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We Eat First with Our (Digital) Eyes:

Enhancing Mental Simulation of Eating Experiences via Visual-Enabling Technologies

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Abstract

This research examines how consumers' intentions to purchase food change depending on the visualisation mode (3D vs. AR) and product format (served vs. packaged). In three studies, we demonstrate that mental simulation of eating experiences (process and outcome) mediate these effects. Study 1 shows that AR visualisation of a served food improves simulation of the eating process over 3D visualisation, with a positive effect on purchase intention. Study 2 reveals that 3D visualisation improves purchase intention for packaged products (high instrumental properties) over served products (low instrumental properties) while the opposite is true for AR visualisation. In addition, interactivity and immersion mediate the effects of 3D (vs. AR) on mental simulation of the eating process for packaged products. Study 3 extends these results by showing that 3D increases purchase intention by eliciting mental simulation of the eating outcome, when the food is visible due to transparent (vs. opaque) packaging (displaying both sensory and instrumental properties), but that no such differences emerge for AR. This research highlights the importance of using different visualisation modes to promote food depending on the product format. The findings have important implications for both offline and online retailers.

Keywords: Digital sensory marketing; Augmented reality; 3D visualisation; Online retailing; Food; Mental Simulation

Introduction

Worldwide revenue generated in food e-commerce continues to experience significant growth and has even accelerated during the coronavirus pandemic (Donthu and Gustafsson 2020; Statista 2020). Platform-to-consumer delivery, as developed by Uber Eats and Deliveroo, is growing faster than restaurant-to-consumer delivery (Statista 2020), demonstrating the increasingly important role of online tools for served dishes. However, in some cases, the food visualisation as depicted online appears insufficient to replace the physical look, feel, and smell available in restaurants and grocery stores (Biswas 2019; Huyghe et al. 2017). Indeed, in 2018, less than one-tenth of customers in Europe (9%), North America (9%), Africa/Middle East (7%) and Latin America (7%) indicated that they would purchase fresh groceries online (Nielsen 2018). Importantly, the first taste usually happens with the eyes, even more so when the food is viewed online (Spence et al. 2016). By stimulating mental simulation online, marketers can help consumers imagine the product experience and thus enhance purchase intention (Kozinets, Patterson, and Ashman 2016; Liu, Batra, and Wang 2017). Creating compelling online depictions of food is thus of utmost relevance to marketers. New visualisation modes, such as three-dimensional (3D) and augmented reality (AR), might help in this way as they convey engaging sensory and interactive experiences (Petit, Velasco, and Spence 2019a). We conduct three experimental studies in which we examine the following questions: How and why might one visualisation mode work better than the another? Does the product format matter in this process?

Visualising products can evoke different mental simulations. AR places the virtual product in the consumer's physical environment, while 3D normally presents it on a neutral background on the device screen. By situating the product in the consumer's physical environment, AR can be a particularly immersive and effective approach for stimulating mental simulation of product experiences (Heller et al. 2019; Van Kerrebroeck, Brengman, and Willems 2017; Yim, Chu, and Sauer 2017) and thus might stimulate perceptual re-enactments of the product's sensory properties (Petit, Velasco, and Spence 2019a). Sensory properties associated with touch, smell, and taste relate to the experiential and hedonic aspects of the product (Hirschman and Holbrook 1982; Peck and Childers 2003). However, 3D has proved very effective in stimulating mental simulation of material, instrumental product properties (Choi and Taylor 2014). Thus, the relevance of AR, compared with other visualisation modes, such as 3D, can depend on the type of information conveyed.

Previous research has mainly examined the effect of 3D and AR on purchase intention separately and focused on the process by which these technologies affect the consumer experience, highlighting the importance of interactivity, immersion, and mental simulation (Choi and Taylor 2014; Heller et al. 2019; Yim, Chu, and Sauer 2017). To our knowledge, our study is the first to compare the relevance of these visual technologies according to the properties conveyed by the product format. Food is typically displayed with or without packaging. Moreover, food packaging can be transparent or opaque and thus reveal the actual food product or mask it entirely. These formats provide different information to consumers (Simmonds and Spence 2017). Presenting food as served can help consumers evaluate its sensory properties. By contrast, packaged products can facilitate the evaluation of instrumental properties through pictorial and/or textual cues; however, they can also help consumers evaluate sensory properties when the food is visible through transparent packaging. Thus, depending on product formats and the associated food properties, marketers might want to choose a different visualisation mode to stimulate consumers' mental simulation.

The contribution of the present research is threefold. First, we show the superiority of AR to 3D in stimulating purchase intention towards served food, regardless of food category (i.e., healthy vs. unhealthy), although they can be associated with different properties. We provide a novel explanation for the underlying mechanisms. Second, we demonstrate that, with regard to product formats, AR is not always the most relevant technology to promote food products. While previous research indicates that product formats provide different information to consumers (Simmonds and Spence 2017), we unveil how these effects differ depending on technology. That is, 3D is more effective for facilitating purchase intention of the food format with higher instrumental properties (highlighted by product packaging) as opposed to the formats evoking sensory properties (i.e., served food), while the opposite is true for AR. We also show a distinction between mental simulation given two kinds of eating experience: the mental simulation of the eating process, which is more likely to be evoked in AR when viewing served food, and the mental simulation of the eating outcome (related to the consequences of consumption), which is more likely to occur when examining packaged products in 3D. We confirm that seeing food stimulates mental simulation (Simmonds and Spence 2017; Spence et al. 2016) and demonstrate that different types of mental simulation can be evoked depending on the product format and the visualisation mode. Third, by showing that interactivity and immersion also mediate the effect of visualisation modes on mental simulation and purchase intention for food with instrumental properties, we extend the importance of perceived media features (Song and Zinkhan 2008; Yim, Chu, and Sauer 2017) to mental simulation of eating experiences.

In summary, our research provides substantial managerial implications by showing that the *combination* of product format and visualisation mode affects the perception of both technological interactive features and cognitive process. Through the right use of these combinations, marketers can aid consumers in imagining their food experience and ultimately in deciding which food to buy online.

Theoretical Background and Hypotheses

Visualisations and Interactions via Visual-Enabling Technologies

Immersive and interactive visualisation modes convey product properties more dynamically and convincingly than traditional visualisations, such as static two-dimensional (2D) images (Daugherty, Li, and Biocca 2008; Li and Meshkova 2013). One such popular visualisation mode is 3D, whose typical interactive features include zooming in and out or 360-degree rotation, allowing consumers to examine products' details from different angles against a neutral background (Kim and Forsythe 2008). Viewing products in 3D leads to higher willingness to pay, more positive product attitudes, and higher purchase intention than viewing products in 2D or even in video (Li and Meshkova 2013; Papagiannidis et al. 2013). However, seeing a visual representation of the product on a neutral background does not necessarily capture how it would look or feel when experiencing it (Hilken et al. 2017; Javornik 2016b). To overcome this limitation, the sensations associated with the product experience need to be better depicted and communicated (Kozinets, Patterson, and Ashman 2016; Petit, Velasco, and Spence 2019a; Spence et al. 2016). AR has the potential to bridge this gap because it situates the virtual product as part of the consumer's physical environment, creating the impression that it actually exists (Azuma 1997; Scholz and Smith 2016). In addition, AR interaction takes place in real time, which means that the viewing angle of the product changes in step with the position of the device, increasing the realism of the product experience (Flavián, Ibáñez-Sánchez, and Orús 2019). Prior evidence suggests that these new visualisation modes help stimulate mental simulation of eating experiences and increase purchase intention (Kozinets, Patterson, and Ashman 2016; Liu, Batra, and Wang 2017; for a review, see Petit, Velasco, and Spence 2019b), but understanding of how they differ in delivering such mental simulation in a food context and beyond is lacking.

Eating Process Simulations via Visual-Enabling Technologies

Through vision, consumers develop expectations of the sensory and instrumental properties of food products (Papies et al. 2017; Piqueras-Fiszman and Spence 2015). The initial perception of a product is stored in memory, and when consumers are exposed to the product again, they mentally simulate these prior perceptual experiences (Barsalou 2008). Mental simulation can be conceptualised as a more automatic and unconscious form of mental imagery initiated by the exposure to product representations (Elder and Krishna 2012). When exposed to a food picture, consumers can simulate how consumption of the food product would feel and taste, even if the product itself is physically absent (Barsalou 2008; Elder and Krishna 2012; MacInnis and Price 1987). Such mental simulation thus helps people fill in missing information (Hirschman and Holbrook 1982; Schwartz and Black 1999). Importantly, vivid mental simulation can have positive effects on purchase intention and behaviour (Elder and Krishna 2012; Petit et al. 2017; Petit, Velasco, and Spence 2018). In the context of food consumption, the mental simulation of the eating process refers to "the spontaneous mental simulation of food consumption experiences including sensory perceptions (e.g., taste and smell), motor states (e.g., chewing food and using utensils), and introspection (e.g., savoring and enjoyment) which occur and thus are encoded during consumption processes" (Xie, Minton, and Kahle 2016, p. 630).

Visual-enabling technology can shape mental simulation of the eating process through their visualisation modes and type of interaction. As evidenced in prior research, 3D has not proved particularly effective in conveying sensory experiences, but it provides a better tool for evaluating instrumental properties of products than 2D (e.g., size, shape; Choi and Taylor 2014). By contrast, AR can create a sensorially richer mediated environment and lead to heightened vividness than a typical 2D visualisation, which in turn can enhance purchase intention (Heller et al. 2019; Poushneh and Vasquez-Parraga 2017; Van Kerrebroeck, Brengman, and Willems 2017; Yim, Chu, and Sauer 2017).The key question here is how different visualisation modes facilitate mental simulation of eating experiences depending on the product formats (served vs. packaged), which highlight specific food properties.

Hypotheses Development

Mental Simulation of the Eating Process for Served Food via AR Visualisation.

Food is a multisensory stimulus that is to some extent valued for its smell, taste, and the overall pleasure of the experience, especially in the served format (Velasco et al. 2018). Although 3D interactive presentations have become increasingly popular, they are less effective in facilitating the evaluation of the sensory properties of foods (Choi and Taylor 2014). This is potentially an issue for served foods, which convey prominent sensory properties (Basso et al. 2018; Simmonds and Spence 2017). Visualising the actual consumption of sensorial food products has positive effects on mental simulation of eating experiences and, subsequently, on purchase intention (Basso et al. 2018; Elder and Krishna 2012; Simmons, Martin, and Barsalou 2005). AR allows users to view the food and interact with it as they would with the actual product (Javornik 2016a; Heller et al. 2019). It should facilitate the mental simulation of the eating process of served food and purchase intention as opposed to 3D. Because mental simulation of eating experiences can have positive effects on consumers' intent and behaviour (Elder and Krishna 2012; Petit et al. 2017; Petit, Velasco, and Spence 2018), we postulate the following:

H1. AR leads to higher purchase intention of served food than 3D.

H2. Mental simulation of the eating process mediates the effect of served food viewed in AR (vs. 3D) on purchase intention, as viewing served food in AR (vs. 3D) increases mental simulation of the eating process, which increases purchase intention.

Seeing a served food product evokes mental simulation of the food's corresponding sensory properties and, thus, the hedonic experience of consumption (Spence et al. 2016), which should be amplified by AR. However, this elicitation of hedonic experiences via AR may not be relevant for all food categories. Previous studies have shown that consumers tend to oppose healthy food considered “nourishing” and “good for them” and tasty food that is “enjoyable”, “fun”, and “exciting” (Raghunathan, Naylor, and Hoyer 2016). Therefore, using a technology favouring the simulation of the eating process for healthy food products would be less effective if they are not perceived as tasty. Relatedly, Shen, Zhang, and Krishna (2016) found that using a “direct-touch” interface (i.e., a tablet) increases the choice of unhealthy (vs. healthy) food options compared with a digital interface creating sensory distance (i.e., a mouse). In addition, Basso et al. (2018) found that using a first- (vs. third-) person perspective in videos increases activity in brain regions that underlie representations of appetitive experiences and food intake for unhealthy but not for healthy food products. As such, the effect of AR on mental simulation of the eating process may be greater for unhealthy food products, but not for the healthy products, leading us to propose:

> **H3.** Viewing served food in AR (vs. 3D) will lead to higher mental simulation of the eating process for unhealthy food, but not for healthy food.

Moderating Effects of 3D and AR on Purchase Intention of Served and Packaged Food.

Although AR may be superior to 3D in evoking mental simulation of the eating process for served food products, it may not be for all types of food presentation. The presentation of food products not only communicates their sensory value but also conveys instrumental information (Hirschman and Holbrook 1982). Instrumental properties, such as size and appearance, allow consumers to interact with products for diagnostic purposes and obtain utilitarian information to satisfy goal-oriented motivations (Hirschman and Holbrook 1982; Peck and Childers 2003). They can compensate for an inability to physically examine a product directly, as they retrieve product information stored in memory (Peck and Childers 2003). When evaluating food products by their packaging, consumers focus on instrumental cues such as claims, certifications, and nutritional value (Hoogland, de Boer, and Boersema

2007) and thus might pay less attention to the experiential aspects. Food packaging provides an indirect product presentation that increases sensory distance and reduces the desire to obtain instant gratification (Huyghe et al. 2017; Kardes, Cronley, and Kim 2006). If packaged products result in less desire to eat them immediately, positioning them as part of the real-time environment might be less relevant). According to Rauschnabel, Felix, and Hinsch (2019), consumers might prefer 3D to AR when they want to ignore the physical environment surrounding the product. Thus, the relevance of visualisation mode changes depending on whether the food product evokes instrumental or sensory attributes. Compared with AR, 3D displays a blank background, enabling consumers to focus on product details, which could be particularly relevant for stimulating purchase intention towards packaged foods (Choi and Taylor 2014; Fiore, Kim, and Lee 2005; Pino et al. 2020) as opposed to served food. Conversely, situating served rather than packaged food in real-time environment would lead to more purchase intentions. We postulate the following:

> **H4.** Visualisation mode (3D/AR) moderates the effect of product format (served vs. packaged) on purchase intention: such that (a) served food leads to higher purchase intention than packaged food when viewed in AR; (b) packaged food leads to higher purchase intention than served food when viewed in 3D.

Interactivity and Immersion.

An important element of visual-enabling technologies is their interactive features, which allow consumers to examine the products in more detail, as has been shown for 3D (Choi and Taylor 2014). Research on perceived interactivity (Sundar 2008; Javornik 2016b; Yim, Chu, and Sauer 2017) specifically underscores the importance of users' perception of how interactive the medium is. Some key dimensions of perceived interactivity are perceived responsiveness and how easy it is to control it (Song and Zinkhan 2008).

Perceived interactivity of an AR app can be lower than that of a website (Javornik 2016b). An interaction with a 3D product occurs by clicking or directly manipulating a touchscreen, whereas for AR, consumers use real-time gestures, such as tilting their heads to inspect the different angles of a virtual try-on or physically moving the device around the virtual product (Hilken et al. 2017). This less-established gesture-based interaction, typical for AR, might be perceived as more difficult to control than the more common touch-based interaction. Moreover, in AR, consumers interact with the virtual object by considering the physical environment at the same time, which makes the interaction visually more complex. In 3D, however, the blank background reduces this complexity, which can facilitate inspection of the product. This would be particularly important for products that consumers want to examine in more detail to learn more about their instrumental properties, as is the case for packaged food. Consequently, consumers would perceive viewing of the packaged food to be more interactive in 3D than in AR. Conversely, such differences in perceived interactivity would not occur if instrumental properties are less salient, which is the case for served food, where the presentation format can directly convey mental simulation of the eating process.

As interactive features allow for a more detailed examination of visual content, they create a more immersive experience for consumers (Hudson et al. 2019). Immersion refers to the state of absorption when viewing virtual content (Cowan and Ketron 2019; Slater et al. 1996), and recent research has demonstrated its importance for AR (Yim, Chu, and Sauer 2017). Interactive features of AR allow consumers to focus on the visual content and thus become more absorbed (Yim, Chu, and Sauer 2017). Such immersion would further affect consumer mental simulation, as being absorbed in the visualisation can help consumers better imagine the eating process. Thus:

H5. Interacting with food in 3D (vs. AR) leads to higher perceived interactivity, which increases immersion and further leads to higher mental simulation of the eating process. These effects occur for a) the packaged food, b) but not for the served food.

Mental Simulation of the Eating Outcome for Transparent Packaged Food Products via 3D Visualisation.

3D visualisation allows consumers to focus on the elements conveying instrumental properties, such as nutritional labels. In addition to instrumental cues, packaged food products can display attractive food visuals or even reveal the actual food, for example, with transparent packaging. This visual representation of food on packaging activates perceptual re-enactments of previous eating experiences (Deng and Srinivasan 2013; Madzharov and Block 2010; Petit, Velasco, and Spence 2018). According to Simmonds and Spence (2017), showing the food directly through transparent packaging can accentuate these effects. Attractive transparent packages are trustworthy and generate greater purchase intention than opaque packaging (Billeter, Zhu, and Inman 2012). Thus, we can expect that the food products with transparent rather than opaque packaging will lead to higher purchase intention when viewed in 3D, while such effects are not expected in AR. Formally:

H6: Visualisation modes moderate the effects of food packaging (opaque vs. transparent) on purchase intention, such that purchase intention will be higher for transparent (vs. opaque) packaging when viewed in 3D, but not in AR.

Transparent packaging also increases expected freshness, quality, and tastiness (Simmonds, Woods, and Spence 2018). Therefore, 3D would be more likely to stimulate mental simulation of eating experiences for transparent than opaque packaged products. However, given that AR does not facilitate viewing of instrumental properties like 3D does, these effects might not occur for AR. Moreover, seeing food through a packaging is not the same as seeing it served on a plate and thus should not generate the same type of mental simulation (Simmonds and Spence 2017). Previous research has found that in addition to the simulation of the eating process (i.e., focused on the eating experience), consumers could simulate the outcome of the consumption experience (i.e., focused on the results of the eating experience, Escalas and Luce 2004; Xie, Minton, and Kahle 2016). Mental simulation of the eating outcome refers to "the spontaneous mental simulation of results and outcomes including sensory perceptions (e.g., after-taste), motor states (e.g., feeling full), and introspections (e.g., satisfactory and energy levels) after a consumption process such as having eaten food" (Xie, Minton, and Kahle 2016, p. 630). The 3D visualisation of packaged products is more likely to stimulate this mental simulation of the eating outcome than the simulation of the eating process. Indeed, packaged products presented in 3D emphasise instrumental properties that often shape the final product assessment and, thus, the outcome of the eating process (Hirschman and Holbrook 1982; Muñoz-Vilches, van Trijp and Piqueras-Fiszman 2020; Peck and Childers 2003; Xie, Minton, and Kahle 2016). So, instead of the eating process, we would expect the mental simulation of the eating outcome to mediate the effect of viewing the transparent (vs. opaque) packaging in 3D, but these differences would not occur in AR. We propose:

> **H7:** Mental simulation of the eating outcome mediates the effects of food packaging (opaque vs. transparent) on purchase intention when viewed in 3D, but not in AR, such that transparent (vs. opaque) packaging viewed in 3D increases mental simulation of the eating outcome, which increases purchase intention.

Overview of Studies

In three studies, we examine the effects of visualisation modes and product format on purchase intention towards food products and analyse the underlying process. Specifically, in Study 1, we test the effect of visualisation mode (3D vs. AR) on purchase intention of served food products through the mental simulation of the eating process and also account for the moderating role of food healthfulness (H1, H2 and H3). We test whether viewing served food in 3D (vs. AR) leads to higher perceived interactivity and subsequently immersion, with positive effects on mental simulation – these effects are further tested both for the packaged (H5a) and served food (H5b) in Studies 2 and 3. In Study 2, we investigate the interaction between product format (served vs. packaged) and visualisation mode (3D vs. AR). Specifically, we test whether visualisation modes moderate the effects of food product format on purchase intention (H4) and whether mental simulation of the eating process mediates these effects. In Study 3, we investigate the effect of transparent (vs. opaque) packaging on mental simulation of the eating outcome and purchase intention when viewed in 3D (vs. AR) (H6 and H7). These processes are also visualised in our graphical abstract.

Study 1: 3D/AR Visualisation of Served Food Products

Participants and Design

Two hundred four prospective candidates for a study program at a French business school (110 women, M_{age} = 20.11 years, SD = 1.60) took part in the study. The experiment followed a 2 (visualisation mode: 3D vs. AR) × 2 (food category: healthy vs. unhealthy) between-subjects design. Participants were recruited in front of a booth at the entrance of the business school and were offered a tote bag in return for their participation.

Materials and Procedure

We simulated two served dishes (salad and a burger) on a smart device app, which we presented in 3D or using AR (Appendix A). The visualisations were courtesy of the Kabaq company. The participants, who were randomly assigned to one condition, were asked to imagine ordering a dish for delivery on a restaurant website and had the opportunity to see the dish in AR (vs. 3D) on a tablet to make their choice. We recorded the time spent interacting with the tablet. In the 3D condition, participants saw a picture of the dish against a grey background, and in the AR condition, the dish was visualised as superimposed on participants' physical environment in the tablet camera view. We deployed the same interaction mode for both conditions: participants could zoom in and rotate the image of the dish with their fingers. While AR interaction is typically movement- rather than touch-based, the app developer specifically designed the interaction mode to be the same for both AR and 3D. This allowed us to isolate the effect of AR versus 3D visualisation on perceived interactivity without potential confounding effects of movement- versus touch-based interaction.

After viewing the dish, participants rated their purchase intention (α = .82; four-item scale, White, MacDonnell, and Ellard 2012), mental simulation of the eating process (α = .89; Elder and Krishna 2012), and level of immersion (α = .86). We measured perceived interactivity with items examining the control aspect of interactivity (α = .70) adapted from Song and Zinkhan (2008). Participants were asked how often they ate salads and burgers on a one-item scale. We measured the variables on seven-point scales and randomised the order of items (see Appendix B). To test whether visual-enabling technologies affect food choice, we also collected behavioural data (Huyghe et al. 2017; Shen, Zhang, and Krishna 2016). Participants were offered four snack options (healthy savoury, unhealthy savoury, healthy sweet, or unhealthy sweet), which we selected from a database that ranks food by tastiness and healthfulness (Pavlicek 2013). They also had the possibility to refuse the snack.

Results

Manipulation Checks.

Participants rated the salad as more healthful than the burger (“How healthy do you think this food is?”) on a scale from 1 to 100 (M_{salad} = 80.91, SD = 13.44 vs. M_{burger} = 35.02, SD = 19.75; $F(1, 202) = 376.34$, $p < .001$, $\eta_p^2 = .65$). However, the dishes did not differ in tastiness (“How tasty do you think this food is?”) on a scale from 1 to 100 (M_{salad} = 66.11, *SD* = 18.91 vs. M_{burger} = 63.94, *SD* = 21.77; *p* = .45).

Purchase Intention.

We conducted a 2 (visualisation mode: 3D vs. AR) × 2 (food category: healthy vs. unhealthy) two-way ANOVA on purchase intention. We included the frequency of consumption and the time spent interacting with the product as covariates. Neither the main effect of dish (*p* = .18) nor the interaction was significant (*p* = .83). Instead, only the main effect of visualisation mode was significant ($F(3, 198) = 11.75$ $p = .001$, $\eta_p^2 = .06$). For details, see Fig. 1), supporting H1.

Mediating Effect of Mental Simulation of the Eating Process.

We used Model 4 in PROCESS v3.1 with a bootstrap analysis (with 5,000 samples) to examine whether mental simulation of the eating process mediated the effect of AR (vs. 3D) on purchase intention. We found a direct effect of AR on mental simulation of the eating process ($\beta = .73$, $t = 3.69$, $p < .001$). Moreover, mental simulation of the eating process had significant direct effects on purchase intention ($\beta = .53$, $t = 11.64$, $p < .001$). The direct effect of visualisation mode was no longer significant (*p* = .07). As expected, the indirect effect of visualisation mode on purchase intention through mental simulation of the eating process was significant for AR compared with 3D (effect = .39, 95% CI [.17; .65] excluded zero), in support of H2.

Finally, we used Model 7 in PROCESS to check moderated mediation with food category (healthy or unhealthy) as moderators to examine H3. The conditional effects showed that AR (vs. 3D) led to higher mental simulation of the eating process for the unhealthy food ($\beta = .92$, $t = 3.28$, $p < .01$), while these effects were only marginally significant for the healthy food (*p* = .06). However, the interaction was not significant (*p* = .34). When examining the indirect effects on purchase intention, the mediation path was significant for the unhealthy food (indirect effect = .49, 95% CI [.19; .83]), but not for the healthy food (effect = .29, 95% CI [-.01; .60]). However, the moderated mediation was not significant (index: .20, 95% CI [–.21; .64]). While there is some evidence for different effects between healthy and unhealthy food categories, H3 is not fully supported.

Perceived Interactivity and Immersion.

Although the mode of interaction in 3D and AR was the same, participants reported a higher sense of interactivity (in terms of measured perceived control) in the 3D condition than in the AR condition (ANOVA: $M_{AR} = 5.14$, $SD = 1.03$ vs. $M_{3D} = 5.62$, $SD = 1.24$; $F(1, 203) = 8.51$, $p = .004$, $\eta_p^2 = .04$) with the same covariates (time spent interacting with device and frequency of salad and burger consumption, depending on the assigned condition). Immersion was higher in the AR than 3D condition ($M_{AR} = 5.69$, $SD = 1.00$ vs. $M_{3D} = 5.20$, $SD = 1.32$; $F(1, 203) = 7.33$, $p = .007$, $\eta_p^2 = .04$). Finally, participants viewing AR (vs. 3D) spent a significantly longer time using the app ($M_{AR} = 62.26$, $SD = 23.97$ vs. $M_{3D} = 48.93$, $SD = 25.39$; $F(1, 203) = 14.72$, $p < .001$, $\eta_p^2 = .07$).

Serial Mediation.

We next examined whether the difference in perceived interactivity (as measured by perceived control) mediated the effects of visualisation mode on mental simulation of the eating process. We ran Model 6 in PROCESS (visualisation mode coded as a dummy variable: 0 = 3D, 1 = AR) with perceived interactivity and immersion as mediators and mental simulation of the eating process as the key outcome variable. The AR (vs. 3D) visualisation mode led to significantly lower perceived interactivity ($\beta = –.48$, $t = –2.98$, $p < .01$). We then regressed perceived interactivity on immersion and found significant direct effects ($\beta = .34$, $t = 5.01$, $p < .001$). The effect of visualisation mode on immersion was positive and significant ($\beta = .65$, $t = 4.12$, $p < .001$). Moreover, we found a significant direct effect of immersion on mental simulation of the eating process ($\beta = .57$, $t = 7.46$, $p < .001$). There were significant indirect effects of viewing served food in AR (vs. 3D) on mental simulation of the eating process through interactivity and immersion as mediators (effect = –.09, 95% CI [–.19; –.03]). We then examined whether food category moderates this serial mediation (Model 83 in PROCESS). 3D (vs. AR) led to higher interactivity, which increased immersion and mental simulation when the viewed food was healthy (effect = –.18, 95% CI [–.32; –.07]), but not when it was unhealthy (effect = –.01, 95% CI [–.10; .08]). The mediated moderation was significant (index: .17, 95% CI [.04; .33]). Specifically, when viewing healthy food, participants perceived 3D (vs. AR) as more interactive, which led to increased immersion and mental simulation, but not when viewing unhealthy food. H5b was partially supported.

Food Choice.

We conducted binomial tests to examine the effect of product taste and product healthfulness on choice of snacks that participants chose after the experiment. Participants did not choose healthy snacks more often than unhealthy snacks (p = .53) or sweet snacks more often than savoury snacks (p = .86). A chi-square test examined the relationship between dish (being exposed to a healthy or an unhealthy food) and snack choice (healthy vs. unhealthy), which was significant ($\chi^2(1)$, = 20.95, $p < .001$). Participants more often chose healthy snacks (64 of 102 participants, 10 participants did not select any option) when exposed to a visualisation of healthy food and vice versa for unhealthy food (59 of 102 participants, 10 participants did not select any option). We also examined the relationship between visualisation mode and snack choice, which was not significant (p = .60).

Discussion

As expected, mental simulation of the eating process mediated the effects of AR on purchase intention compared with 3D, in support of H1 and H2. While we noted some differences between healthy and unhealthy food categories, the moderation was not significant; thus, H3 was not supported, suggesting that the effects of AR on purchase intention via mediated effects of mental simulation do not vary significantly between the two categories. A reason for this result is that participants considered healthy food to be tasty in our study, in contrast with previous research (Raghunathan, Naylor, and Hoyer 2016; Xie, Minton, and Kahle 2016). However, we uncovered underlying additional mediating effects. 3D led to higher interactivity than AR when the examined food was healthy. Also, interactivity and immersion mediated the effects of AR (vs. 3D) on mental simulation of the eating process for the healthy food, but not for the unhealthy food, partially confirming H5b. Healthy food is often perceived as more utilitarian than unhealthy food (Antonides and Cramer 2013; Loebnitz and Grunert 2018), focusing consumers more on examining its instrumental properties (Maehle et al. 2015). 3D (as opposed to AR) provides a more fitting visualisation mode for such a purpose, thus increasing the mental simulation of the eating process indirectly through higher perceived interactivity and immersion.

Finally, purchase intention was lower in 3D than in AR. This may be because 3D is more relevant for the evaluation of instrumental rather than sensory properties (Choi and Taylor 2014). The food was visualised as being served, which highlights its sensory and experiential aspects by conveying the experience of having the actual food front and centre and eating it (Basso et al. 2018). AR embeds the food in the real environment, which better supports the evaluation of served food products. By contrast, for packaged food products, which put more emphasis on instrumental properties, 3D might be more relevant (Choi and Taylor 2014; Deng and Srinivasan 2013; Simmonds and Spence 2017). In Study 2, we directly contrast product formats (i.e., served vs. packaged) to test how they affect mental simulation of the eating process and purchase intention, depending on the visualisation mode (3D vs. AR).

Study 2: 3D/AR Visualisation of Served versus Packaged Food Products

Participants and Design

Two hundred and four candidates (77 women, M_{age} = 21.18 years, *SD* = 2.09) applying to a French business school took part in the study, which followed a 2 (technology: 3D vs. AR) × 2 (product format: served vs. packaged) between-subjects design. Candidates were recruited in front of a booth at the entrance of the school and randomly assigned to one of the conditions. They were offered a tote bag as compensation for their participation.

Materials and Procedure

Four versions of ice cream were developed by an AR software company for this experiment. The served version presented a cup of chocolate ice cream, and the packaged version depicted the packaging of Häagen-Dazs chocolate ice cream (Appendix A). At the beginning of the experiment, participants were told to imagine that they were shopping online and that the brand Häagen-Dazs offered to show the ice cream in 3D (vs. AR). They had two minutes to observe the ice cream. As in Study 1, in the 3D version, participants could zoom in and rotate the image from all angles with their fingers. In the AR version, the image was superimposed in participants' physical environment via the tablet. They could move closer to or farther away and orient the tablet to inspect the details. Such interactions are typical for these two technologies (Javornik 2016a).

After viewing the stimuli, participants rated their purchase intention (α = .86) and mental simulation of the eating process (α = .90) on the same scales as in Study 1. We measured brand familiarity and ice-cream consumption using a one-item scale. We again measured immersion (α = .83; three items, Yim, Chu, and Sauer 2017) and perceived interactivity (α = .83; eight items, measuring both perceived control as in Study 1 and responsiveness, following a more extensive version of the scale by Song and Zinkhan [2008]), using seven-point scales.

Pre-test Ice Cream

We separately investigated the food properties of the served and packaged ice-cream stimuli by randomly showing a static 2D image of either served or packaged ice cream to 103 participants recruited on Prolific Academic. We asked them questions about their perceived instrumental, sensory, and affective properties. The items associated with the instrumental properties (α = .79) examined the extent to which the product information and characteristics were presented on the image, the items for the sensory properties examined the sensory appeal of the image (α = .87), and the items for the affective properties examined whether the product appealed to emotions (α = .85). We adapted the scales from Brakus, Schmitt, and Zhang (2014). Participants reported the packaged ice-cream as being significantly higher in instrumental properties (M_{Packaged} = 4.90, *SD* = 1.09, M_{Served} = 4.33, *SD* = 1.29; $F(1, 102)$ = 3.96, p = .049, η_p^2 = .04), though there was no difference in sensory properties (p = .47) or affective properties (p = .33). While an actual 3D or AR interaction with the stimuli can effectively influence the perception of such properties, this test demonstrated how the two types of product format differ when viewed in a 2D image.

Results

Purchase Intent and Mental Simulation of the Eating Process.

We conducted a 2 (visualisation mode: 3D vs. AR) × 2 (product format: served vs. packaged) two-way ANOVA on purchase intention, with brand familiarity and ice cream consumption as covariates. Neither the main effect of visualisation mode (p = .68) nor the main effect of product format was significant (p = .54). However, the interaction between the two factors was significant ($F(3, 198)$ = 18.64, p < .001, η_p^2 = .09). Post hoc Bonferroni-corrected tests revealed that purchase intention was higher for the served food than the packaged food in AR ($M_{\text{AR\_Served}}$ = 5.51, *SD* = .99 vs. $M_{\text{AR\_Packaged}}$ = 4.55, *SD* = 1.18; t = 4.43, p <.001), supporting H4a. Conversely, 3D packaged food ($M_{\text{3D\_Packaged}}$ = 5.39, *SD* = .84) lead to higher purchase intention than 3D served ($M_{\text{3D\_Served}}$ = 4.65, *SD* = .128, t = 3.44p = .004), supporting H4b. Also, the served food in AR led to higher purchase intention than the served food in 3D (t = 3.74, p = .0016), providing further evidence for H1, which was supported in Study 1. Finally, purchase intention was higher for the packaged food in 3D than the packaged food in AR (t = 4.18, p = .001). We found no difference between the AR served and the 3D packaged conditions (t = 0.63, p > .999) or between the AR packaged and the 3D served conditions (t = 0.42, p > .999; for details, see Fig. 1).

We ran a 2 × 2 ANOVA between visualisation mode (3D vs. AR) and product format (served vs. packaged) on mental simulation of the eating process. The interaction was significant ($F(3, 200) = 15.47$, $p < .001$, $\eta_p^2 = .07$). A post hoc Bonferroni test showed that mental simulation of the eating process in the served AR condition ($M_{AR\_Served} = 5.70$, SD = 1.36) was significantly higher than that in the AR packaged ($M_{AR\_Packaged} = 4.21$, SD = 1.48, t = 5.28 p < .001), 3D packaged ($M_{3D\_Packaged} = 4.76$, SD = 1.45, t = 3.36, p = .005), and 3D served ($M_{3D\_Served} = 4.73$, SD = 1.21, t = 3.79, p = .003) conditions. However, mental simulation of the eating process was not significantly different between the AR and 3D packaged conditions (t = 1.91, p = .81). Other conditions were not significantly different (for details, see Fig. 2.).

Interactivity and Immersion.

Participants reported a higher sense of interactivity in the 3D condition than in the AR condition ($M_{AR} = 4.86$, SD = 1.07 vs. $M_{3D} = 5.39$, SD = .72; $F(1, 203) = 16.63$, $p < .001$, η_p^2 = .08). There was also a significant main effect of product format, such that participants perceived the served format as more interactive than the packaged format ($M_{Packaged} = 4.86$, SD = 1.05 vs. $M_{Served} = 5.39$, SD = .75; $F(1, 203) = 17.31$, $p < .001$ $\eta_p^2 = .08$). The interaction effect was also significant ($F(3, 203) = 32.84$, $p < .001$, $\eta_p^2 = .14$). A post hoc Bonferroni test showed that perceived interactivity was significantly lower in the packaged AR condition ($M_{AR\_Packaged} = 4.28$, SD = 1.03) than in the packaged 3D ($M_{3D\_Packaged} = 5.45$, SD = .70, t =

6.75, p < .001), served 3D (M_{3D_Served} = 5.32, SD = .75, t = 5.86, p < .001), and served AR (M_{AR_Served} = 5.47, SD = .74, t = 6.89, p < .001) conditions. Other conditions were not significantly different in terms of interactivity.

There were no significant differences in immersion between the AR and 3D conditions (M_{AR} = 5.38, SD = 1.27 vs. M_{3D} = 5.27, SD = 1.13; F(1, 203) = .49, p = .49), but participants reported the served conditions as more immersive than the packaged conditions ($M_{Packaged}$ = 5.53, SD = 1.20 vs. M_{Served} = 5.12, SD = 1.17; F(1, 203) = 7.28, p = .008, η_p^2 = .04). The interaction across the four conditions was also significant (F(3, 203) = 28.57, p < .001, η_p^2 = .13). A post hoc Bonferroni test showed that the packaged AR condition was significantly less immersive ($M_{AR\_Packaged}$ = 4.77, SD = 1.16) than the packaged 3D ($M_{3D\_Packaged}$ = 5.47, SD = 1.08; t = 3.17, p = .009) and served AR (M_{AR_Served} = 6.02, SD = 1.05; t = 5.70, p < .001) conditions. The served AR condition was significantly more immersive than the served 3D condition (M_{3D_Served} = 5.06, SD = 1.15, t = 4.38, p < .001). Other conditions were not significantly different in terms of immersion.

We tested H5 with Model 83 (PROCESS v 3.1) to determine if perceived interactivity and immersion mediate the effects of visualisation mode on mental simulation of the eating process and we accounted for the product format. When viewing packaged food, AR (vs. 3D) led to significantly lower perceived interactivity (β = –1.17, t = –7.25, p < .001), but these effects were not observed for the served food (p = .38). Interactivity positively affected immersion (β = .70, t = 8.97, p < .001), which led to mental simulation of the eating process (β = .49, t = 5.90, p < .001). The direct effects of AR (vs. 3D) on mental simulation of the eating process were marginally significant (β = .35, t = 1.97, p = .05). The indirect effects of AR (vs. 3D) on mental simulation of the eating process were significant for the packaged food (effect = –.40, 95% CI [–.66; –.20]), but not for the served food (effect = .05, 95% CI [–.05;

.16]). The moderated mediation index was significant (index = -.45, 95% CI [-.76; -.22]). H5a and b were supported.

Moderated Mediation Analysis.

To further explain different effects of product format (served vs. packaged) on purchase intention depending on the visualisation mode as hypothesised in H4, we now tested for possible mediations in this process. First, we focused on mental simulation of the eating process as the key mediator and purchase intention as the main outcome variable. We ran Model 7 (PROCESS v3.1) with food packaging as the independent variable (0 = served, 1 = packaged) and the visualisation mode as the moderator. The interaction between the visualisation mode (3D vs. AR) and food packaging (served vs. packaged) significantly predicted mental simulation of the eating process, as reported previously (β = –1.52, t = –3.93, p < .001). Specifically, the effects of the AR packaged version were significantly lower than those of the AR served version (β = –1.49, t = –5.44, p < .001), but the 3D conditions did not differ significantly (p = .91). Moreover, mental simulation of the eating process had a significant effect on purchase intention (β = .35, t = 6.86, p < .001), while the direct effects of the product format on purchase intention were not significant (p = .33). The indirect effects of the packaged (vs. served) condition on purchase intention through mental simulation of the eating process were significant for AR (β = –.53, 95% CI [–.84; –.27]) but not for 3D (β = –01, 95% CI [–.16; .21]). The moderated mediation index was significant (index = –.54, 95% CI [–.95; –.22]. Thus, when food is viewed in AR, the packaged format leads to lower mental simulation of the eating process and, consequently, lower purchase intention than the served format; however, no such differences occur in 3D. Perceived interactivity and immersion additionally mediated this process (see Appendix C). These results indicate that using AR has advantages for served over packaged products, because served food in AR leads to stronger mental simulation of the eating process. Conversely, the stronger effects of 3D for the packaged product than the served product on purchase intention are not explained by mental simulation of the eating process and require further examination.

Discussion

Our results indicate that 3D is more relevant for evaluating packaged than served products. Conversely, AR is significantly more conducive for served than packaged food, in support of H4. Furthermore, we found a negative indirect effect of viewing packaged (vs. served) food in AR on purchase intention, with a mediating effect of interactivity, immersion, and mental simulation of the eating process. These effects did not emerge in 3D. These results explain why packaged (vs. served) food in AR leads to lower purchase intention. When viewing packaged food in AR (and thus examining instrumental properties), participants' perceived interactivity as lower (i.e., they perceive less control, and the technology appears less responsive) than when viewing served food.

When evaluating the effect of visualisation mode, we found that interactivity and immersion mediate the effects of 3D versus AR on mental simulation of the eating process and purchase intention for the packaged food, but not for the served food, confirming H5. Specifically, participants perceived the 3D packaged version as significantly more interactive than the AR packaged version, but no such differences were observed for the served food.

In Study 2, we demonstrated that 3D is more relevant for the evaluation of packaged food and that AR is more efficient for served food. However, compared with AR for served food, mental simulation of the eating process did not mediate the stronger effects of 3D packaged (vs. served) food on purchase intention. First, the reason for these results may be that it was not possible to see the food in the package, and it is usually the sight of food that stimulates mental simulation of eating experiences (Simmonds and Spence 2017; Simmons, Martin, and Barsalou 2005). Second, unlike served food products, packaged food products highlight instrumental properties. In general, these properties focus on the consequences of an experience rather than the experience itself (Hirschman and Holbrook 1982; Muñoz-Vilches et al. 2020; Peck and Childers 2003; Xie, Minton, and Kahle 2016), suggesting that the mental simulation of the eating outcome is more likely to be simulated than the mental simulation of the eating process, as postulated in H7. To test this hypothesis, we conducted Study 3, in which we compare two types of packaged products: a transparent packaged product that offers a glimpse of the food (valuing both instrumental and sensory properties) and an opaque packaged product that provides only textual (instrumental) information.

Study 3: 3D Visualisation of Transparent vs. Opaque Packaged Products

Participants and Design

Two hundred and two participants recruited through a participant pool at a British business school (91 men, M_{age} = 23.02, SD = 5.90) took part in the study in exchange for an online retail voucher. The study followed a 2 (packaging format: transparent vs. opaque) × 2 (visualisation mode: 3D vs. AR) between-subjects experimental design.

Materials and Procedure

Two versions of a Krispy Kreme Doughnuts box were developed by an AR software company to represent two packaging formats. One featured a Krispy Kreme Doughnut opaque box that did not show any doughnuts, and the other featured a box with a transparent section that showed several glazed doughnuts packed inside. The boxes were visualised in both 3D and AR. In the 3D version, the doughnut box was presented against a light grey background, and the user could interact with it by enlarging or minimizing the box with their fingers to see specific elements more closely or turn the box to see it from a different angle. In the AR version, the doughnut box appeared overlaid in the physical surrounding in real time. Participants could interact with it in the same manner as in 3D, but they could also see it from different angles or change the visual proximity to it by physical moving the tablet around. The two boxes provided identical nutritional information and product details (Appendix A). The colours, the look and feel, and the material were the same. The assignment of participants to the different conditions was random.

Participants first answered questions about how hungry they were, how much they liked doughnuts in general and the Krispy Kreme Doughnuts brand in particular, and their familiarity with the brand. They were given a smart tablet and asked to examine and interact with the doughnuts box. Then, they were asked to report their purchase intention (α = .85), mental simulation of the eating process (α = .88), and mental simulation of the eating outcome (α = .82). Finally, they were asked about their desire to add a topping to the doughnuts (and thus related behaviour, α = .88, 10-point Likert scale), the instrumental properties of the presented stimuli (α = .78), the associated sensory value (α = .92), and perceived attractiveness (α = .86). We controlled for media novelty (α = .86), which can enhance consumers' cognitive allocation of attention (Yim, Chu, and Sauer 2017). Again, we measured perceived interactivity (α = .79). All scales are available in Appendix B.

At the end of the study, participants received their voucher and were thanked for their participation. Before leaving the lab, they were offered the same glazed Krispy Kreme doughnuts on a plate that they visualised on the tablet. Next to the plate were napkins and small paper bags. The participants were told that the doughnuts were a ‘thank you’ for their participation and that they could take them now to eat or take them in the bag to eat later. Choosing to consume the product now rather than later served as a measure of consumer motivation to eat the doughnut (Dassen, Houben, and Jansen 2015).

Pre-test Food Properties

We conducted an online pre-test on Prolific Academic in which 61 participants (41 women, M_{age} = 33.79, SD = 9.31) evaluated the static image of the transparent or opaque Krispy Kreme Doughnuts boxes in terms of their corresponding sensory (α = .94) and instrumental (α = .89) properties and attractiveness (α = .91). The pre-test showed that the transparent box was significantly higher in sensory ($M_{\text{Transparent}}$ = 5.12, *SD* = 1.53 vs. M_{Opaque} = 3.96, *SD* = 1.35; $F(1, 60) = 9.97$, $p = .003$, $\eta_p^2 = .15$) and instrumental ($M_{\text{Transparent}}$ = 5.21, *SD* = 1.09 vs. M_{Opaque} = 3.90, *SD* = 1.40; $F(1, 60) = 16.39$, $p < .001$, $\eta_p^2 = .22$) properties. This pre-test confirms that the two boxes differed in these specific properties.

Results

Mental Simulation and Purchase Intention.

We conducted a 2 (visualisation mode: 3D vs. AR) × 2 (packaging format: transparent vs. opaque) two-way ANOVA on our key dependent variables: mental simulation of the eating process, purchase intention, and mental simulation of the eating outcome. The main effect of packaging format was significant for mental simulation of the eating process (M_{Opaque} = 4.68, *SD* = 1.57 vs. $M_{\text{Transparent}}$ = 5.48, *SD* = 1.46; $F(1, 201) = 13.98$, $p < .001$, $\eta_p^2 = .07$), but there was no main effect due to visualisation mode ($p = .51$), and the interaction was not significant ($p = .13$). A post hoc Bonferroni test showed that the transparent 3D package led to significantly higher mental simulation of the eating process than the opaque AR package ($M_{\text{3D\_Transparent}}$ = 5.72, *SD* = 1.34 vs. $M_{\text{AR\_Opaque}}$ = 4.76, *SD* = 1.59; $t = 3.37$, $p = .008$) and the opaque 3D package ($M_{\text{3D\_Opaque}}$ = 4.57, *SD* = 1.56; $t = 3.75$, $p = .002$) but was not significantly different from the transparent AR package ($M_{\text{AR\_Transparent}}$ = 5.25, *SD* = 1.54; $t = 1.66$, $p = .69$). The AR transparent package was not significantly different from the 3D opaque ($t = 2.10$, $p = .19$) or AR opaque ($t = 1.62$, $p = .57$) packages. Finally, the AR and 3D opaque versions did not differ ($t = 0.58$, $p > .99$).

Similarly, we found a main effect of packaging format on mental simulation of the eating outcome (M_{Opaque} = 4.24, SD = 1.70 vs. $M_{\text{Transparent}}$ = 4.73, *SD* = 1.51; $F(1, 201) = 4.71$, $p = .03$, $\eta_p^2 = .02$), while the main effects of visualisation mode were not significant ($p = .81$). Importantly, there was a significant interaction effect ($F(3, 201) = 4.79$, $p = .03$, $\eta_p^2 = .02$), with the post hoc Bonferroni test showing that the transparent 3D package led to significantly higher mental simulation of the eating outcome than the opaque 3D version ($M_{\text{3D\_Transparent}}$ =

5.01, $SD = 1.43$ vs. $M_{3D\_Opaque} = 3.99$, $SD = 1.78$; $t = 3.01$, $p = .014$) and was not significantly different from the transparent AR ($M_{AR\_Transparent} = 4.46$, $SD = 1.55$; $t = 1.87$, $p = .49$) and opaque AR ($M_{AR\_Opaque} = 4.43$, $SD = 1.63$; $t = 1.96$, $p = .37$) versions. Moreover, there were no differences between the two AR conditions ($t = 0.11$, $p > .99$). Finally, opaque 3D did not differ from transparent AR ($t = 1.37$, $p = .91$) or opaque AR ($t = 1.26$, $p > .99$, for details, see Fig. 2).

In terms of purchase intention, there were no significant main effects of visualisation mode ($p = .51$), and the interaction was also not significant ($p = .20$). The main effect of packaging format on purchase intention was significant ($M_{Opaque} = 3.98$, $SD = 1.42$ vs. $M_{Transparent} = 4.36$, $SD = 1.28$; $F(1, 201) = 3.96$, $p = .048$, $\eta_p^2 = .02$). The post hoc Bonferroni test showed that none of the four conditions differed significantly from the other ($p > .05$). The significance of these results did not change when we included doughnut liking, brand familiarity, hunger, and gender as covariates, H6 was not supported.

Interactivity and Immersion.

A one-way ANOVA showed that perceived interactivity differed significantly across the four conditions ($F(3, 201) = 3.37$, $p = .02$, $\eta_p^2 = .05$). Specifically, participants perceived 3D as more interactive than AR ($M_{3D} = 6.03$, $SD = .77$ vs. $M_{AR} = 5.69$, $SD = 1.03$; $F(1, 201) = 6.63$, $p = .01$, $\eta_p^2 = .03$), but there were no significant differences between the two packaging formats ($M_{Opaque} = 5.73$, $SD = 1.05$ vs. $M_{Transparent} = 5.95$, $SD = .80$; $F(1, 201) = 2.77$, $p = .097$, $\eta_p^2 = .01$). Interactions across the four conditions were not significant ($p = .30$). A post hoc Bonferroni test showed significantly higher perceptions of interactivity for the transparent package in 3D than the opaque AR ($M_{AR\_Opaque} = 5.54$, $SD = 1.19$ vs. $M_{3D\_Transparent} = 6.05$, $SD = .79$; $t = 2.65$, $p = .03$). The other conditions did not differ significantly ($p > .05$).

Immersion did not differ significantly across the four conditions ($p = .42$), neither between AR and 3D ($p = .86$) nor between the two packaging conditions ($p = .37$). However, the conditions differed in terms of novelty (F(3, 201) = 3.55, p = .015, η_p^2 = .05); participants perceived the 3D opaque package (M_{3D_Opaque} = 3.84, SD = 1.42) as less novel than the AR transparent package ($M_{AR\_Transparent}$ = 4.74, SD = 1.42; t = 3.06, p = .02) and the AR opaque package (M_{AR_Opaque} = 4.61, SD = 1.56; t = 2.54, p = .05). The two 3D conditions did not differ in novelty ($M_{3D\_Transparent}$ = 4.52, SD = 1.26; t = 2.42, p = .14).

We examined H5a and ran Model 6 in PROCESS to test the indirect effects of AR and 3D (AR = 1, 3D = 0) on mental simulation of the eating process with perceived interactivity and immersion as the mediators. 3D led to higher perceived interactivity (β = -.34, t = -2.58, p = .01), which further increased immersion (β = .20, t = 2.21, p = .03). Immersion also increased mental simulation of the eating process (β = .25, t = 2.82, p < .01). The indirect effects were significant (effect = -.02, 95% CI [–.05; -.0002]), supporting H5a.

Moderated Mediation.

One of the key aims in this study was to better understand the effect of 3D packaged food (with both sensory and instrumental properties) on purchase intention. As we postulated in H7, such effects can be due to the mental simulation of the eating outcome. Thus, we tested whether showing (or not showing) the food on the packaged product modified evaluations across the two visualisation modes. We conducted moderated mediation (Model 7, PROCESS) with packaging format (opaque = 0, transparent = 1) as the independent variable, mental simulation of the eating outcome as the mediator, purchase intention as the dependent variable, and visualisation mode as the moderator. The interaction between packaging format and visualisation mode was significant (β = –.99, t = –2.19, p = .03). Specifically, in the 3D condition, the transparent package had a significantly stronger effect on mental simulation of the eating outcome than the opaque package (η^2 = 1.02, t = 3.07, p = .002), but these effects were not significant in AR (p = .91). Moreover, mental simulation of the eating outcome had a significant effect on purchase intention (β = .17, t = 2.93, p = .004). The direct effects on purchase intention were not significant (p = .12). Finally, packaging format had a significant indirect effect on purchase intention through mental simulation of the eating outcome for 3D, such that the transparent package led to significantly higher purchase intention through mental simulation of the eating outcome (effect = .18, 95% CI [.03; .38]). These significant indirect effects of packaging format did not emerge for AR (95% CI [–.10; .12]). The moderated mediation index was significant (index = –.17, 95% CI [–.41; –.01]), also with hunger, brand familiarity, gender, or novelty as covariates. Perceived interactivity and immersion did not additionally mediate this process (Appendix C).

Behavioural Intent and Actual Behaviour.

We examined participants' desire to add a flavour topping of their choice to the doughnuts. We found a significant main effect of visualisation mode: those that viewed the AR (vs. 3D) visualisation reported a significantly higher desire to add a topping (M_{AR} = 6.80, SD = 2.51 vs. M_{3D} = 5.98, SD = 2.61; $F(1, 201) = 4.54$, p = .034, η_p^2 = .02), when hunger served as a covariate. We then analysed behavioural data (doughnut taken with a napkin or put in a bag) with a one-tailed two-proportion z-test that measures whether there is a significant difference between two independent samples on a single, categorical variable. We compared the proportion of participants who took the doughnut with a napkin in the sample. As noted previously, in each condition some participants did not take a doughnut; we excluded them from this calculation (19 in total). We compared 3D versus AR and found marginally significant differences (z = –1.45; p = .07); participants in the 3D condition took a higher number of doughnut with the napkin than those in the AR condition. Other conditions did not differ significantly.

Discussion

The results from Study 3 provide new insights into how consumers respond to food visualisation mode via 3D and AR, depending on whether the packaging format shows the food (transparent) or not (opaque). The two packaging formats differed in terms of instrumental and sensory properties, such that both properties were deemed as higher with the transparent packaging. The results show that mental simulation of the eating process is higher when consumers view a transparent (vs. opaque) package in 3D, but no such differences emerge for AR. Study 3 demonstrates that a packaged food that is high in both instrumental and sensory properties, performs better than a packaged food with low such properties when viewed in 3D. Our previous results showed that people evaluate packaged (vs. served) food more positively in 3D. Study 3 evidences that such effects are exacerbated with transparent packaging that shows the actual food.

We found that purchase intention was higher for transparent packaged products, independently of visualisation mode (not supporting H6). This lack of main effect of visualisation mode can be explained by the fact that the opaque packaged product was perceived to be low in both instrumental and sensory properties and was therefore unattractive for purchase, regardless of whether it was visualised in 3D or in AR. By contrast, the transparent packaged product was high in both sensory and instrumental properties, suggesting that this product was more attractive than the opaque one, regardless of the type of visualisation mode. However, despite the lack of direct effect of visualisation mode, the moderated mediation highlighted that 3D is more relevant to increase purchase intention for transparent (vs. opaque) packaged products due to its ability to stimulate the mental simulation of the eating outcome, which is not the case for AR with this packaging format.

Concerning our behavioural data, it may appear contradictory at first glance. Participants reported a greater desire to add a topping to their doughnut in the AR than in the 3D condition. Conversely, they were more likely to want to eat the doughnut immediately in the 3D than the AR condition. However, these two opposite behaviours could be the result of different processes. The desire to add a topping does not necessarily mean that people like the product; they may just add a topping to make the consumption more enjoyable. As AR integrates the product in the environment, consumers are more likely to imagine the actual doughnut and the associated eating experience than in 3D (as shown with served food in Studies 1 and 2). This makes people more likely to imagine adding a topping and, therefore, to desire adding it to their doughnut. By contrast, choosing to eat the product immediately rather than later could be considered as a behavioural intention to consume the product, suggesting that 3D would have more impact than AR on actual behaviour for packaged products. While these results offer novel insights, further investigation will be required to validate this interpretation.

General Discussion

Across three studies, we examined the differences in consumer purchase intention towards food products and the mediating role of mental simulation of eating experiences, depending on the visualisation mode and the product formats in which the food is presented. In Study 1, we showed that viewing served food in AR (vs. 3D) leads to higher mental simulation of the eating process, which positively affects purchase intention (confirming H1 and H2). These indirect effects did not differ between the food categories (healthy and unhealthy, rejecting H3). We also established across the studies that the effects of viewing served food in 3D vs. AR on mental simulation of the eating process are not mediated by perceived interactivity and immersion (an exception was healthy served food), but that these mediation effects are significant for packaged food (supporting H5). Crucially, Study 2 then directly compares two types of product formats (served vs. packaged). In the AR condition, served (vs. packaged) food that had low (vs. high) instrumental properties, led to higher purchase intention, while in the 3D condition, purchase intention was higher for packaged food than served products (confirming H4). Importantly, we found that mental simulation of the eating process mediated the effects of served (vs. packaged) food on purchase intention when viewed in AR, but not in 3D. Finally, Study 3 showed that transparent (vs. opaque) packaged product that is high (vs. low) in both sensory and instrumental properties, increases purchase intention via mediating role of mental simulation of the eating outcome when viewed in 3D, with no such effects in AR (confirming H7).

Theoretical Contributions

This research provides several theoretical contributions. First, we reveal key differences in the effects of visualisation mode on purchase intention of food products and the underlying process related to mental simulation. Previous work indicates that 3D is not efficient to evoke sensory properties and might thus not be relevant for evaluating food products (Choi and Taylor 2014). Our research shows that AR, by situating served food in the real-time environment, can be more fitting than 3D for stimulating the eating process and evoking sensory properties. Therefore, our findings contribute to prior work on mental simulation and visual-enabling technologies (Bonner and Nelson 1985) by revealing the importance of mental simulation in assessing food products online and by highlighting the different efficiencies of AR and 3D in stimulating this process.

Second, we found that AR is not always the most relevant visualisation mode to promote food products. 3D appears more effective in promoting packaged food products than in promoting served food products. While this result is in line with Choi and Taylor (2014), our research further develops that study by showing how people perceive such food formats differently depending on the visualisation mode and by explaining the underlying mechanism. Our results show that 3D is more relevant for stimulating purchase intention for packaged food presenting high sensory and instrumental properties (transparent packaging) than when these two properties are weak (opaque packaging). This greater efficiency of 3D for transparent packaged products might be due to the sight of food, which stimulates mental simulation of eating experiences (Simmonds and Spence 2017; Simmons et al. 2005; Spence et al. 2016). In addition, our research reveals that seeing food through a packaging in 3D does not stimulate mental simulation in the same way as seeing food served in AR. While the latter promotes mental simulation of the eating process, looking at the food through the 3D package facilitates the mental simulation of the eating outcome. The reason for the 3D effect is that this visualisation mode helps consumers focus more on the instrumental properties that often relate to the consequences of product consumption rather than the actual experience (Hirschman and Holbrook 1982; Muñoz-Vilches et al. 2020; Peck and Childers 2003).

Finally, we offer novel findings to prior literature on perceived interactivity (Song and Zinkhan 2008) and immersion when visual-enabling technologies are employed (Javornik 2016b; Yim, Chu, and Sauer 2017). In our studies, participants perceived viewing packaged food in 3D (vs. AR) as more interactive, which mediated further effects on immersion and increased mental simulation of the eating process. This suggests that when viewing virtual objects that have higher instrumental properties (packaged or healthy served food), consumers find it easier to examine them against blank backgrounds as opposed to seeing them integrated in a real-time environment, which is visually more complex. Conversely, such differences are not observed for served food that has low instrumental properties, as it does not require such a detailed examination. While prior research shows that perceived interactivity in AR positively affects immersion and that it can differ depending on the technology used (Song and Zinkhan 2008; Yim, Chu, and Sauer 2017), we highlight that these differences between 3D and AR depend on product formats.

Managerial Implications

We provide useful marketing implications for both online and offline retailing channels. For online food retailers, AR would be relevant to facilitate purchase decisions for served food products, as it would directly connect the visualisation with the eating process and thus help consumers imagine eating the food. This could prove particularly useful for takeout or online deliveries, which are becoming increasingly more common via online platforms (e.g., Uber Eats, Deliveroo) and have grown in recent months due to the coronavirus pandemic. Such visualisations may also help consumers imagine eating the dishes and thus reduce sensory distance, which can be particularly useful for fresh groceries, as people have reservations to purchasing them online (Huyghe et al. 2017; Nielsen 2018).

Situating the food in real-time environments may not always be the optimal tool. Our results show that 3D facilitates purchase intention for packaged food. Many food products are presented in a form of packaging (e.g., cake, rice, pasta) on retailers' websites, a 3D visualisation would be a good option for increasing sales of these products. Importantly, our findings indicate that 3D is particularly relevant for transparent packaged products that highlight both sensory and instrumental properties. Packaging not only provides functional information but also is part of the consumption experience, for which sensory properties play a key role (Krishna, Cian, and Aydınoğlu 2017; Velasco and Spence 2019; Velasco et al. 2016). Therefore, 3D might be particularly relevant to promote food products whose package is an essential part of the eating experience (e.g., can of beer, chocolate box) (Petit, Velasco, and Spence 2019b). Note also that representing products in a virtual manner can be a viable solution to support retailers in their efforts to reduce the use of packaging, thus responding to increasing environmental concerns (Magnier and Schoormans 2017).

Limitations and Future Research Directions

This research is not without limitations. First, the mode of interaction in visual-enabling technologies needs to be addressed further. While we carefully controlled for the mode of interaction in Study 1, the interaction with 3D and AR differed in Studies 2 and 3. We accounted for the effects on perceived interactivity in our analysis, but it would have been informative to compare the effects related to the different modes of interaction for the same visualisation mode. However, presenting a 3D product on a blank background without the ability to manipulate it with tapping or clicking would eliminate some core features of a 3D representation.

Second, contrary to previous work, we did not find any differences in purchase intention and food choice between unhealthy and healthy options depending on the visualisation mode (Basso et al. 2018; Raghunathan, Naylor, and Hoyer 2016; Shen, Zhang, and Krishna 2016). Given findings in previous research, we expected zooming/rotating the product with fingers to lead to an increase in unhealthy food choices (Shen, Zhang, and Krishna 2016). However, in prior studies, the healthy and unhealthy food products were distinguished by their tastiness. Conversely, in our study, these products had equivalent levels of tastiness, as we focused solely on manipulating the healthfulness to avoid any confounding effects. Future studies might examine the role of tastiness when food is presented via visual-enabling technologies.

Finally, Study 3 reveals inconsistent behavioural results at first glance. Participants reported a significantly higher desire to add a doughnut topping in AR but were more likely to want to eat the doughnut immediately in the 3D condition. In the discussion of Study 3, we suggested that these two behaviours might actually relate to different processes. We encourage further research to examine behavioural variables more directly related to purchase intention, such as by analysing the actual amount that consumers would be willing to pay or observing whether their preference for a food item over money as compensation changes depending on the condition.

In summary, in the context of a growing food e-commerce market and a customer experience that is increasingly being transformed by the integration of new technologies (Hoyer et al. 2020), it is critical to understand the circumstances under which different visualisation modes such as 3D and AR may or may not add value to firms. In this research, we present, for the first time, the conditions under which 3D and AR may support retailers in creating food visualisation experiences that translate into added value for the firm. In the digital world, it is no longer a question of using new technologies to gain a competitive advantage, but of knowing which one to use to enhance the evaluation of product properties.

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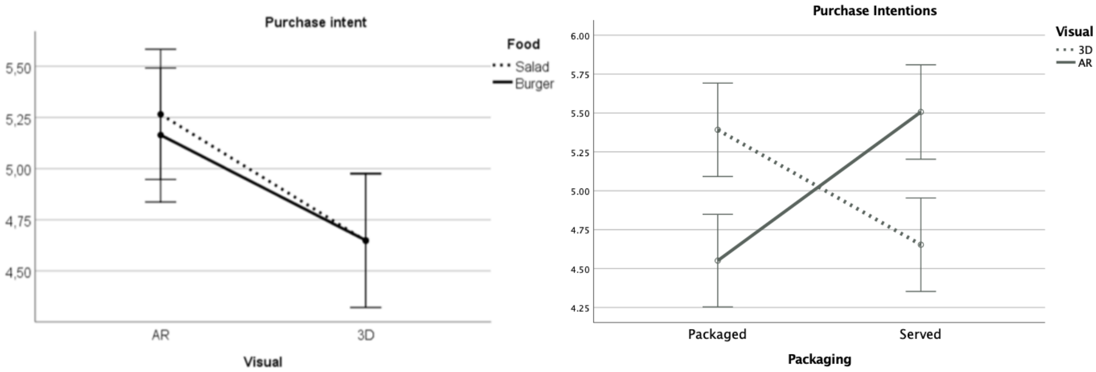

Fig. 1. Purchase intention in Study 1 (left) and Study 2 (right); 95% CI error bars.

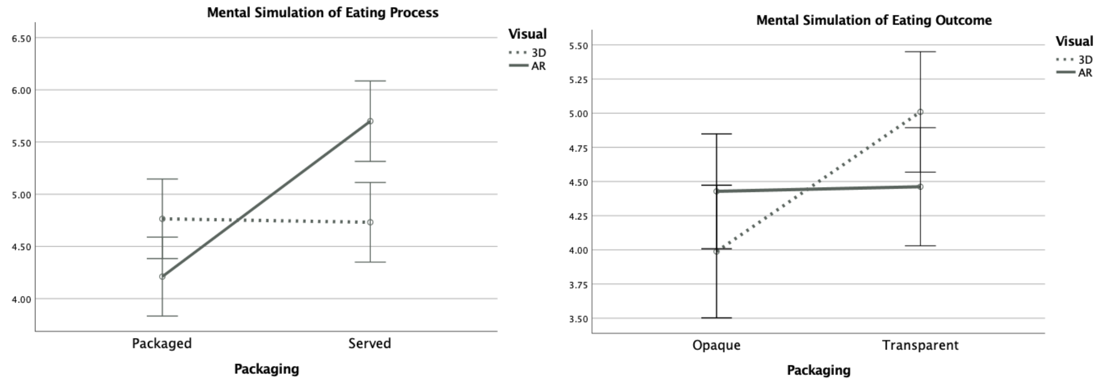

Fig. 2. Eating simulation of eating process in Study 2 (left) and eating outcome in Study 3 (right); 95% CI error bars.

Appendix A. Stimuli

Study 1: 3D models of served salad (left) and burger (right) as healthy and unhealthy conditions, respectively; same stimuli appeared overlaid in real-time environment in the AR condition.

Study 2: 3D model of served ice cream (left) and packaged ice cream (right); same stimuli appeared overlaid in real-time environment in the AR condition.

Study 3: Transparent (left) and opaque (middle) doughnut box as overlaid on a table (middle) and box information from the side (right) in the AR condition; same box appeared against a grey background in the 3D condition.

Appendix B

Measurement scales of key variables with the corresponding items

Mental eating simulation process (adapted from Elder and Krishna 2012)
Images of eating the food come to mind when viewing it.
You could imagine eating the food while viewing it.
You imagined eating the food.

Mental eating simulation outcome (Xie, Minton, and Kahle 2016)
You could you imagine how you will feel after eating the food while viewing it.
Images of how you will feel after eating the food came to mind when viewing it.

Purchase intention (White, MacDonnell, and Ellard 2012)
I would likely purchase this food.
I would be willing to buy this food.
I would likely make this food one of my first choices in this product category.
I would exert a great deal of effort to purchase this ice cream.

Interactivity* (Song and Zinkhan 2008)
*Control**
I felt I had a great deal of control over my experience with the app.
While I was using the app, I was always able to do what I thought I was doing.
*Responsiveness***
Interacting with the ice-cream processed my input very quickly.
Interacting with the ice-cream was very fast.
I was able to see I want without any delay.
I felt I was getting an instantaneous information.
Interacting with the ice-cream was very slow in responding to my request. (reversed)
The ice cream reacted to my interaction immediately.
*In Study 1, we measure the interactivity with perceived control, while in Studies 2 and 3 we employ both perceived control and responsiveness as interactivity measures

Immersion (Duncan and Nelson 1985)
How would you describe your state when viewing the food?
Not at all immersed/Deeply immersed
Not at all absorbed/Deeply absorbed
My attention was not focused/My attention was focused

Media novelty (Yim, Cicchirillo, and Drumwright 2012)
This app is new.
This app is unique.
This app is different.
This app is unusual.

Media familiarity (Yim, Chu, and Sauer 2017)
To what extent are you familiar or unfamiliar with this type of media?
Unfamiliar/Familiar

Inexperienced/Experienced
Not knowledgeable/Knowledgeable

Desire to add topping
I would like to add a topping of my choice to the Krispy Kreme Doughnuts product.
This Krispy Kreme Doughnuts product does not need additional topping. (reversed)
I wish this Krispy Kreme Doughnuts product had a topping of my choice.

Instrumental properties (Brakus, Schmitt, and Zhang 2014)
The image presents the features of the ice-cream product.
The image shows the information about the ice-cream product.
The image presents the characteristics the ice-cream product has.
The image conveys the characteristics of the ice-cream product.

Sensory properties (Brakus, Schmitt, and Zhang 2014)
The image of ice-cream product has sensory appeal.
The image of ice-cream product engages my senses.
The image of ice-cream product is focused on sensory appeal.

Affective properties (Brakus, Schmitt and Zhang 2014)
The image of ice-cream product appeals to feelings.
The image of ice-cream product is affective.
The image of ice-cream product is emotional.

Appendix C

Study 2: Perceived interactivity and immersion as mediating effects of food presentation format on mental simulation of the eating process and purchase intention

We also estimated the moderated serial mediation with perceived interactivity, immersion, and mental simulation of the eating process as our mediators and with purchase intention as the key outcome variable. We ran Model 83 in PROCESS (Hayes, 2012). Again, the visualisation mode (3D vs. AR) was specified as the moderator and food packaging (served vs. packaged) as the independent variable. The interaction significantly predicted perceived interactivity (β = –1.31, t = –5.73, p < .001). Participants perceived the packaged food product in the AR condition as significantly less interactive than the served food product (β = –1.18, t = –7.32, p < .001), but no such differences occurred in 3D (p = .43). Furthermore, the effects of perceived interactivity on immersion were significant (β = .62, t = 7.69, p < .001), with no direct effects of packaging condition on immersion (p = .56). Moreover, immersion significantly affected mental simulation of the eating process (β = .52, t = 6.42, p < .001). The effects of interactivity on mental simulation of the eating process were also significant (β = .30, t = 2.81, p < .01). Finally, there were significant direct effects of mental simulation of the eating process on purchase intention (β = .18, t = 3.08, p < .01), though the direct effects of packaging on purchase intention were not significant (β = .27, t = 1.892.02, p = .06). The indirect effects of packaged (vs. served) food when viewed in AR on purchase intention through interactivity, immersion, and mental simulation of the eating process were significantly lower (effect = –.07, 95% CI [–.15; –.02]), but no such differences occurred in 3D (effect = –.001, 95% CI [–.01; .03]). The moderated mediation index was significant (index = –.07, 95% CI [–.16; –.02]). These results show that in the AR condition, the packaged version leads to significantly lower purchase intention than the served version through the mediating effects of interactivity, immersion, and mental simulation of the eating process. Such differences between packaged and served food are not present in 3D.

Study 3: Perceived interactivity and immersion as mediating effects of food presentation format on mental simulation of the eating outcome and purchase intention

We also examined whether perceived interactivity and immersion mediated the effect of transparent (vs. opaque) packaging on mental simulation of the eating outcome and, consequently, on purchase intention (Model 6, Hayes, (2012)); however, this serial mediation was not significant (*effect* = .001, 95% CI [–.0004; .004]). Visualisation mode did not moderate this process (Model 83) (index = .001, 95% CI [–.001; .005]). This result indicates that participants perceived no crucial difference in how they could interact with the transparent or opaque package and that this similarity between the two packaging formats occurred both 3D and AR.