the rest of the mindful eating aspects.

Key takeaways. Practitioners suggested several changes to improve the MEDEC cards, which included increased language sensitivity, labels' clarity, groups' cohesion, and easier manipulation of the cards' shape. These suggestions included labels that further reduced judgmental language, increased clarity by renaming the labels of three cards, removing the Metabolization card, and adding a new card on Pausing, an orange-colored group of cards on internal bodily sensations, and revised the cards' shapes for easier handling.

6.2.3 Perceived Feasibility of Technologies for Mindful Eating Practice. Our findings indicate that presenting a variety of technologies and design exemplars has also helped practitioners consider their potential as therapeutic tools integrated in mindful eating practice (7/36): "*I work with clients for six sessions, so apps or smart tableware could complement therapy.*

Marketing these tools to therapists, rather than just individuals, would be very interesting to me" (P4-P). While some practitioners expressed interest in using such exemplars during their sessions with clients (6/36): "*I have short mindful eating sessions with my clients, where they eat crackers or cheese mindfully. I'd like to try in one of those sessions [smart] plate to observe its impact*" (P17-D), others considered integrating them into clients' daily life (4/36): "*I think using a plate when they have their food, maybe once a day, could help to have mindful eating behavior in the long term*" (P19-D).

Perceived Feasibility of Cards for Mindful Eating Practice. An interesting, less expected outcome was that one third of practitioners also noted that the MEDEC cards could also be used as prompts to support clients' awareness of mindful eating aspects during therapy sessions (12/36): "*cards are useful for reminding individuals of mindful eating. I plan to use the body, food, and mindful eating elements in sessions. Having the cards nearby helps clients practice slow chewing and understand digestion and metabolism better*" (P11-N).

Key takeaways. Practitioners suggested the MEDEC cards' potential value not just as a design tool but also to support clients' psychoeducation of mindful eating aspects during their mindful eating practice.

7 DISCUSSION

In this section, we revisit the research questions to highlight key findings and main contributions. Fig. 7 provides an overview of the three research questions, their mapping to the work described in our review of health research on mindful eating, a scoping review of technologies targeting mindful eating aspects, and workshops with mindful eating practitioners. This figure also highlights the key outcomes and contributions both within and across research questions.

Fig. 7. Overview of the three research questions (RQ1-RQ3) mapped to the reported work (review of health research on mindful eating, scoping review of technologies targeting mindful eating aspects, workshops with mindful eating experts), and main outcomes.

RQ1. Which are the main mindful eating aspects informed by health research?	**RQ2: How have these main aspects of mindful eating been supported or hindered by existing technologies targeting them?**	**RQ3: What is the value of the MEDEC cards as a tool to communicate and represent the mindful eating aspects and to critique design exemplars of technologies targeting them?**
Study: Review of health research on mindful eating	**Study: Scoping review of technologies targeting aspects of mindful eating** **Study: Workshop with mindful eating experts**	**Study: Workshop with mindful eating experts**
Outcomes: • Theoretical foundation for designing mindful eating technologies • Main aspects of mindful eating • Design of the MEDEC cards	**Outcomes:** • Understanding how technologies targeting aspects of mindful eating support or hinder mindful eating • Practitioners' critique of design exemplars and how they support or hinder mindful eating aspects • Curated corpus of design exemplars with different types of technologies targeting aspects of mindful eating • Expert evaluation of key technology features impacting mindful eating	**Outcomes:** • Practitioners' feedback on MEDEC cards • Revised MEDEC cards • Initial vocabulary for eating actions
Outcomes: Novel design space for mindful eating technologies		

7.1 (RQ1) Which are the main mindful eating aspects informed by health research?

To address RQ1, we reviewed health research on mindful eating, focusing on its principles, the five most common valid measurement scales, and the most effective interventions. The reviewed work reflects a rich conceptual space not trivial to integrate due to the large number of dimensions, such as subscales for measuring mindful eating and their inconsistent terminology. To address this challenge, we followed a two-stage process.

First, we adopted the parsimonious two-factor mindfulness model [28] encompassing present moment awareness and non-judgmental attitude, which we tailored to eating experiences, as (i) present moment awareness of bodily sensations, emotions, and thoughts related to eating experiences [73, 120, 159], particularly problematic ones like cravings [235], and (ii) non-judgmental attitude toward these experiences [120]. The former emphasizes focused attention on the eating experience, reducing distractions, and savoring food through sensory awareness (e.g., taste, texture, and smell). It incorporates bodily awareness of hunger/satiety cues, promoting slower eating, smaller portions, and attentiveness to bodily sensations. It also includes the relationship to food by fostering awareness of internal and external triggers and emotional responses, and promoting healthy food choices. The latter emphasizes non-judgmental acceptance of eating experiences and of one's body, aiming to encourage a balanced, deliberate, and reflective approach to eating behaviors. In Table 4, we provide an overview of the identified main aspects of mindful eating organized under these two dimensions. Second, we mapped these main aspects to the various principles of mindful eating (second column), the MB-EAT intervention (third column), and the various subscales of mindful eating measurement scales (last five columns). For the latter, we carefully looked at each of the five scales (MEQ, MES, MEBQ, MEI, and FFaMES). For a detailed description and critique with example items, see (Supplementary material 1). By engaging with the subscales' items, we identified which of the two main dimensions of mindful eating they relate to. The leftmost five columns in Table 4 also show for each scale the original names of its subscales in italics, followed by text in brackets offering our extended explanation of what subscales measure.

In the light of these outcomes, we define mindful eating is *(i) present moment awareness of eating experience as focused attention on slowly savoring food with all bodily senses, appreciating food's nourishment and provenance, with eating experiences being cued by internal bodily sensations of hunger or satiety, or by moderate emotional eating, rather than impulsively triggered by emotions or thoughts, and (ii) non-judgmental acceptance of eating related emotions, thoughts, and experiences, while maintaining mental distance from them, as well as non-judgmental acceptance of one's body.* Our working definition extends previous ones focusing either on the presence moment awareness of sensory aspects of eating [184, 229], or on non-judgmental awareness of physical and emotional eating sensations [73], while these previous definitions provide limited integration of both dimensions, as well as limited account of the broader aspects of mindful eating as reflected in 5 validated mindful eating scales MES [110], MEQ [41], MEBQ [251], MEI [199] and FFaMES [40], the 5 principles of mindful eating [171] and the MB-EAT program [144, 145].

HCI Contribution. The identified mindful eating has been captured in the design of MEDEC cards, using informative labels and icons. HCI scholars interested in mindful eating technologies are encouraged to engage with the main aspects of mindful eating described above while benefiting from their solid theoretical and empirical foundation. Scholars can aim to support specific aspects in isolation, or several of them, while addressing potential tension between those supporting present moment awareness of eating experiences, and non-judgmental acceptance of them.

7.2 (RQ2) How have these main aspects of mindful eating been supported or hindered by existing technologies targeting them?

For RQ2, we conducted a scoping review of technologies targeting mindful eating aspects to understand their design features, which may support or hinder mindful eating aspects. In addition, we also conducted workshops with mindful eating experts who critiqued 17 design exemplars of such technologies and their value in supporting mindful eating. Findings from the scoping review indicate a growing body of work on technologies that target aspects of mindful

Table 4. We define mindful eating as consisting of (i) present moment awareness of eating experience as focused attention on slowly savoring food with all bodily senses, appreciating food's nourishment and provenance, with eating experiences being cued by internal bodily sensations of hunger or satiety, or by moderate emotional eating rather than triggered by impulsive emotional eating, and (ii) non-judgmental acceptance of eating related emotions, thoughts, and experiences, as well as of one's body. These are mapped to mindful eating principles, principles of the MB-EAT program, and the subscales of the five most common valid scales for measuring mindful eating (MEQ, MES, MEBQ, MEI, and FFaMES). The original names of the sub-scales are shown in italics in the column, with the text in brackets offering an expanded explanation of what these scales truly measure.

MEDEC Cards		**Principles of mindful eating MB-EAT program**	**MB-EAT program**	**Mindful Eating Scales**				
				MEQ	**MES**	**MEBQ**	**MEI**	**FFaMES**
Mindful eating main aspects: Present moment awareness of eating experience								
Card label	**Card definition**							
Presence with the meal	Focused attention on eating rather than other activities	Reduce distractions while eating	Full attention on eating	*Distraction* (or engagement in thoughts while eating albeit not focused on eating)	*Act with awareness* (or lack of mindless eating)	• *Eating without distraction* (or not multitasking while eating) • *Eating with awareness* (or lack of mindless eating)	*Focused attention* (on eating or deliberate focus of attention on eating)	
Savoring food	Focused attention on bodily sensations to intensify the pleasure of eating experience	Savor food	Savor and enjoy food					
Awareness of bodily sensations during eating: Sight, Sound, Taste Smell, Texture, Temperature	Focused attention on bodily sensations for savoring food	Mindful taste	Mindful taste	*Awareness* (of bodily sensations and feelings associated with eating)	*Awareness* (of food aspects and bodily sensations while eating)	*Focused eating* (or focused attention on eating and awareness bodily sensations)	*Awareness of senses while eating* (or awareness of food aspects and bodily sensations)	
Slowly eating through: Chewing thoroughly, Bite size, Modest portion size, Pausing briefly during eating	Focused attention on savoring food through slowly eating	Ability to slowly savor food: • Reduce eating rate • Reduce portion sizes	Ability to slowly and deliberately savor food: slow chewing, smaller quantity, quality over quantity					
Awareness of internal bodily sensations: Hunger, Fullness/Satiety, Digestion	Awareness of internal bodily sensations before, during, and after eating as cues to start or stop eating, or inform nourishing eating	Awareness of hunger and satiety cues	Bodily awareness of hunger and fullness	*Disinhibition* (or inability to recognise fullness and to stop eating)		*Hunger and satiety cues* (or awareness and trust in these bodily cues)	*Eating in response to awareness of fullness* (or eating based on bodily awareness of hunger/ fullness)	
Unbalanced relationship to food	Awareness of negative emotions (stress, loss of control) and thoughts as triggers for impulsive emotional eating		Awareness of negative emotions and thought patterns associated with eating	*Emotional response* (or emotional eating cued by negative emotions)			• *Awareness of eating triggers and motives* (as negative emotions rather than body cues of hunger/ fullness) • External cues triggering eating such as accessible palatable food	• *Internal awareness* (of emotions and thoughts related to eating) • *External awareness* (of external tempting cues for eating)
Balanced relationship to food	Awareness of positive emotions and thoughts about intentional, moderate comfort eating, i.e., guilt-free enjoyment		Guilt-free enjoyment of moderate comfort eating					
Nourishing food	Awareness of nutritious food and eating, beyond mere calorie tracking		Information on healthy food options, nutrition, energy					
Gratitude for food	Awareness of food provenance supporting gratitude for food and its mindful eating						*Interconnectedness* (or gratitude for food and its provenance which can impact food choices)	
Mindful eating main aspects: Nonjudgmental acceptance of eating experience								
Non-judgmental acceptance of eating related emotions, thoughts, and experiences, and non reactance to them	Non-judgmental acceptance of (negative) emotions, thoughts, and cravings associated with eating, and mental distance for less impulsive eating triggered by them		Notice negative emotions and thought patterns about eating nonjudgmentally, with self compassion and without impulsively responding to them		• *Acceptance* (or nonjudgmental attitude for emotions and thoughts related to eating) • *Non-reactivity* (or accepting and not reacting to thoughts and emotions related to hunger)		• *Accepting attitude (*or nonjudgmental attitude towards eating experiences) • *Non-reactive stance* (or not reacting impulsively to emotional or external cues for eating) • *Non-attached attitude* (towards eating experiences)	• Nonjudgment (or nonjudgmental acceptance of one's eating) • Nonreactance (or not reacting impulsively to emotional or cues for eating)
Non-judgmental bodily acceptance	Non-judgmental acceptance of one's body		Self-acceptance of one's body					

eating. However, most such research addresses mindful eating with (i) limited theoretical grounding in mindful eating research in health and (ii) in isolation, as seldom more than two mindful eating aspects have been integrated into one technology. Moreover, much research has focused on wearables and smart tableware technologies for slowly savoring food, including chewing slowly, taking small bites, and controlling portion size, or mobile apps and AR/VR for promoting healthy eating, or the relationship to food. Findings also indicate specific design features of wearables or smart tableware such as punitive light feedback for uneven eating rate [134], punitive haptic feedback for gazing at screen [129], reward/ punitive feedback for chews per swallow [133], or superimposing food volume [181], food images and scents [182] with AR/VR technologies. In contrast, limited attention has been given to other important aspects of mindful eating, such as non-judgmental acceptance of emotions and thoughts associated with eating, bodily awareness, and gratitude for food (Fig.3).

Besides the limited theoretical underpinnings, there is also limited engagement with mindful eating interventions. Most work has primarily focused on everyday eating, with limited attention given to clinical populations [21]. Although mindful eating is informed by MB-EAT therapy for EDs [145], it has also shown benefits for non-clinical populations in improving their relationship to food, regulating food intake, and increasing interoceptive awareness and emotional regulation [139, 145]. In this respect, most of the reviewed work has focused on traditional qualities of user experience, such as pleasure, surprise, or play [123, 151], which are especially relevant for food interaction. However, in the context of mindful eating, these may become problematic if they take the focus of attention away from the food or distract from the actual eating experience. Furthermore, most technologies aim to provide real-time feedback when users fall short of targeted eating behavior, such as slow chewing, which can interfere with the *presence with the meal* and *non-judgmental* aspects of mindful eating. In contrast, mindful eating emphasizes self-acceptance and encourages self-compassion to counter self-judgmental attitudes when one falls short in their practice [98].

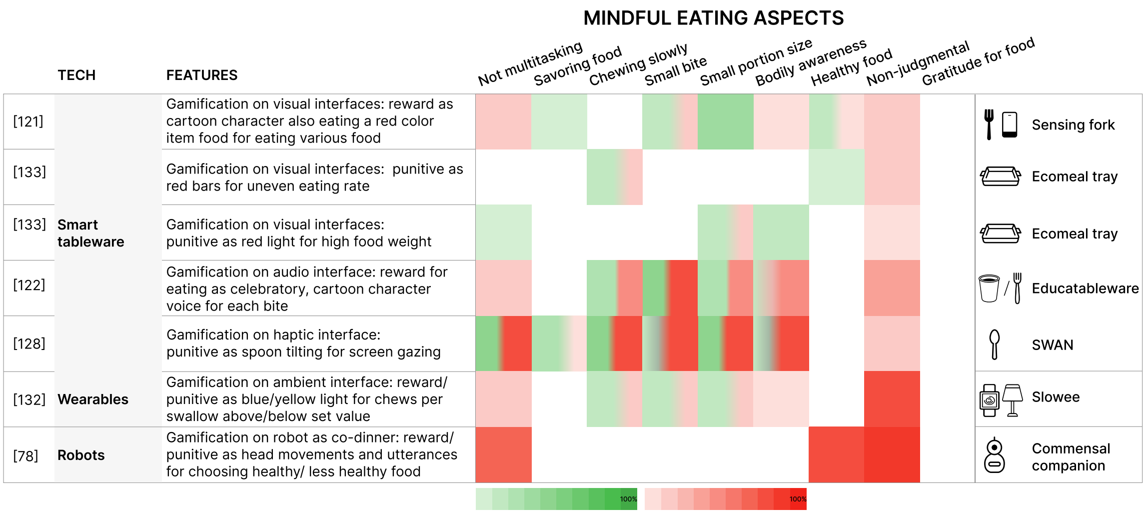
To summarize the scoping review: a rich body of work has focused on slow chewing and eating, small portion size, savoring food, bodily awareness, healthy nutrition intake, presence with the meal, and gratitude for food. However, limited attention has been given to the presence of the meal and non-judgmental acceptance of emotions and thoughts associated with eating. Our findings show that despite the breadth of technologies exploring or aiming to support mindful eating, most such work is fragmented, with limited focus on integrating different mindful aspects and limited theoretical underpinnings.

Findings from our workshops with mindful eating expert practitioners complement the ones from the scoping review, highlighting three main tensions among the main mindful eating aspects across different types of technologies.

The first such tension includes mindful aspects related on the one hand to eating speed: chewing slowly, small bites, and portion size, and on the other hand to non-judgmental aspects. This tension impacts particularly smart tableware and wearable technologies, which integrate sensors to track eating actions, and actuators to provide rewarding or punitive real-time feedback on chewing slowly, small bites, or portion size. While such feedback could support slow eating, it can lead to a self-judgmental attitude towards one's eating experiences, which is problematic. Interestingly, tableware technologies, through their affordance of being easily integrated in an eating setting, hold potential for supporting non-multitasking aspects. However, this potential is hindered either by the intensity of the provided real-time feedback on the eating speed or by the deliberate design to accommodate screen consumption during mindful eating.

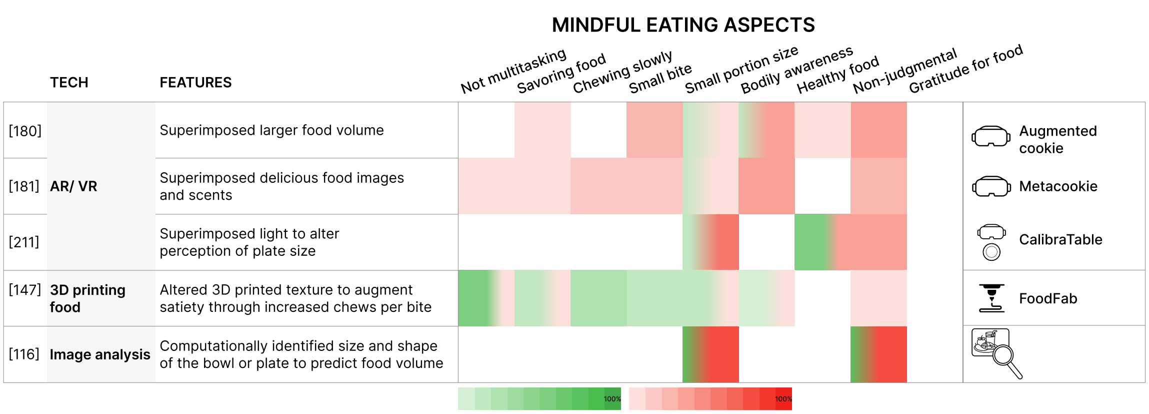
The second main tension includes the mindful eating aspects of food amount, such as small portion size on the one hand, and non-judgmental attitude, and bodily awareness on the other hand. This tension concerns technologies such as image analysis, predicting food volume, or AR/VR, which alter the perception of food volume. While this could

Fig. 8. Technologies providing real-time gamified feedback on eating speed, food amount, or variety. Experts' evaluation of their features supporting or hindering aspects of mindful eating. The visualization shows the distribution of the average number of experts' positive and negative evaluations of different features (left) from three types of technologies (smart tableware, wearables, and robots (right), mapped to mindful eating aspects (top). Colors represent: green for positive feedback, and red for negative feedback, with a more intense color representing more participants who provided feedback.



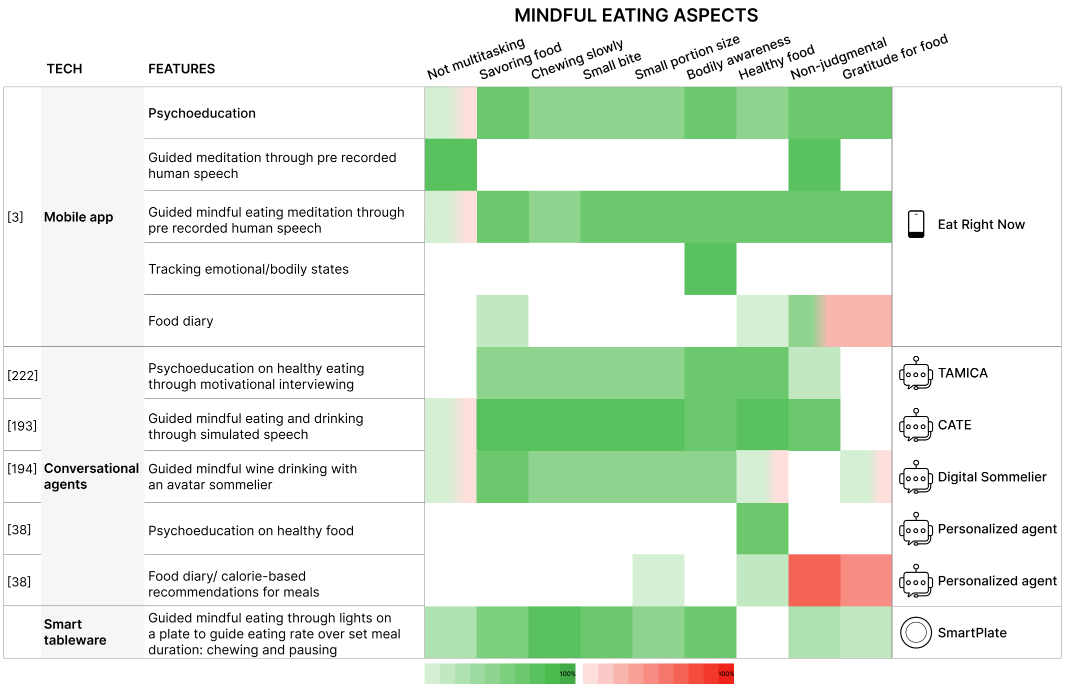
support reducing the volume of food to be eaten, in the long run, it is detrimental, fostering a judgmental attitude towards portion size and impairing users' bodily awareness due to an altered perception of food.

Fig. 9. Technologies predicting or altering the perception of food qualities. Experts' evaluation of their features that support or hinder aspects of mindful eating. The visualization shows the distribution of the average number of experts' positive and negative evaluations of different features (left) of the three types of technologies: AR/VR, image analysis, and 3D printing food (right), mapped to mindful eating aspects (top). Colors represent green for positive feedback, and red for negative feedback, with more intense colors representing more participants who provided feedback



The third main tension includes those related to slow savoring and non-multitasking, particularly for technologies such as mobile apps and conversational agents whose exemplars were most appreciated. Such technologies do not

Fig. 10. Technologies providing psychoeducation for healthy or mindful eating, guided meditation, and tracking eating. Experts' evaluation of design features supporting or hindering aspects of mindful eating. The visualization shows the distribution of the average number of experts' positive and negative evaluations of different features (left) of the three types of interfaces: mobile app, conversational agents, smart tableware (left), mapped to mindful eating aspects (top). Colors represent green for positive feedback, red for negative feedback, with more intense colors representing more participants who provided feedback



provide real time feedback, but leverage qualitative content, often in text or speech format, to inform users about mindful eating and healthy eating, and to guide meditation. One limitation of these technologies is their integration in eating settings, particularly for those with visual interfaces, which require users to shift attention from the eating experience to the screen, thus hindering the non multitasking aspect. Less surprisingly, while less common, food diary or tracking functionality of these technologies can promote a dieting mindset, and thus hinder non-judgmental aspect.

To better understand these tensions and how specific technology types support or hinder mindful eating aspects, we mapped the main functionalities of these technologies to the main mindful eating aspects. Figures 8, 9, and 10 show these mappings for the three groups of technologies highlighted in tensions above, such as smart tableware, wearable, and robots (Fig. 8), AR/VR, image analysis, and 3D food printing (Fig. 9), and mobile apps, conversational agents, and SmartPlate (Fig. 10).

These figures show the distribution of the average number of experts' positive and negative evaluations of eachspecific design feature impacting each mindful eating aspect. We now describe these impactful design features for each of these three groups of technologies.

Technologies providing real time gamified feedback on eating speed, food amount, or variety. Fig. 8 shows that most of these functionalities provide some benefits for slow eating and portion size (green cells), albeit many of these (red cells) hinder non-judgmental, as well as non multitasking aspects as discussed above. These exemplars integrate sensors on the hand, chin, neck, or concealed in eating utensils to capture their movement, to provide real time feedback on eating actions: speed/rate, amount, healthy or various food (Fig. 8). Besides moving utensils, stationary ones such as trays could integrate actuators, i.e., LED lights [134] to provide feedback on food amount. These exemplars leverage rewards [122, 123, 133] or punitive feedback in visual [134], aural [123], or haptic modality [129] to provide real-time feedback in support of slowly chewing [133], slow eating [134], less food [134], or various, healthy food [123].

Technologies altering perception of food qualities, or predicting food volume. Fig.9 shows that these functionalities provide limited perceived benefits for portion size (green cells); however, many of these (red cells) hinder the non-judgmental aspect, as well as bodily awareness as discussed above. These technologies do not track eating-related movements, but focus instead on food and stationary eating utensils through AR/VR to predict or alter perception of food volume, appearance, smell, or texture (Fig. 9). Augmented cookie [181] superimposes larger images of food to alter food volume, while Metacookie [182] integrates HMD and olfactory display to alter food smell and texture. Calibratable uses a camera and LED light placed beneath a transparent tabletop to detect plate position and projects light around the food [212] to alter food volume. These examples leverage illusion to alter the user's perception of food. Augmented cookie aims to limit food intake while increasing the perception of satiety [181], while Metacookie superimposes images and smells of chocolate or strawberry on a plain cookie to support the perception of more delicious food [182]. VR plate lights plates of a different size than the physical plate, supporting the perception of larger food portions [212]. An interesting exemplar in this group is 3D food printing technology, which alters texture to augment satiety through increased chews per bite. FoodFab personalizes 3D printed dough based on users' food preferences and hunger levels. The printed food varies in internal structure to support different texture experiences, perceived satiety, and chewing times; i.e., high-density, low-structure requires less chewing time [148]. These functionalities of the FoodFab exemplar were appreciated by most practitioners as beneficial for eating slowly, savoring food, bodily awareness, as well as non multitasking, as 3D printed food is consumed with no additional screen to demand attention.

Technologies providing psychoeducation for healthy or mindful eating, guided meditation, and tracking eating. Fig.10 shows that these functionalities provide strong support for savoring, slow eating, and bodily awareness aspects, with the least supported aspect being non-multitasking. Such technologies do not provide real-time feedback, but inform users about mindful and healthy eating and guide brief meditation sessions on mindfulness or mindful eating. The Eat Right Now is a top-rated mindful eating app [90] providing psychoeducation on mindful eating. Other technologies include conversational agents such as TAMICA [223] that support understanding of mindful eating through motivational interviewing functionality; this exemplar, which received exclusively positive feedback. CATE [194] and Digital Sommelier [195] support savoring of tea or wine through guided mindful drinking, which were received favorably, with the main limitations pertaining to non-multitasking and healthy food. Not at least, tracking functionality such as that of Personalized chatbot exemplar [38] can hinder gratitude and non-judgmental aspects, as tracking functionality promotes a diet mindset and encourages perceiving food as a source of calories, which hinders the non-judgmental and gratitude aspects. As shown in Fig.10, tracking functionalities are less appreciated.

An interesting exemplar in this group is the SmartPlate. While in the form of tableware, this exemplar does not track eating but provides visual guidance on slow eating, using lights that lit up, one at a time, around the plate. This functionality is akin to guided mindful eating, albeit in a visual rather than traditional audio format. It is also integrated in the physical plate, thus supporting multi-tasking.

HCI Contribution. The visualization of experts' evaluation of key technology features supporting or hindering aspects of mindful eating can be used as a resource for design. HCI researchers with an interest in mindful eating technologies could use, thus explore the range of technologies such as those in our design exemplars, and their key design features with the potential to support mindful aspects, (i.e., guided meditation, tracking bodily/emotions with wearables, lights for guiding eating rate with smart tableware), or hinder them (i.e., superimpose food images with AR/VR) as assessed by our expert practitioners. The corpus of design exemplars is generative and could be further extended with new classes of technologies as the field matures.

7.3 (RQ3) What is the value of the MEDEC cards as a tool to communicate and represent the mindful eating aspects, and to critique design exemplars of technologies targeting them?

Findings indicate practitioners' overall appreciation of the MEDEC cards, particularly their ability to communicate well the mindful eating aspects through the labels' textual content, and visual content depicted through icons. These outcomes indicate the value of cards for materializing abstract concepts into tangible form, and of our design choices for the MEDEC cards, thus extending previous HCI findings on design cards [94, 109, 154, 188, 252], particularly from the health domain [138, 177] to the less explored cards for the mindful eating space. The sensitizing questions were also valued for their ability to prompt reflection and critique, which align with previous findings on card design [138, 177].

In addition to the positive feedback described above, participants made useful suggestions for improving the cards to ensure more sensitive language (4 cards), increased labels' clarity (3 cards), removing 1 card, generating 2 new cards, increased group cohesiveness (4 cards), and better overall support for cards' manipulation to create configurations of mindful eating cards positioned around the technology card to which they apply. The rationale for each of these changes, detailed in Section 6.2, led to a revised MEDEC set consisting of 29 cards. The section below describes the design of the two new icons and the small changes made in the overall visual layout.

Revised MEDEC Cards: Icons. We have generated a new icon for the new card: "pausing briefly during eating", and revised other 5 icons for "presence with the meal" (previously "non multitasking"), "unbalanced relationship to food" and "balanced relationship to food" (previously "relationship with food"), non judgmental acceptance of eating related emotions, thoughts, and experiences, and non reactance to them" (previously "non judgmental"), and "nourishing food" (previously "healthy food". For the former, we draw inspiration from mindfulness metaphors such as the clock for intentional slowing down [119] and pausing icons from Microsoft, such as media pause one, which we placed within a circular arrow, around a small fruit, and above crossing palms in meditation posture to suggest pause during eating.

For the "presence with the meal" card, we draw from metaphors of mindfulness, such as the lotus flower [83, 230] symbolizing stillness and presence [97], which we placed within a deep round bowl to suggest focus of attention on the meal. For "unbalanced relationship to food" and "balanced relationship to food," we leveraged the balance metaphor, previously used in HCI through visual representations of a seesaw or teeter-totter, which require gentle adjustments to remain balanced [15]. Rather than contrasting healthy and less healthy food choices like in our previous card, we used emoticons for negative emotion for an unbalanced relationship to food, and positive emotion for a balanced relationship. We placed each emoticon on the left-hand side of the scale and an image of comforting food on the right-hand side. For an unbalanced relationship, we unbalanced the scale, indicating the larger, uncontrolled amount of comforting food, and for a balanced relationship, we kept the scale balanced. For the "non judgmental acceptance of eating related emotions, thoughts and experiences, and non reactance to them" we draw again from mindfulness meditation metaphors of acceptance and distancing such as "thoughts like clouds in the sky" [136], or "thoughts or emotions like cars passing by" [240], as well as the metaphor of clouds [99] represents distancing and non-engagement. Thus, we combined the icon of a person sitting content in meditation, who is accepting, yet not reacting to their cravings, represented within a cloud, placed at some distance from them. Finally, for the "nourishing food" card, we used the same image of healthy food being cooked in a container, but replaced the frying pan with a pot as a healthier food preparation option, and for increased clarity, placed it on top of a two-eye stove.

Revised MEDEC Cards: Visual Layout. In addition to changing the shapes of the cards, which we described in Section 6.2.2, we have made two more minor changes to improve the clarity of the cards. First, in addition to the label, we provided on each card a brief description of the label's meaning, using accessible, jargon-free, and sensitive language. Second, we placed the sensitizing questions on the front of the cards to ensure increased usability, a choice that other HCI scholars also preferred [138, 177]. Table 4 shows the final iteration of the MEDEC cards in the light of practitioners' feedback, with the main changes including a change to a rectangular shape for all cards, provision of a description for each card label, and sensitizing questions at the front of the cards.

Regarding the layout, we draw inspiration from previous card shapes and dimensions [138, 177], and chose a rectangular format measuring 10 cm × 6.5 cm to better support tangibility and manipulation of the MEDEC cards. Within the rectangular shape, we created a left panel for the label and icon, both succinct and quick to grasp, with the label at the top, and icon at the bottom. On the larger, right-hand side panel, we placed the descriptions and sensitizing questions, at top and bottom, respectively. We also provided the length of the right-hand side of each card, the name of the group to which it belongs: technology or mindful eating aspect. Within the latter, we further specified for pink cards the two main dimensions of presence moment awareness of eating experience, or non-judgmental acceptance, and two further subgroups for yellow cards: awareness of bodily sensations for savoring food, and awareness of internal bodily sensations.

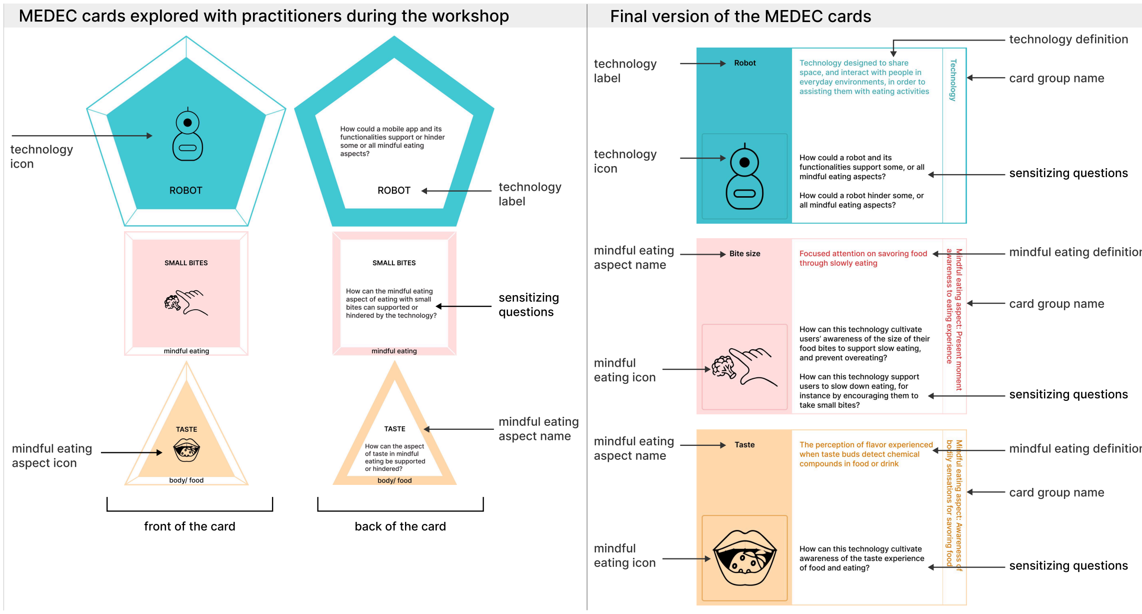
To enhance differentiation and glanceability, we applied the same color scheme: blue for technology, yellow for bodily awareness aspects of mindful eating (both external and internal), and pink for the rest of the mindful eating aspects. We also applied these colors as background to the left-hand side panels. These three colors were also used for the descriptions and grouping names.

Finally, for 4 cards of the revised set: "balanced relationship to food", "unbalanced relationship to food", "non-judgmental acceptance of eating-related emotions, thoughts, and experiences, and non-reactance to them", and "pausing briefly during eating", which also have the most changes regarding their labels, or icons, we elicited additional feedback from 8 participants. All 8 participants appreciated them, 5 did not suggest any further changes, and 3 suggested minor changes regarding sensitive language, overlap of two sensitizing questions, and increased clarity of one icon. Thus, we changed "negative emotions" to "difficult emotions" for "unbalanced relationship to food" card; kept only one sensitizing question for "pausing briefly during eating" card; and regarding the icon of the "pausing briefly during eating" card, we added the suggested plate with cutlery positioned to form a V shape as per table etiquette, thus replacing our image of a food item.

Vocabulary for Eating Actions. We also reflected on our approach to communicating the design exemplars and eating actions. A key challenge was the various terms used in HCI research to describe eating actions, terms like eating time [134], eating pace [134], number of chews per swallow [133], and others [122] often lacking consistency and clear definitions. To address this, we reviewed food science research on the microstructure of eating [54], which includes reflexive actions like chewing and their temporal dynamics [11, 95, 227]. We then identified and defined key terms from this research as they apply to our design exemplars. We advance thus an initial vocabulary of eating actions:

- *bites* as a single hand-to-mouth movement placing food or drink in the mouth [11]
- *chews* as are rhythmic movements of opening and closing the mouth while crushing food and their temporal aspects such as duration, speed, and rate [250]

Fig. 11. The final iteration of the MEDEC cards from the version of the cards explored with practitioners during workshops (left) to the revised version (right), also available for download in the supplementary material. The main changes include a rectangular shape for all cards, provision of descriptions for each card label, and sensitizing questions at the front of the cards.



- *eating speed* as the ratio of eating episode duration to the number of bites [11]
- *eating rate* as the ratio of overall meal weight to meal duration [253].

In light of this vocabulary, most exemplars focus on the number of bites [122, 134, 148], the number of chews and swallows [133], and temporal aspects such as meal duration, which can be adjusted by the user in the apps [134, 148], and eating rate [148].

HCI Contribution. Our evaluation of MEDEC cards indicates their value as a design critique tool. This is an important contribution given the limited research for supporting better theoretically grounded exploration of mindful eating technologies. We also introduce an initial vocabulary of eating actions to support more consistent communication of design features targeting the microstructure of eating [54], which is primarily supported by smart tableware and 3D food printing technologies.

7.4 Towards A Design Framework for Mindful Eating Technologies

We start by reflecting back on mindful eating aspects as bridging concepts, and their component: *design articulations*, which we leverage to advance a space for designing mindful eating technologies. This leverages the three sets of distinct functionalities of the three groups of technologies discussed above.

For this, we first created a two-dimensional design space consisting of two orthogonal axes of modalities/content: input (Y axis) and output (X axis). This represents a design space within which both existing technologies and new possibilities can be mapped (Figure 8). We further extended this design space towards a design framework by applying the lens of the mindful eating construct, and its main aspects overlaid over the output axis of the design space. While the generativity of the design space is combinatorial, the generativity of the design framework is normative as it makes less visible regions of the design space salient for their alignment with the main mindful eating aspects. The design framework is intended to support researchers, designers, and developers interested in mindful eating technologies to work with the identified main aspect of mindful eating and a set of design principles (Appendix, Table 14, which we articulated to guide a theoretically grounded exploration of these technologies. Within the design framework, the SmartPlate represents a theory-informed instantiation, as the identified main aspects of mindful eating informed the generation of this instantiation. Moreover, across the 36 expert practitioners, their critique revealed the SmartPlate's theoretical validity: it is a recognizable and meaningful instantiation of most of the framework's main aspects of mindful eating, indicating that these aspects can become operationalized in design practice.

We also populated the design space with the papers from the scoping review, thus highlighting areas of interest within the current state-of-the-art, beyond those of our design exemplars, as well as less explored areas which hold potential for novel future designs of mindful eating technologies. We further reflect on the generative value of our design framework for inspiring novel design articulations supporting novel technology-based interventions for mindful eating, such as those supporting psychoeducation, bodily awareness, and mindful eating meditation. We also show how the framework can be extended by integrating additional input technologies, such as olfactory sensors, ingestible sensors, or AI, and additional output technologies, such as smart materials or olfactory interfaces.

7.4.1 Mindful Eating Aspects as Bridging Concepts. Given their rigorous grounding in health research on mindful eating definitions [73, 184, 229], principles [171], measurement scales [39, 40, 110, 199, 251], and most effective interventions [35, 142, 143, 145], the identified mindful eating aspects represent bridging concepts: a form of design knowledge connecting theory and practice to inform both novel designs, and theory development [51]. Therefore, by communicating these aspects, the MEDEC cards are translational design tools, translating abstract concepts from mindful eating research into more concrete knowledge that could more accessibly inform technology design [32, 49, 109, 188].

Since, in addition to theoretical grounding, bridging concepts [51] have two other components: design exemplars, and design articulations, we now focus on outlining the latter two for mindful eating aspects as bridging concepts. Regarding design exemplars, Section 4.4 describes their set for illustrating main mindful eating aspects, and our rationale for curating them from the eight types of technologies identified from the scoping review (3.2): mobile apps, wearables, smart tableware, AR/VR, robots, conversational agents, 3D food printing, and image analysis.

For design articulations, we now deepen our reflection on workshops' findings on design exemplars, and their specific functionalities which support or hinder the main aspects of mindful eating 7.2. Bourgault and Jacobs [33] followed a similar approach to explore the bridging concept of digital fabrication by curating 30 design exemplars of material carving, which they analyzed to identify design articulations that support carving actions such as linear movements, a grid within which movements are executed, and the boundary of the grid shape. The above Figures 8, 9, and 10 show the mapping of the main aspects of mindful eating to the main functionalities of three groups of technologies: (i) smart tableware, wearables, and robots, (ii) AR/VR, image analysis, and 3D food printing, and (iii) mobile apps, conversational agents, and our own smart tableware exemplar (SmartPlate), respectively.

Thus, Figure 8 indicates two main functionalities of the first group of smart tableware and wearable technologies: (a) providing real time gamified feedback on eating actions for slow eating [134], or healthy eating [122, 123], and (b) sensing situated eating actions such as chew numbers, and their temporal dynamics such as duration of chewing [133]. It is important to decouple the input (sensors) from the output (gamified audio or visual feedback), as the former, but not the latter, was perceived as hindering mindful eating.

The three main functionalities of the second group of AR/VR, image analysis, and 3D food printing (Fig. 9) are (a) altering physically the haptic qualities (i.e., texture) of specific food items to increase bodily awareness of texture, and bodily cues for satiety [148], (b) altering virtually the visual qualities of specific food items [182], and (c) analysing, or predicting qualities of specific food items (i.e., volume) to reduce the amount of food being eaten [180]. While the first one was perceived by our expert practitioners as supporting mindful eating, the latter two were critiqued for hindering it. Here, we also decouple the input (analyzing food qualities) from the different outputs: 3D printed food with enhanced texture, virtual images of altered food qualities, or predictions of food volume, the latter two of these hindering mindful eating.

Not at least, the five main functionalities of the third group of mobile apps, conversational agents, and SmartPlate tableware (Fig. 10) are (i) tracking eating behavior, cues, and triggers, (ii) providing psychoeducation about healthy and mindful eating, (iii) providing generic, pre-recorded guided mindfulness or mindful eating meditation on screens, (iv) providing situated, dialogical guided mindful eating meditation on screens, (v) providing situated guided mindful eating meditation on tableware. All practitioners strongly appreciated these exemplars on most of the mindful eating aspects, with the main limitation being food dairy, which hinders the non-judgmental aspect, and non-multitasking for screen-based exemplars. These functionalities include input (tracked eating behavior, cues, triggers; user speech) and output (visualizations of tracked data on eating-related experiences, generic or situated interventions, speech), albeit with limited integration. For instance, tracked eating cues or triggers are limitedly leveraged to provide in situ intervention on guided mindful eating.

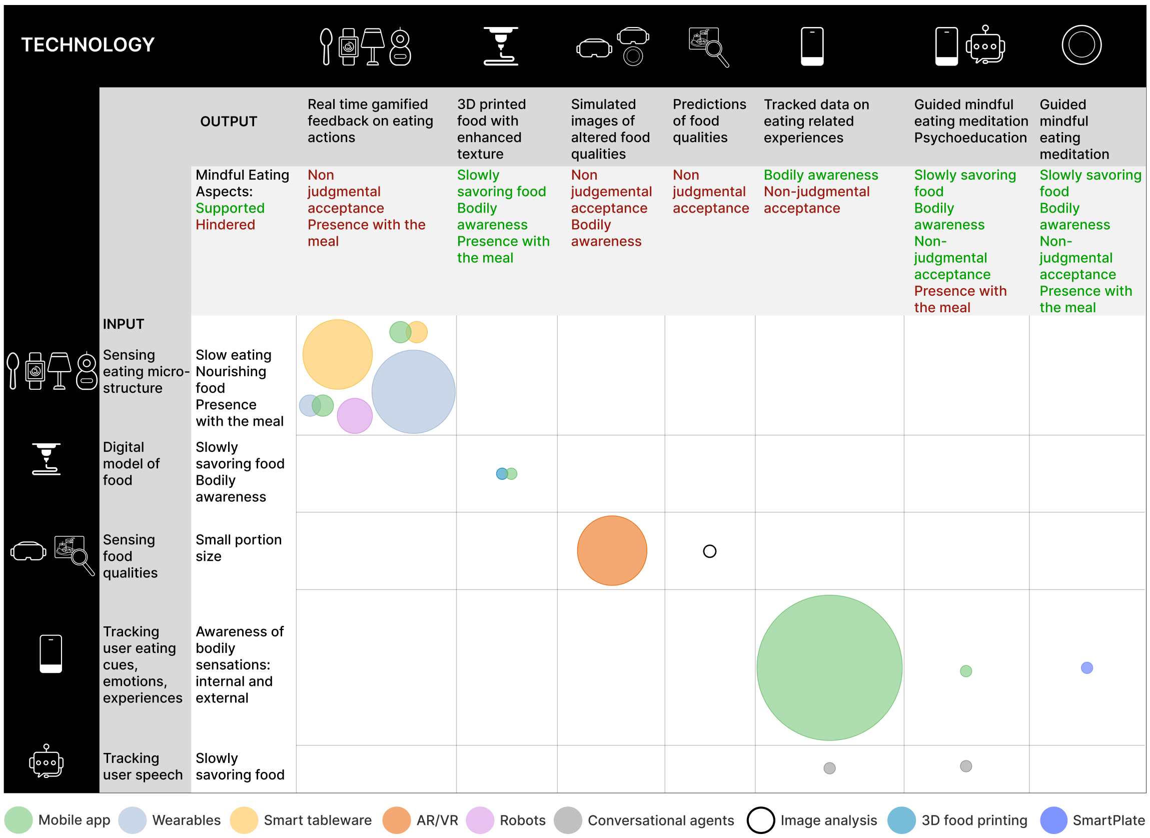
7.4.2 Design Framework. Informed by our scoping review and empirical data, we articulate an initial design framework to encourage and support HCI researchers and interested designers to engage in this space. The framework builds on the three groups of technology types identified above, for which we articulate their main input and output functionalities. As described above, these three groups of technologies leverage five types of input: (i) sensors for tracking eating microstructure (chewing speed) which can be on the user's body, integrated in eating utensils, or in the eating environment, (ii) digital model of food, (iii) sensors for capturing food qualities (i.e., camera), (iv) tracked user data on eating experiences, bodily cues, or triggers for emotional eating, (v) user speech with conversational agents for dialogical interventions (psychoeducation, guided mindful eating intervention). These technologies also support the following six types of output: (i) real-time gamified feedback on eating actions, (ii) 3D printed food with enhanced texture, (iii) simulated images of altered food qualities, (iv) predictions of food qualities (i.e., volume), (v) tracked data on eating aspects, (vi) generic or situated interventions (i.e., guided mindful eating meditation).

Since all hindered mindful eating aspects pertain to output functionalities, we argue for the value of decoupling them from input ones. Thus, Figure 12 shows for each of the eight technology types we explored: mobile apps, wearables, smart tableware, AR/VR, robots, conversational agents, 3D food printing, and image analysis, their input functionalities (rows) and output functionalities (columns), as well as mindful eating aspects supported or hindered by them.

The first output of data on the microstructure of eating focuses on "*direct experience*" of eating, delivered by systems that track such data, commonly through gamified feedback "*altered experience*" is supported by systems that alter users' perception of food, through physical or simulated alteration of food, "*predicted food aspects*" is supported by systems that predict food qualities, "*bodily and emotional experience of eating*" delivered by systems supporting users to track such data, while "*guided experience*" is delivered by systems supporting guided mindfulness meditation.

Direct experience technologies include smart tableware, wearable, and robots embedding movement sensors or cameras. While such data, for instance, on chewing speed, or portion size, has the potential to support mindful eating aspects of

Fig. 12. The design framework of mindful eating technologies, which consists of a two-dimensional design space on which the mindful eating main aspects are overlaid. The design space covers the eight technology types we explored: mobile apps, wearables, smart tableware, AR/VR, robots, conversational agents, 3D food printing, and image analysis, their input functionalities (rows) and output functionalities (columns), as well as mindful eating aspects supported or hindered by them. The design space is also populated with the number of papers from the scoping review, placed in the respective cells based on the input/output of their described prototypes. The circles' colors indicate the types of technologies for these prototypes: green (mobile apps), light blue (wearable), yellow (smart tableware), orange (AR/VR), pink (robots), gray (conversational agents), white (image analysis), blue (3D food printing), and purple (SmartPlate). The size of the circles' diameter indicates the percentage of the respective technology as reflected in the number of papers from the scoping review. Thus, the circles reflect the main areas of interest within the current state-of-the-art, while the less populated areas in the design space highlight the generative value of the design framework for inspiring novel designs of mindful eating technologies.



"slow eating", "nourishing food", such potential is hindered by these technologies providing gamified real-time feedback as this impacts users' non judgmental acceptance of their eating experiences.

Altered experience technologies include AR/VR, which alter users' perception of food, albeit in different ways, as 3D printing food alters physical food items, while AR/VR alters simulated food items and their qualities like volume. The latter offer does not support any aspects of mindful eating, and particularly hinders "non judgmental acceptance", and "bodily awareness". In contrast, 3D printed food is highly beneficial, as texture altered to increase satiety supports mindful eating aspects of "slowly savoring food", "bodily awareness", as well as "presence with the meal" since no additional screens are needed during the eating experience.

Predicted food aspects includes image analysis technologies which can analyze food, but when the output is predicting the amount of food on the plate, they hinder "non judgmental acceptance" of the user's eating experiences.

Tracked data on eating experiences is provided most often by mobile apps through user input on their emotions, bodily cues, or triggers for eating, or food, captured through time. If data on bodily cues such as hunger or satiety can support "bodily awareness", data on food calories or problematic eating hinder non judgmental acceptance" of the user's eating experiences.

Guided mindful eating technologies are mostly mobile apps, and conversational agents, as well as new ones such as SmartPlate tableware. Through their generic or situated guidance, these technologies support mindful eating aspects of "slowly savoring food" and "bodily awareness", and particularly important "non judgmental acceptance of eating experience". We also highlight the different affordances of these technologies for guided mindful eating meditation. While mobile apps support pre-recorded guided mindful eating meditation, they do so with a focus on generic food items such as raisins and elements of psychoeducation within the meditation session. Thus, while useful to inform about mindful eating, such pre-recordings are less suited for a situated mindful eating session, like having a snack in the afternoon. In contrast, we have situated guided mindful eating meditation supported by conversational agents, which can match the food item to that eaten by the user, or by SmartPlate, which also supports a situated, here-and-now, mindful eating session. In addition, SmartPlate also supports "presence with the meal", an aspect which screen based technologies such as mobile apps hinder.

Figure 12 also shows the coverage of each area in this design space, as we populated it with our 17 design exemplars [3, 38, 78, 117, 122, 123, 123, 129, 133, 134, 148, 180, 182, 194, 195, 223] and over 40 technologies targeting aspects of mindful eating from our scoping review.

As we can see, while most smart tableware, wearable, and robot technologies focus on direct experience using sensor data on eating microstructure, those focusing on alter experience or prediction of food aspects use food data, and those that track eating experience or guide experience leverage user data, this does not have to be the case. Indeed, the sensitive design of mindful eating technologies can consider alternative outputs from the given input data. This allows the exploration of the best combinations of input-output technologies to better support mindful eating and limit the hindrance of any of its aspects.

For example, smart tableware, wearable, and robots can support the regulation of eating movements, which is instrumental for slow eating, as well as bodily awareness and presence with the meal. However, the latter aspects, despite their massive importance, are either not supported by these technologies or even hindered. Bodily awareness and presence with meal aspects are instead supported by guided experience systems, such as mobile apps that leverage user data, although these apps may lack access to eating microstructure data. Moreover, since direct experience technologies overwhelmingly provide real-time, gamified feedback, they hinder non-judgmental acceptance. In contrast, guided experience technologies support non-judgmental awareness. So, the two core aspects of mindful eating: presence with the meal, and non-judgmental acceptance, capture a high-level tension between direct experience and guided experience technologies. The design framework highlights such tensions, as well as novel design opportunities to address them, as shown below.

7.4.3 The Generative Value of Design Framework: Novel Design Articulations. We now illustrate the generative power of our design framework for opening up novel design opportunities for mindful eating technologies. We highlight such opportunities for each type of output technologies while integrating input data from other technologies. Such output functionalities consist of mindful eating interventions, such as those supporting bodily awareness, mindful eating meditation, as well as those for psychoeducation. We also show how the framework can be extended by integrating additional input technologies, such as olfactory sensors, ingestible sensors, or AI, and output technologies, such as smart materials or olfactory interfaces.

The sensor data on microstructure of eating can be leveraged to design novel interventions for psychoeducation on eating microstructure, which can be delivered through a range of technologies, from smart tableware, wearable devices, or robots to mobile apps. This data can also be used to prompt the delivery of situated interventions on guided mindful eating. However, rather than providing explicit punitive or rewarding feedback for immediate behavior correction, these interventions can leverage subtle or more ambiguous feedback on the microstructure of eating, as the value of these qualities of feedback for emotional awareness [213], and mindful meditation [52] has been previously suggested. Other output technologies include smart materials whose subtle and ambiguous feedback have been shown to support emotional awareness and regulation [241]. Smart tableware technologies are probably best positioned to deliver such interventions, since they can be integrated into the eating experience without the use of additional displays or screens, which may take attention away from the meal. An illustration of such smart tableware and its subtle feedback is the SmartPlate design. Such interventions can also be prompted by tracked user data on eating experiences, so that, for example, the real-time identification of cravings can be used to recommend on-the-spot guided mindful eating interventions.

Digital models of food can inform novel psychoeducation interventions on bodily external sensations of eating that can capture various parameters of texture, beyond those explored by the FoodFab 3D printed food [148]. We can also imagine additional technologies supporting such interventions through multisensory interactions [82] such as olfactory sensors as input technologies, and olfactory interfaces as output technologies, for which HCI interest has emerged [25]. Data from these input technologies can also be used to design novel interventions for bodily awareness while savoring food with altered physical qualities.

Sensed data on food qualities captured through AR/VR technologies can be used to inform novel psychoeducation interventions on bodily internal sensations through simulated content by materializing less accessible internal processes, which have also started to be explored in HCI, such as digestion [202] or gut health [260]. Data from these input technologies can also be used to design novel interventions for training such interoceptive awareness, leveraging the gut as a site for interaction [81]. In addition, image analysis of food can be used for psycho-education interventions on healthy eating, balancing, for example, prediction of food amount with predictions of nutrients, which can also be used to make it easy to act on recommendations for healthier, more nutritious meals.

Tracked user data on eating-related emotions, bodily cues, or triggers, as well as eating experiences (albeit less so the problematic data on caloric intake and food amount) can be used to inform personalized psychoeducation on emotional eating. Together with the microstructure of eating data, this can also inform personalized interventions for emotional and bodily awareness and regulation prompted by bodily data or the microstructure of eating data, as well as personalized, in-situ interventions for guided mindful eating meditation. The latter could also be prompted by bodily data and the microstructure of eating data, for instance, once craving is experienced. Bodily data could include both user-tracked and automatically captured through ingestible sensors [147]. Such personalized, in situ guided mindful eating meditation interventions can leverage user speech in order to adapt the guidance to the current meal that the user is eating mindfully, potentially already highlighted by the Digital Sommelier [195].

Not at least, AI technologies can be used on tracked data informing interventions like the one described above, as well as data on user engagement with such interventions, in order to make informed recommendations for the most appropriate interventions in a specific context.

8 LIMITATIONS AND FUTURE WORK

We acknowledge four limitations and their potential impact on findings, as well as our efforts to mitigate them. First, we focused on the ACM DL [2], which is the most frequently utilized database in reviews of HCI research [58, 64, 214] and the relevant medical research from PubMed. The search engine of the ACM DL comes with its own imitations, previously acknowledged in HCI research [58, 219], such as occasionally inconsistent results for identical search terms and date ranges. To address this issue, we ensured the consistency of our search results by revisiting the search at two different times (Section 4.1).

Second, we also acknowledge that the revised MEDEC cards (Iteration 2) could have been perceived as more polished and information-rich. Thus, this may have led to reduced critique of the cards, stemming in part from the HCI documented aesthetic–usability effect [225, 237]. It could, however, also reflect that the feedback on the Iteration 1 of the cards has already captured the most issues and suggestions for improvements, which we addressed in Iteration 2. The exploration with the additional 15 experts thus provided an opportunity to confirm the clarity of those refinements, as well as to explore additional types of technologies identified through the second search on the ACM DL and on the PubMed (Section 4.1).

Third, our findings indicate that while most technologies are not explicitly designed for mindful eating, they address some of their main aspects, and thus are useful to be explored by us. While such support is uneven, with most technologies targeting only a few of these aspects, there is potential for integrating different technologies to provide richer support. As highlighted by the design framework that we advanced, this requires sensitive design to account for (i) the tension among the mindful aspects, i.e., present moment awareness vs non-judgmental acceptance of eating experiences, and (ii) different technologies' affordances for supporting, or hindering mindful eating aspects. Moreover, few technologies support non-judgmental acceptance, while AR/VR technologies altering food taste and portion size can be particularly problematic for mindful eating and even more so for vulnerable users such as those with EDs [91]. Awareness of these ethical concerns is crucial when designing for mindful eating technologies.

Fourth, we engaged with mindful eating practitioners to evaluate the MEDEC cards. Our choice for this stakeholder group was grounded in the state-of-the-art, as by engaging practitioners rather than end users, we could better establish the theoretical and empirical rigor required by the MEDEC tool. The cards also have the potential to support the design of mindful eating technologies, both for the general population and for people living with eating disorders. Similar to previous HCI research on design cards [5, 109, 188], we will also explore the value of the MEDEC cards as a design tool with other stakeholders, such as designers, technology developers, and end users.

9 CONCLUSION

In this study, we present an analysis of health research on mindful eating principles, measurement scales, and therapeutic interventions such as the MB-EAT program to identify the main aspects of mindful eating. We also conducted a scoping review of 73 papers on technologies targeting these aspects of mindful eating, from which we curated 16 design exemplars that represent the breadth of these technologies. To bridge the gap between theory and practice, we designed the MEDEC cards, which we used in workshops with 36 mindful eating practitioners to critique the design exemplars. Workshop findings informed design articulations as functionalities for mindful eating technologies. Informed by our scoping review and empirical data, we also advanced a theoretically-informed design framework for mindful eating technologies.

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10 NOTE

Within References, the 73 papers included in the scoping review are marked with an asterisk (*).

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A APPENDICES

A.1 Method Supplementary Tables

Table 5. Demographic profile of practitioners. Regarding sex, F: female and M: male. Regarding education levels, BSc: Bachelor of Science, MSc: Master of Science, and PhD: Doctor of Philosophy. Regarding certificates, MB-EAT: Mindfulness Based Eating Awareness Training, MB-SR: Mindfulness Based-Stress Reduction, IE: Intuitive Eating, and ME-CL: Mindful Eating-Conscious Living.

ID	Age	Sex	Expertise	Country	Education	Occupation	Certificates
P1	29	F	6 years	Turkey	BSc	Dietitian	MB-EAT
P2	48	F	5 years	Switzerland	MSc	Nutritionist	ME-CL
P3	40	F	10 years	UK	BSc	Dietitian	MB-EAT
P4	51	M	8 years	UK	PhD	Psychologist	MB-SR
P5	55	F	3 years	France	MSc	Nutritionist	MB-EAT
P6	31	F	3 years	India	MSc	Dietitian	MB-EAT
P7	36	F	5 years	Turkey	BSc	Nutritionist	Intuitive Eating
P8	44	F	4 years	UK	PhD	Nutritionist	MB-EAT
P9	57	F	18 years	USA	BSc	Dietitian	MB-EAT
P10	62	F	7 years	USA	PhD	Psychologist	MB-SR
P11	42	F	2 years	Germany	MSc	Nutritionist	MB-EAT
P12	44	F	8 years	Brazil	MSc	Nutritionist	MB-EAT
P13	42	F	7 years	Ireland	BSc	Nutritionist	MB-EAT
P14	52	F	5 years	Canada	MSc	Mindfulness coach	MB-SR
P15	58	F	25 years	USA	MSc	Dietitian	MB-EAT
P16	50	F	8 years	USA	MSc	Mindful eating coach	MB-SR
P17	26	F	3 years	Turkey	BSc	Dietitian	
P18	54	F	29 years	USA	MSc	Dietitian	
P19	37	F	7 years	UK	MSc	Dietitian	MB-EAT
P20	30	F	4 years	USA	MSc	Dietitian	MB-EAT
P21	62	M	2 years	USA	MSc	Mindfulness coach	MB-SR
P22	42	F	10 years	UK	BSc	Dietitian	MB-EAT
P23	53	F	20 years	USA	MSc	Mindful eating coach	MB-EAT
P24	35	F	14 years	UK	MSc	Dietitian	
P25	47	F	15 years	UK	PhD	Nutritionist	MB-EAT
P26	26	F	3 years	UK	BSc	Dietitian	
P27	32	F	6 years	USA	MSc	Dietitian	MB-EAT
P28	32	F	12 years	UK	BSc	Dietitian	MB-EAT
P29	42	F	11.5 years	UK	PhD	Therapist	MB-SR
P30	37	F	4 years	UK	MSc	Therapist	MB-SR
P31	33	F	11 years	UK	MSc	Dietitian	MB-EAT
P32	43	F	6 years	UK	BSc	Therapist	MB-SR
P33	45	F	10 years	UK	BSc	Mindfulness Coach	MB-SR
P34	48	F	25 years	USA	MSc	Therapist	MB-SR
P35	44	F	20 years	Canada	MSc	Dietitian	MB-EAT
P36	58	F	14 years	UK	MSc	Nutritionist	MB-EAT

Table 6. Table presents the allocation of the selected six or seven exemplars out of the total of 17 to participants, to ensure that each participant was shown exemplars from at least three different types of technologies from the eight available ones: mobile apps, wearables, smart tableware, AR/VR, robots, conversational agents, 3D food printing, and image analysis. Practitioners saw three exemplars of smart tableware: two of AR/VR, or two of conversational agents, and each participant was shown the design exemplar for the mobile app, and our own design: the SmartPlate tableware.

ID	TECHNOLOGIES																	
	Mobile app (Eat Right Now)	Smart Tableware						3D Printing food (Food fab)	Wearable (Slowee)	AR/VR			Conversational Agent (CA)				Robot	Image analysis
		SWAN spoon	Ecomeal tray	Sensing fork	Educatableware fork	Educatableware cup	Smart plate			Metacookie	Augmented cookie	Calibratable	TAMICA	Digital somellier	CATE	Personalised CA		
P1	*	*				*	*		*	*		*						
P2	*		*		*		*	*	*									
P3	*			*		*	*		*		*	*						
P4	*	*				*	*	*	*									
P5	*			*	*	*	*	*	*									
P6	*	*	*				*		*		*	*						
P7	*	*				*	*		*	*		*						
P8	*	*				*	*		*	*		*						
P9	*			*		*	*		*		*	*						
P10	*	*		*			*	*	*									
P11	*				*	*	*		*	*		*						
P12	*	*	*				*	*	*									
P13	*			*		*	*		*		*	*						
P14	*			*		*	*	*	*									
P15	*	*	*				*		*	*		*						
P16	*		*			*	*		*	*	*							
P17	*	*	*				*	*	*									
P18	*	*				*	*		*	*	*							
P19	*		*			*	*		*	*		*						
P20	*	*	*	*			*	*	*									
P21	*	*		*			*		*	*		*						
P22	*						*						*	*			*	*
P23	*						*								*	*	*	*
P24	*						*						*	*			*	*
P25	*						*								*	*	*	*
P26	*						*						*	*			*	*
P27	*						*								*	*	*	*
P28	*						*						*	*			*	*
P29	*						*								*	*	*	*
P30	*						*						*	*			*	*
P31	*						*								*	*	*	*
P32	*						*						*	*			*	*
P33	*						*								*	*	*	*
P34	*						*						*	*			*	*
P35	*						*								*	*	*	*
P36	*						*						*	*			*	*

A.2 Final Set of the MEDEC Cards

Table 7. Revised MEDEC Cards: blue-colored cards representing the technology types

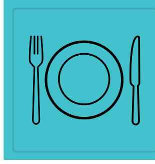
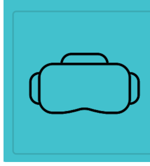
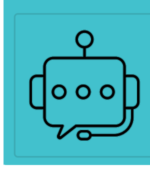
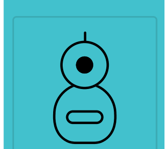
Smart tableware 	Tableware such as forks, plates, or cups integrating sensors (i.e., weight, movement), and actuators (i.e., lights, sound) to provide real-time feedback How could a smart tableware and its functionalities support some, or all mindful eating aspects? How could a smart tableware hinder some, or all mindful eating aspects?	Technology
Mobile app 	Software designed to run on smartphones or tables with can support different functionalities from tracking eating to education or guided mindful eating How could a mobile app and its functionalities support some, or all mindful eating aspects? How could a mobile app hinder some, or all mindful eating aspects?	Technology
Wearable 	A smart device worn on the body to collect and track data and provide feedback How could a wearable technology and its functionalities support some, or all mindful eating aspects? How could a wearable hinder some, or all mindful eating aspects?	Technology
Augmented reality Virtual reality 	Technologies design to support immersive experiences; AR overlays virtual content onto the real world, and VR replaces the real world with a virtual environment How could a AR or VR technology and its functionalities support some, or all mindful eating aspects? How could a AR or VR technology and its functionalities hinder some, or all mindful eating aspects?	Technology
3D printing food 	Technology which creates edible items, layer by layer, using food-grade materials How could a 3D printing food and its functionalities support some, or all mindful eating aspects? How could a 3D printing food hinder some, or all mindful eating aspects?	Technology
Conversational agents 	Technology which simulates human conversation through text or speech providing various functionalities from inform and educating to guiding mindful eating meditation How could a conversational agent and its functionalities support some, or all mindful eating aspects? How could a conversational agent and its functionalities hinder some, or all mindful eating aspects?	Technology
Robots 	Technology designed to share space, and interact with people in everyday environments, in order to assisting them with eating activities How could a robot and its functionalities support some, or all mindful eating aspects? How could a robot hinder some, or all mindful eating aspects?	Technology
Image analysis 	Software which analyses images i.e., those of food to extract important information i.e., portion size, ingredients, or estimated nutritional content How could image analysis technology and its functionalities support some, or all mindful eating aspects? How could image analysis technology and its functionalities hinder some, or all mindful eating aspects?	Technology

Table 8. Revised MEDEC Cards: yellow-colored cards representing the rest of the mindful eating aspects

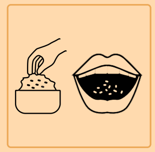
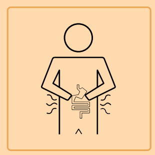
Sight		The bodily sensation that allows us to perceive visual information by detecting light, color, and shape through the eyes	How can this technology cultivate awareness of the visual experience of food and eating?	Mindful eating aspect: Awareness of bodily sensations for savoring food
Texture		The perception of the surface qualities of an object, like smoothness or roughness, detected through touch	How can this technology cultivate awareness of the visual experience of food and eating?	Mindful eating aspect: Awareness of bodily sensations for savoring food
Sound		The perception of vibrations through the ears to detect and interpret sound	How can this technology cultivate awareness of the sound experience of food and eating?	Mindful eating aspect: Awareness of bodily sensations for savoring food
Hunger		The bodily feeling signaling the need for food, triggered by physiological cues like low energy or empty stomach	How can this technology cultivate users' awareness of hunger cues, for instance by pausing and checking for them before, during, and after meals?	Mindful eating aspect: Awareness of internal bodily sensations
Taste		The perception of flavor experienced when taste buds detect chemical compounds in food or drink	How can this technology cultivate awareness of the taste experience of food and eating?	Mindful eating aspect: Awareness of bodily sensations for savoring food
Satiety		The bodily feeling of satisfaction and reduced desire to eat, signaling that the body has had enough food	How can this technology cultivate users' awareness of satiety or fullness cues, for instance by pausing and checking for them before, during, and after meals?	Mindful eating aspect: Awareness of internal bodily sensations
Smell		The perception of odors detected by receptors in the nose when airborne molecules interact with the olfactory system	How can this technology cultivate awareness of the smell experience of food and eating?	Mindful eating aspect: Awareness of bodily sensations for savoring food
Digestion		The process by which the body breaks down food into smaller components to absorb nutrients	How can this technology cultivate awareness of eaten food, and its impact on digestion? How can it support gut health?	Mindful eating aspect: Awareness of internal bodily sensations

Table 9. Revised MEDEC Cards: pink-colored cards representing mindful eating bodily sensory aspects

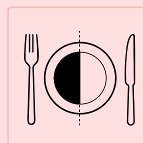
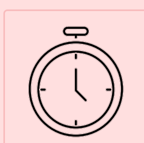
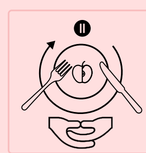
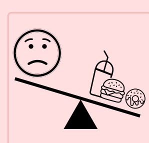
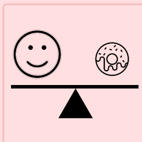
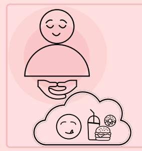
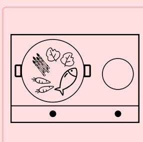
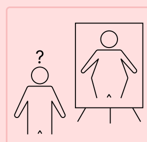
Card	Icon	Definition	Questions	Aspect
Temperature		The perception of heat or cold detected by sensory receptors in the skin and body	How can this technology cultivate awareness of the temperature experience of eating, when food is both touched by hand, or inside the mouth?	Mindful eating aspect: Awareness of bodily sensations for savoring food
Presence with the meal		Focused attention on eating rather than other activities	How can this technology better support for present moment awareness of eating experience? How can this technology limit distractions (internal and external) that may hinder present moment awareness of eating experience?	Mindful eating aspect: Present moment awareness of eating experience
Savoring food		Focused attention on bodily sensations to intensity the pleasure of eating experience	How can this technology better engage each of the five senses (touch, sight, hearing, smell, and taste), sequentially while eating? How can this technology encourage users to engage all five senses simultaneously while eating?	Mindful eating aspect: Present moment awareness of eating experience
Modest portion size		Focused attention on eating rather than other activities	How can this technology cultivate users' awareness of the meal's portion size to support slow eating, and prevent overeating? How can this technology support users to develop non-judgmental attitude towards their portion sizes?	Mindful eating aspect: Present moment awareness of eating experience
Chewing thoroughly		Focused attention on savoring food through slowly eating	How can this technology better support users to slowly and thoroughly chew their food until it completely liquefies in the mouth before swallowing?	Mindful eating aspect: Present moment awareness of eating experience
Pausing briefly during eating		Focused attention on savoring food through slowly eating	How can this technology encourage users to take brief pauses to focus on breath during eating to ensure slow, mindful eating?	Mindful eating aspect: Present moment awareness of eating experience
Bite size		Focused attention on savoring food through slowly eating	How can this technology cultivate users' awareness of the size of their food bites to support slow eating, and prevent overeating? How can this technology support users to slow down eating, for instance by encouraging them to take small bites?	Mindful eating aspect: Present moment awareness of eating experience
Unbalanced relationship to food		Awareness of emotional eating: difficult emotions and thoughts as triggers to start or stop eating, i.e., stress, loss of control	How can this technology cultivate awareness of emotional eating? How can this technology support users identify and manage their triggers for emotional eating?	Mindful eating aspect: Present moment awareness of eating experience

Table 10. Revised MEDEC Cards: pink-colored cards representing bodily sensory aspects

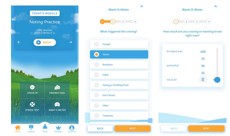
Balanced relationship to food 	Awareness of positive emotions and thoughts about intentional, moderate comfort eating, i.e., guilt-free enjoyment	How can this technology cultivate awareness of balanced relationship to food and eating? How can this technology support users develop a balanced relationship to food?	Mindful eating aspect: Present moment awareness of eating experience
Non-judgmental acceptance of eating related emotions, thoughts, and experiences, and non reactance to them 	Non-judgmental acceptance of difficult emotions, thoughts, and cravings associated with eating, and mental distance for less impulsive eating triggered by them	How can this technology help users accept their emotions related to food, and cravings, without reacting impulsively?	Mindful eating aspect: Non-judgmental acceptance
Nourishing food 	Awareness of nutritious food and eating, beyond mere calorie tracking	How can this technology cultivate awareness of nutritious food and eating, and encourage users to consider the nutritional value of their food? How can this technology account for the challenges of calorie tracking?	Mindful eating aspect: Present moment awareness of eating experience
Non-judgmental bodily acceptance 	Nonjudgmental acceptance of one's body	How can this design promote body acceptance, and limit self-judgmental attitudes?	Mindful eating aspect: Non-judgmental acceptance
Gratitude for food 	Awareness of food provenance supporting gratitude for food and its mindful eating	How can this design encourage users to reflect on the source of their food, and the effort involved in its production? How can this design include prompts or rituals to help users express gratitude before, during, or after a meals?	Mindful eating aspect: Present moment awareness of eating experience

A.3 Design Exemplars

Table 11. 6 of our 17 design exemplars from eight classes of technologies: mobile apps [1] and smart tableware [2–6]. © Copyright held by the author(s) and used with permission.

Mobile App

The **Eat Right Now** is a mindful eating mobile app providing psychoeducation on healthy eating, tools to track emotional and bodily states, and guided meditations in audio modality.

1.


Smart Tableware

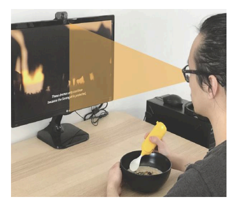
The **Ecomeal tray** is a smart tableware that integrates a weight sensor placed under the tray capturing the weight of plated food and the speed at which it changes, while the eating pace is displayed on a mobile app. The tray also has LED lights that turn red if the weight of food placed on the plate exceeds a set value, thus encouraging small portions.

2.

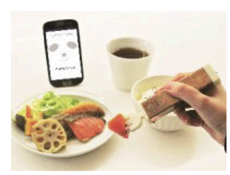

EducaTableware is a smart tableware and cup that provides auditory feedback to reward kids while they eat. A speaker attached to the smart tableware integrates a motion sensor and electrodes that detect the electrical current passing through the child's hand or mouth and the consumed food. As the food comes into contact with the fork/cup and mouth, the fork/cup plays pre-recorded voices of cartoon characters, providing a reward or incentive for eating.

3.


The **Swan spoon** is a smart crockery that supports focusing attention on the plate of food and not on other stimuli like a screen in front of the user. It involves a camera capturing users' gaze while looking at the screen, and a movement sensor detecting each movement of the spoon. If this rhythm is broken by periods when the person does not move the spoon and looks at the screen, the spoon provides real-time vibrations (>2 min break), rotates and drops the food (>3 min breaks), or tilts backward and drops the food (>8 min break).

4.


Sensing fork is another smart crockery that integrates a movement sensor, a photocell sensor to detect the color of food in the fork's tines, and a smartphone game to provide real-time reward on a visual interface through a character who eats a dumpling of the same color as one consumed by the user.

5.


The Smart Plate does not involve sensors and leverages ambiguity. It takes the user's meal duration through a mobile app and schedules the actuation of LED lights embedded equidistantly in the plate's rim so that they are lit one by one covering the whole of the plate's perimeter by the time the meal ends. Lights are aimed at facilitating awareness of slow chewing and eating rates. The plate is programmed to periodically pause or dim its lights during the meal, prompting users to pause, take a deep breath, and reflect on their eating experience.

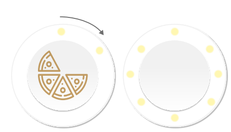
6.


Table 12. 7 of our 17 design exemplars from eight classes of technologies: wearable [7], 3D printed food [8], AR/VR [9-11], robot [12], and image analysis [13]. © Copyright held by the author(s) and used with permission.

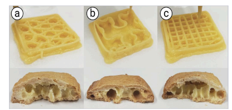
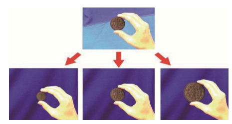
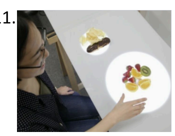
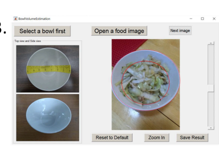
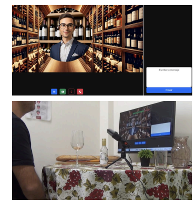
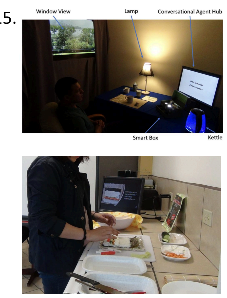
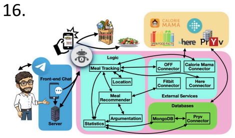
Wearable	**The Slowee system** is a wearable that integrates a touch sensor in a necklace to detect swallowing, and an EMG sensor on the chin to detect the speed of movement while chewing. Slowee delivers real-time feedback through vibrations on a wristband if the chewing speed exceeds the set threshold or blue ambient light is shown as a reward for slow chewing, or yellow light as feedback for normal speed.	7. 
3D Printed food	**Foodfab** is a system personalizing 3D printed dough based on users' food preferences and hungriness levels entered through a user interface. The 3D-printed food varies in internal structures to support different texture experiences, chewing times, and perceived satiety.	8. 
AR/ VR	The **AR-based system** developed by Narumi and colleagues superimposes images of food items such as cookies, of a larger than the real size to limit food intake while increasing the perception of satiety.	9. 
	Metacookie is a pseudo-gustatory system that integrates AR head-mounted and olfactory displays to superimpose images of chocolate or strawberry on a plain cookie while also delivering the smell of chocolate or strawberry to support people's perceive it as more delicious for an improved hedonic experience.	10. 
	Calibratable involves a mini camera and LED light placed beneath a transparent tabletop to detect the plate's position and to project the light around the food. The aim is that the VR-based light plate of a different size than the physical plate supports people's perception of larger food portions.	11. 
Robot	This system is a social robot in the form of a toy-sized anthropomorphised head intended to influence food choice through non-verbal behaviors such as head movement, gaze and non-verbal vocalizations. The user has two bowls of food in front of them, one with healthy food and one with less healthy food, and the robot encourages selection of food from the healthy bowl by alternating its gaze on user's dominant hand and the target bowl. It also rewards user for selecting food from the healthy bowl through happy sounds and nodes, or, if they select from the other bowl, it responds with sad sounds and bows.	12. 
Image analysis	This system integrates a camera and machine learning algorithm for image analysis. The camera takes a photo of the empty bowl or plate in which the user has taped a paper ruler centrally across its bottom and sides. The image is analysed to computationally identify the size and shape of the bowl or plate, and machine learning algorithms are used to reconstruct the interior surface based on the observed distortions of the ruler and ruler markers from the bowl or plate image, in order to predict food volume.	13. 

Table 13. 7 of our 17 design exemplars from eight classes of technologies: conversational agent [14-17].

Conversational agent	**Digital sommelier** a human-like conversational system guides users through a wine-tasting experience. It includes a PC, a motion-sensor-equipped wine glass to detect actions like picking up, swirling, or smelling, and a microphone to capture spoken input. The digital sommelier appears as a lifelike animated young male professional who interacts via speech.	14. 
	CATE is a conversational agent aims to replicate human-like conversations with users, to guide users in the process of preparing and savoring tea along with a snack. The system includes a smart box with tea and snacks, PC for speech interaction and instructional images, a kettle with LED lights, a display showing a window view with scenic background, and a lamp for better visibility. The system initiates small talk by asking questions about the participant's well-being and stress levels to provide a comforting experience. Additionally, following a mindful approach, the system guides the user through the tea-tasting process, encouraging the use of all senses, prompting them to identify tea and snack's color, smell it, and taste. Relaxing background music complements the experience.	15. 
	This **conversational agent** aims to replicate human-like conversations. It integrates a camera for tracking meal images, a tracker of user's weight, visualizations the collected data to provide the user with direct feedback. The system first asks the user to specify the meal type meal and send a picture. It uses image analysis to identify the food items, as most probable food items, their calories and nutrients. Based on the current state of missing nutrients and burnt calories, the system makes meal recommendations within calorie intervals, with only lightweight food options being recommended if a user has already exceeded their calorie limit. Once a meal is selected, the user receives a link to the recipe and the option to track it directly.	16. 
	TAMICA is conversational agent that using motivational interviewing technique to explore barriers to healthy eating, and to support with goal setting. It integrates microphone, keyboard, mouse, and a screen, and its design was informed by motivational interviewing. The system answers user's questions while identifying and recording salient information, provides answers delivered into a person-centered style, and provides abstractive summarization of user's needs and barriers in order to support reflection on open questions.	17. 

A.4 Design Principles for Mindful Eating Technologies

Our design framework translates the identified main aspect of mindful eating into a set theoretically informed design principles to guide systematic exploration of the broader design space, and the development of mindful eating technologies. Below are the six theoretically informed design principle for mindful eating technologies.

Table 14. Theoretically informed design principle for mindful eating technologies to guide systematic exploration of the broader design space.

Supporting presence with the meal. Support presence with the meal or focused attention on eating rather than other activities, particularly screen-based ones. This suggests leveraging subtle guidance, carefully integrated to support focused attention on eating in modalities such as visual, audio, or tactile. For example, the subtle lights on the periphery of the SmartPlate aimed to support attention on eating rather than distracting it on the lights per se, or 3D printed food or olfactory interfaces that maintain focused attention on the eating experience rather than competing with the user's attention.
Supporting slowly savouring food. Supporting slowly savouring food with focused attention on bodily sensations through slowly chewing to intensify the pleasure of eating. Designers can track the microstructure of eating and leverage subtle guidance towards slow eating pace, deliberate pauses, or deliberate changes in food qualities such as texture. Examples include speech-based guided mindful meditation for a situated eating experience rather than generic guidance. Other examples include the lighting pattern of the SmartPlate to guide the pace of eating while integrating brief pauses, or 3D printed food to alter food texture to increase chewing duration and decrease eating pace.
Supporting bodily cues. Supporting bodily cues focuses on awareness of hunger, fullness/satiety, or digestion before, during, and after eating. Non-judgemental tracking on mobile or smartwatch apps can capture such cues with validated short scales. Novel design opportunities can leverage XR technologies to materialize less accessible bodily experiences, such as digestion, as psychoeducation. This design space is currently less populated, opening up novel design opportunities.
Supporting balanced relationships with food. Supporting balanced rather than unbalanced relationships with food or awareness of emotions related to eating, including comfort eating and emotional eating. Psychoeducation interventions on mobile apps can foster awareness of emotional cues for eating and support just-in-time adaptive emotion regulation strategies. Tracking emotions related to eating requires careful design, particularly for people living with problematic eating or eating disorders.
Supporting awareness of nutritious food and gratitude. Psychoeducation on healthy and nutritious eating, rather than calories, can be supported by mobile apps alongside micro-interventions for food gratitude that leverage brief journaling or video narratives of food provenance.
Supporting non-judgmental acceptance. Supporting non-judgmental acceptance of eating experience and one's body. Subtle feedback on less ideal aspects of the microstructure of eating requires particular attention, as emphasized feedback, particularly gamified feedback, can challenge non-judgmental acceptance. Subtle, emotionally neutral feedback such as that provided by the SmartPlate can better support mindful eating.