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Beyond the plate: Social representation and future thinking in 3D food choices

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ABSTRACT

Social representations are spread through interactions, influencing how information is shared and understood within communities. To gain a comprehensive understanding of 3D-printed food acceptance, Study 1 adopts a constructivist approach using a model based on Social Representation Theory. This model serves as a critical predictor of consumer acceptance. In contrast, Study 2 not only examines sensory aspects but also explores time orientation forecasting to explore how these foods may be accepted in the future.

Structural Equation Modelling and hierarchical cluster with multigroup analysis were employed to analyze the data. Around 612 Australian consumers participated in the surveys**.** Study 1 demonstrates the significant influence of perceived risk beliefs as a psychological barrier on all variables. Study two contributes to the growing body of research on 3D-printed foods by demonstrating how consideration of future consequences (CFC), both immediate and future-oriented, influences hedonic eating values of 3D-printed foods. The findings reveal high and low-sensory consumers respond differently in terms of hedonic and healthy eating values, highlighting the importance of sensory preferences in shaping consumer acceptance of 3D-printed foods.

This research makes a dual contribution: theoretically, it advances our understanding of 3D-food technology adoption by integrating Social Representation Theory and temporal decision-making frameworks; empirically, it provides novel evidence on how perceived risks, sociocultural constructions, and time orientation influence consumer acceptance of 3D-printed foods. By uncovering the differentiated impact of sensory preferences on hedonic and health-related choices, it offers actionable insights for marketers, policymakers, and food innovators seeking to advance sustainable and consumer-aligned food futures.

1. Background

While 4D-printed foods already showcase exciting future innovations triggered by external stimuli (Oral et al., 2021), three-dimensional (3D) food printing remains a groundbreaking and rapidly evolving technology with immense potential to transform food processing and product development, offering unparalleled advantages in customization, sustainability, and personalized nutrition (Fasogbon and Adebo, 2022). New exponential market opportunities present themselves for creating protein-based products with varied and tailored textures through the application of 3D printing technology (Abdollahi et al., 2025). Even though consumers are aware of 3D-printed foods (Silva et al., 2024), there is currently a lack of empirical evidence to determine how consumers are likely to adapt to 3D-printed foods in the future, including the evolving social perceptions surrounding their acceptance.

To understand the limited uptake of 3D-printed foods, Social Representation Theory (SRT) offers a useful lens. As a social constructivist framework, SRT explains how shared beliefs shape consumer awareness, interpretation, and behaviour (Devine-Wright, 2009). The objectification process, where unfamiliar concepts become familiar, is key to driving consumer action (Moscovici, 1984). Through this process, practitioners who consider a social constructivist approach based on the idea that knowledge, meaning, and reality are constructed through social interactions and shared experiences can determine how consumers intend to adapt to 3D foods.

Study 1 is grounded in Social Representation Theory (SRT)**,** focuses

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on understanding how consumers collectively interpret and negotiate the unfamiliar concept of 3D-printed foods through existing cultural beliefs, values, and everyday language. It identifies consumers' perceived risks as influencing both the Epistemic Motivation variables of SRT (Suspicion of Novelties, Adherence to Technology, and Adherence to Naturalness), and the Personal Relation variables of the SRT (Eating as an Enjoyment and Eating as a Necessity), which collectively determine intention levels.

However, given that 3D food printing is still an emerging technology with far-reaching implications for the future of food production, it was essential for Study 2 to explore the temporal dimension, specifically, how time orientation influences the future use of 3D-printed foods. This forward-looking perspective also informs long-term adoption behaviours in 3D-food innovation.

Together, these studies offer a comprehensive understanding: the first reveals how 3D-printed foods are socially constructed in the present, while the second examines how Time orientation can reveal how food innovation diffuses over time. Understanding this mindset is therefore vital to guiding the successful integration of 3D-printed foods into mainstream markets and effectively meeting customers' needs.

2. Study 1. Social representation theory and 3D-printed foods

2.1. Introduction

This research investigates 3D-printed foods and examines social representation theory to demonstrate how consumers comprehend and adjust to novelty and uncertainty, facilitating the transition from unfamiliarity to familiarity and eventual behavioural action (e.g., Moscovici, 1984). Several studies have applied Social Representation Theory (SRT) to explore food-related perceptions at individual and group levels (Monaco and Bonetto, 2019). SRT marks a bold leap forward for marketing research, as it is a field deeply rooted in the study of social phenomena (Penz and Sinkovics, 2013). To initiate this inquiry, we offer a concise overview of the theory and integrate perceived risks to analyze these interrelationships.

2.2. Perceived risks beliefs

Risk-related concerns play a critical role in shaping consumer choices, particularly when the risks are perceived as involuntary or beyond individual control. Given its influence on consumer behaviour, the inclusion of perceived risk within the SRT framework is both necessary and conceptually required to understand the psychological and cultural barriers that influence consumer acceptance of food technologies.

While 3D food printing has been described in sociocultural research as a futuristic, creative, healthy, efficient, natural, and sustainable innovation (Lupton and Turner, 2017), consumer hesitancy remains evident. Despite these positive portrayals, studies of Manstan and McSweeney (2020) indicate that many consumers are still unwilling to eat or purchase 3D-printed foods due to underlying perceptions of risk.

We propose that perceived risk beliefs acting as psychological resistance are likely to have a direct effect on both the Epistemic Motivation of SRT (Suspicion of Novelties, Adherence to Technology and Adherence to Naturalness), as well as Personal Relation from a hedonic perspective (Eating as an Enjoyment and Eating as a Necessity). Many consumers perceive 3D-printed food as risky, often viewing it with suspicion due to potential health risks and concerns about harmful by-products (Brunner et al., 2018). However, to meet modern-day challenges, there is a clear need for disruptive innovations, and novel foods are critical for food security, safety and sustainability (Siegrist and Hartmann, 2020). This prompts further inquiry into the perceived risks affecting consumers' food choices, leading to the following hypotheses.

H1. Perceived risk beliefs heighten consumer suspicion of food novelty innovations.

Food-related risks also influence the indirect effects on the environment and society (Verneau et al., 2014), and the risk perception of food technologies increasingly outweighs any likely benefits (Grunert, 2002). Hypothesizing that psychological resistance driven by risk beliefs does not necessarily lead to outright rejection but may coexist with a cautious acceptance or preference for technological innovations perceived to address those risks. As a result, we propose:

H2. Perceived risk beliefs act as psychological resistance and are positively associated with consumers' adherence to food technology solutions

It is critical to understand why consumers often rely on the concept of "naturalness" as a heuristic for safety and quality. When consumers perceive higher risks, whether related to health, unfamiliarity, or artificiality, they tend to psychologically resist such foods due to a lack of naturalness. Research has shown that consumers perceive 3D-printed foods as more useful when the technology can produce natural foods (Groot, 2018). Given this discussion, we posit that:

H3. Perceived risk beliefs act as psychological resistance and are positively associated with consumers' adherence to naturalness in food evaluations.

Results show significant and positive roles of 3D printed food attributes (health, fun, creativity and natural content) in the Value-Attitude-Belief model (Lee et al., 2021). Testing this relationship between perceived risks and eating as an enjoyment helps uncover nuanced consumer attitudes towards 3D-printed foods. Offering insights into how enjoyment might coexist with or even counterbalance perceived risks, ultimately informing strategies to enhance acceptance and adoption, in this light, we suggest the following hypothesis:

H4. Perceived risk beliefs serve as psychological resistance and are positively associated with consumers' emphasis on eating 3D-printed foods for enjoyment.

Although 3D printing was initially seen as a novelty in the culinary world, it has quickly emerged as a transformative necessity, reshaping how food is produced, personalized, and consumed to meet the evolving needs of modern society (Shoeibi, 2023). When eating is framed as a necessity, as opposed to a choice or indulgence, consumers are more risk-averse. Understanding these risks helps assess whether consumers will accept 3D-printed foods as a viable part of their daily diet, not just as a novelty. Accordingly, we hypothesise:

H5. Perceived risk beliefs serve as a psychological resistance and are positively associated with consumers' emphasis on eating out of necessity.

2.3. Social representation theory

Social Representation Theory (SRT) refers to shared beliefs and values that are held by a social group concerning a specific object or concept. Founded on a constructionist approach, which means that knowledge, meaning and reality are created through social interactions and shared understanding, within this context, it perceives the subject and the object as interlinked rather than independent constructs (Moscovici, 1988). propose that the theory of social representation unfolds possibilities to justify the relationship with novelties in routine thinking and adds to the concepts concerning new foods. They suggest that new foods are unknown and require novelty-reducing clarifications before consumers can accept them. They also question whether consumers have a shared understanding of new foods and the type of contention that signifies this social representation (Bäckström et al., 2004). SRT can provide an understanding of a consumer's collective voice (Behrens et al., 2015). While SRT does not lend itself to any methodological process (Bauer and Gaskell, 1999), it has been applied to research innovation, debated, and vibrant topics (Bauer and Gaskell, 1999).

Several authors have even used platforms such as Twitter to study worldwide social representations of new food trends. Despite seemingly straightforward food choices, there are complex behaviors influenced by several interacting factors (Koster, 2009), thus producing varied results. The use of the SRT has important ramifications and has been identified as an important predictor of new food choices (; Huotilainen et al., 2006; Onwezen and Bartels, 2013). In this light, we consider it useful to use SRT to examine their relationships to 3D-printed foods.

Besides, researchers have effectively employed Social Representation Theory to predict willingness to adopt novel food technologies, highlighting the role of shared societal beliefs in shaping acceptance (Huotilainen et al., 2006). Complementing this, the Theory of Normative Social Behaviour has provided valuable insights into the influence of social norms on consumer choices (Borg et al., 2020). Additionally, the integration of the Technology Acceptance Model and Consumer Socialisation Theory has compellingly demonstrated how trust mediates acceptance, highlighting how both cognitive and social factors influence consumer acceptance of technology (Harrigan et al., 2021). More specifically, it is important to understand how information is disseminated by explaining group behaviours and meanings involving the use of 3D-printed foods, since SRT is embedded in the history of groups and is presented with new characteristics through the media (Huotilainen et al., 2006).

Backstrom et al. assert that attitudes, trait studies, and the social constructionism inherent in the social representation theory are compatible and claim that social representation theory opens avenues to explain the relationships to newness in routine thinking. They opine that SRT provides a framework to explain the relationships concerning novelty in habitual cognition. Using the predictive ability of social representation of new foods, they examined attitudes and traits on consumers' willingness to try new foods. It is evident from some of the extant literature that SRT and its dimensions on food are critical in explaining consumers' influences on food choice. Founded on this, we build the following hypotheses for 3D food choices, assuming that the antecedent factors of SRT for food novelties and perceived risks echo different effects on food choices. Building on Backstrom et al. five-factor solution (two factors representing personal relations and three factors representing epistemic motivation) for measuring social representations of new foods, we develop the following hypotheses.

2.4. Hypothesis development

Huotilainen et al. (2006) used SRT to examine new foods and found that trust is a counterpart of suspicion, while adherence to natural food and adherence to technology were negatively related. Furthermore, Huotilainen et al. (2006) raised a point showing how innovativeness relates to the social representation of new foods and identified that low suspicion of new foods and adherence to natural foods, when added to the predictive model, improved the prediction significantly. These constructs were further demonstrated by Chen (2018) on genetically modified foods and the results showed that adherence to technology and food as a necessity showed a significance to consuming genetically modified foods, while resistance to and suspicion of novelties showed a significant negative influence. These studies show the value of SRT and would provide insight for understanding the intention to choose 3D-printed foods.

According to , viewing food as a necessity reflects a utilitarian and emotionally detached relationship with eating, where food is reduced to its most basic function, i.e., sustenance. Although Backstrom and their associates viewed food as a necessity, proving an indication of the indifference and unimportance of food, we considered the more positive aspects of food as a necessity. This is because, in their view, perceiving food purely as a necessity reflects a utilitarian mindset where eating is reduced to a biological function, suggesting indifference, lack of engagement, and the perceived unimportance of food in daily life. This perspective facilitates a passive or even burdensome relationship with food, where its social, cultural, or pleasurable dimensions are largely ignored. Drawing from above, we propose:

H6. The dimension of social representation related to eating as a necessity is positively associated with the intention to choose 3D-printed food.

Furthermore, Backström views food as a source of enjoyment as reflecting a hedonistic dimension, emphasizing the sensory pleasure, indulgence, and emotional gratification associated with eating. This perspective highlights the role of food not merely as sustenance but as a central element in experiences of joy, comfort, and personal satisfaction. As a result, we highlight:

H7. The dimension of social representation related to eating for enjoyment is positively associated with the intention to choose 3D-printed food.

Certain food novelties tend to elicit resistance, skepticism, and even fear. Integrating these innovations into established cognitive frameworks and everyday eating habits can therefore be challenging. This dimension reflected skepticism and hesitation toward innovations, particularly focusing on unfamiliar foods and, more specifically, functional foods. It conveyed a cautious attitude, emphasizing perceptions of such foods as superficial, underlying their vanity . Novel foods and technologies ranging from food additives to nanoparticles are often perceived as unfamiliar and uncertain, requiring a process of uncertainty reduction before consumers are willing to accept or adopt them. Accordingly, we hypothesise:

H8. The dimension of social representation related to suspicion of novelties is positively associated with the intention to choose 3D-printed food.

Backström and colleagues identified a technology-oriented attitude toward new foods as one of the key dimensions influencing consumer perceptions. This dimension reflects a belief in human ingenuity and the capacity of technology to solve pressing food-related challenges. In this context, food is a domain where innovation and adherence to technology in scientific processes play a central role in shaping consumer attitudes and future food acceptance. In light of this, we propose:

H9. The dimension of social representation related to adherence to technology is positively associated with the intention to choose 3D-printed food.

Backstrom et al. suggest that this dimension reflected a strong adherence to natural foods in guiding food choices. Consumers with this orientation often associate natural foods with purity, health, safety, and authenticity, while viewing highly processed or technologically modified foods with suspicion (Huotilainen et al., 2006). Such an outlook often results in resistance to food innovations that are perceived as artificial or synthetic, reinforcing the cultural ideal that "natural is better" in food consumption practices. We therefore advance the following hypothesis:

H10. The dimension of social representation related to adherence to naturalness is positively associated with the intention to choose 3D-printed food.

Fig. 1 outlines the proposed conceptual model and the hypotheses.

3. Methodology

3.1. Scales and sampling

We adopted scales used by , these original scales were further modified by Onweaen and Bartels (2013). The questionnaire comprised 5 components of social representation (SR). The questions for risk

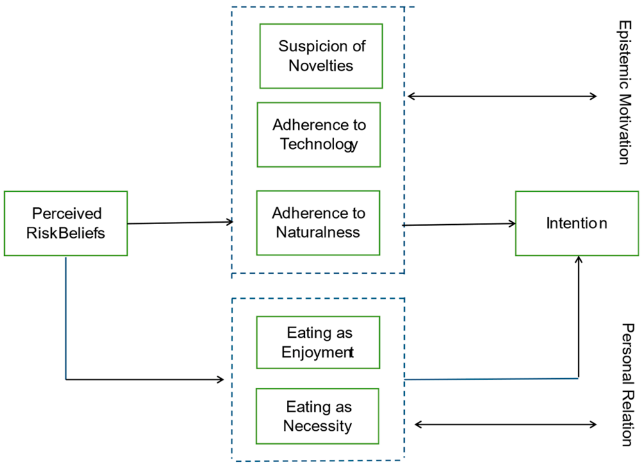


Fig. 1. SRT conceptualised model.

perception beliefs were extracted from Cox and Evans (2008) these are specifically related to innovative and advanced technologies. Food choice scales were extracted from various authors and customized for our study (De Kock et al., 2022; Cox and Evans, 2008). All questions were anchored on a seven-point Likert scale (1=strongly disagree, 7=strongly agree).

A reputable market research firm utilised its panel to recruit participants across Australia. Respondents were selected through a stratified sampling method to ensure representation across key demographics, including gender, state, and region. Participants were invited via an online platform to complete the survey, and inclusion criteria (e.g., age 18+) were applied to ensure relevance to the research context. Data collection was conducted in accordance with Australian market research ethics guidelines, including informed consent and confidentiality protocols.

Survey 1 consisted of approximately 411, half of which were collected from a different online panel. Survey 2 consisted of 201 respondents. Instructions were given regarding the importance of the sample and distribution of the survey; confidentiality was maintained. Structural Equation Modelling (AMOS 28), a multivariate data analysis, was employed for this study. This method is used for analyzing complex relationships and is much more powerful than other multivariate techniques (Hair et al., 2017). Structural Equation Modeling (SEM) is a statistical technique that allows researchers to examine complex relationships between observed variables and underlying latent constructs simultaneously, combining factor analysis and regression modelling in one framework. A pilot test was conducted and tested on 30 consumers for both surveys, resulting in some modifications made to survey one for consistency and clarity.

3.2. Findings

Convergent validity is assessed by employing item loading and average variance extracted (AVE). Average Variance Extracted (AVE) measures the amount of variance captured by the construct in relation to the variance due to measurement error, reflecting convergent validity. Not all items are loaded on suspicion of resistance to novelties. The convergent validity is supported as all of the factors are above 0.60 (see Table 1). Composite Reliability (CR) assesses the internal consistency of the construct, similar to Cronbach's alpha, but is considered more suitable for structural equation modelling. The CR values are above 0.7 and the AVEs are above 0.5, which explains that each of the constructs is greater than 50 % of the variance of its measured items (see Table 1) (Hair et al., 2017). The two-step structural equation modelling (SEM) was used to analyse the data. The confirmatory factor analysis (CFA) examined the reliability of the measurement scales (see Table 1). We

Table 1
Study 1 - factor loadings, AVE, and CR values.

Suspicion of Novelties AVE 0.54 CR 0.80	
• There are some doubts about novelties like 3D	0.698
• New foods like 3D are useless vanity	0.71
• I have resistance to and suspicion of novelties like 3D	0.801
Adherence to Technology AVE 0.74 CR 0.90	
• 3D printing food technology can provide solutions to global food problems	0.798
• I believe in the potential of 3D printing food technology	0.9
• 3D printing food technology is trustworthy	0.885
Adherence to Naturalness AVE 0.59 CR 0.86	
• I would like to eat only food having no additives	0.809
• I feel good when I eat clean and natural food	0.778
• I trust in organically grown food	0.71
• I value naturalness in everything	0.796
Eating as an Enjoyment AVE 0.65 CR 0.88	
• I treat myself to something really delicious	0.79
• Eating is a highlight of my day	0.866
• Delicious food is an essential part of weekends	0.827
• Eating is very important and enjoyable for me	0.747
Eating as a Necessity AVE 0.58 CR 0.82	
• I require information on new foods	0.678
• I care about how my food is produced	0.853
• I care about what I eat to prevent hunger	0.753
Perceived Risk AVE 0.56 CR 0.83	
• 3D printed foods are likely to have long-term negative health effects.	0.874
• It can be risky to switch to 3D printing foods too quickly	0.738
• 3D printed foods technologies may have long term negative environmental effects	0.734
• Society should not depend heavily on technologies to solve its food problems	0.627
Intention to choose 3D-Printed Food AVE 0.78 CR 0.91	
… foods are a healthy experiential choice	0.902
– foods gives more control over food choices.	0.89
— foods can help have a balanced diet.	0.869

deleted those with low loadings and those indicated by high modification indexes (Churchill, 1979). To assess the model fit many indices were used, the normed Chi-square ($\chi2$ /*df*) $\chi2$ = 791.593(226), $\chi2$ /*df* = 3.1; RMSEA indicated 0.073, the comparative fit index (CFI) 0.92, Tucker-Lewis index (TLI) 0.90 and GFI 0.88 and AGFI 0.84 all indicated a reasonable fit (Byrne, 2012). Factor loadings represent the strength of the relationship between each observed item and its underlying latent construct, indicating how well the item measures the construct.

Discriminant validity measures include cross-loadings. It evaluates whether constructs are truly distinct from one another by comparing the square root of the AVE to inter-construct correlations. While there is a close relationship between Intention Choice and Technology, they are distinct; however, this could be a potential limitation, but not a disqualification of the discriminant validity. When used alone, cross-loadings and the Fornell-Larcker criterion may incorrectly specify discriminant validity; hence, the preference is also to use the hetero-trait mono-trait ratio (HTMT). HTMT identifies the ratio among trait correlations to the ratio within-trait correlations and rates the true correlations between the measured variables (Henseler et al., 2015). This is a rigorous test. The thresholds maintain 0.850 for strict and 0.900 for liberal discriminant validity. The two studies ' HTMT ratios for both models show that each item is highly correlated with its construct rather than with any other construct, and the 95 % confidence intervals for all HTMT ratios were <1. Thus, establishing discriminant validity (Hair et al., 2017). In the Appendix, we present the demographics.

The second stage of structural equation modeling (SEM) involves the analysis of the path model. AMOS 28.0 SEM with a maximum likelihood estimation technique was used (Arbuckle, 2011). The analysis indicated satisfactory results. The model fit indices were as follows: ($\chi2$ /*df*) $\chi2$ =11.776/3PCMIN/DF 3.9, fairly reasonable given the other fit indices. GFI 0.92; CFI.99; IFI 0.99; TLI=0.97; RMSEA 0.08 demonstrating that the proposed model reasonably fits with the data.

3.3. Result discussions

Table 2 evaluates the direct effects of 3D-printed food choices; only one hypothesis was found non-significant, i.e. H7: The dimension of social representation related to eating for enjoyment is positively associated with the intention to choose 3D-printed food.

All hypotheses from H1 to H5 were positively significant, showing perceived risk beliefs serve as psychological resistance to all, with the exception of H2, which revealed a negative relationship (β = −0.32; $p <$ .001). In the case of 3D-printed foods, this resistance manifests as hesitation or refusal to accept these products, even if the technology offers benefits like customization or sustainability. The stronger the perceived risks, the more consumers resist the technology, reducing their willingness to incorporate 3D-printed foods into their diet.

In the case of H1: Perceived risk beliefs heighten consumer suspicion of food novelty innovations was significant (β = 0.67; $p <$ .001). In essence, perceived risks make consumers more cautious and doubtful about novel foods, which can be a major barrier to the adoption and acceptance of innovative food technologies. Hypothesis H3: Perceived risk beliefs act as psychological resistance and are positively associated with consumers' adherence to naturalness in food evaluation was significant (β = 0.45; $p <$ .001). This means that risk concerns reinforce the importance consumers give to naturalness when deciding what foods to accept or reject. Furthermore, H4: Perceived risk beliefs serve as psychological resistance and are positively associated with consumers' emphasis on eating 3D foods for enjoyment was significant (β = 0.23; p < .001). The presence of risk concerns might make consumers more likely to emphasize pleasure and sensory experience when deciding whether to try or accept these foods. Lastly, H5: Perceived risk beliefs serve as a psychological resistance and are positively associated with consumers' emphasis on eating out of necessity was significant (β = 0.37; $p <$ .001). Interestingly, instead of rejecting these foods completely, consumers who hold these risk beliefs may shift their focus toward eating 3D-printed foods out of necessity, for example, viewing them as practical or essential options when no better alternatives are available.

Regarding H6: The dimension of social representation related to eating as a necessity is positively associated with the intention to choose 3D-printed food, while results revealed a significant negative relationship (β = −0.14; $p <$ .001). This suggests that consumers who view eating some foods primarily as a necessity are less likely to intend to choose 3D-printed food. This shows that as consumers make more diverse or unconventional food choices, their adherence to viewing 3D food strictly as a necessity decreases. Furthermore, H8: The dimension of social representation related to suspicion of novelties is positively associated with the intention to choose 3D-printed food. This negative relationship suggests that consumers tend to have higher resistance to novelties and more suspicion towards new foods; however, the beta value of 0.09 indicates a low relation where food choice has an obvious impact but is not highly influential (β = −0.09; $p <$ .001). This finding suggests that consumers who exhibit higher suspicion toward novel foods are less likely to intend to choose 3D-printed food, supporting the idea that food neophobia or resistance to innovation restricts acceptance of emerging food technologies.

Although the effect size is modest (β = −0.09), the significance indicates that suspicion of novelty plays a meaningful, albeit limited, role in shaping consumer attitudes toward 3D-printed foods. The relatively low magnitude of the relationship implies that while distrust towards new foods can influence food choices, it may not be the dominant predictor of consumer intention in this context.

Hypothesis H9: The dimension of social representation related to adherence to technology is positively associated with the intention to choose 3D-printed food. The 'adherence to technology' dimension of social representation is positively associated with intention to choose 3D-printed food. This indicates that technology is a critical factor that significantly impacts the decision to choose 3D-printed food. The high beta value (β = 1.01; $p <$ .001) suggests that technology has a major role in shaping consumer choices regarding 3D-printed foods. While H10: The dimension of social representation related to adherence to naturalness is positively associated with the intention to choose 3D-printed food was positively significant and supported the hypothesis (β = 0.13; $p <$ .001). The beta value of 0.13 indicates a modest relationship, where food choice has a discernible impact but is not overwhelmingly influential. One would expect a negative influence as naturalness may matter, but it could be just one of the factors influencing intention, diluting its overall effect. The overall model explains 84 % of the variance for intention to choose 3D foods.

4. Theoretical contributions

This larger constituent of work aimed at understanding new food concepts by conceptualizing SRT with multiple dimensions, thus providing a more nuanced explanation of consumers' food choices better . This research makes an interesting novel theoretical contribution to understanding SRT and consumers' perceptions towards 3D foods. The social representation theory broadly covers thoughts, beliefs, and behavioural connotations held by the public regarding an innovative phenomenon that can be conceptualized into models (Huotilainen, 2006). Secondly, this research extends the SRT model by theorizing and integrating perceived risks where the risk perception increasingly outweighs any likely benefits (Grunert, 2002). Lastly, our findings validate study, by showing how 3D-printed foods are socially constructed and ingrained into the sociocultural fabric of society. These factors go beyond individual preferences by incorporating historical, cultural, and social dimensions that impact food behavior and decisions.

5. Managerial implications

The results of this rigorous process of adding perceived risks demonstrate that this study provides a valid measure that practitioners can use to assess 3D food consumption behaviour. Theoretically, the SRT logic can be used by practitioners to inform strategic decision-making for new and emerging 3D-printed food products. Thus by understanding consumer innovativeness and the associated risks in relation to four

Table 2
Study 1 - estimates and hypothesis.

			Std Estimate	S.E.	C.R.	Hypotheses
Per Risk Belief	→	Sus of Novelties	0.679***	0.028	18.705	H1
Per Risk Belief	→	Adherence to Tech	−0.327***	0.048	−7.004	H2
Per Risk Belief	→	Adherence to Natural	0.459***	0.042	10.464	H3
Per Risk Belief	→	Eating as Enjoyment	0.23***	0.04	4.784	H4
Per Risk Belief	→	Eating as Necessity	0.373***	0.032	8.151	H5
Eating as Necessity	→	Intention	−0.14***	0.05	−4.475	H6
Eating as Enjoyment	→	Intention	−0.033	0.032	−1.405	H7
Sus of Novelties	→	Intention	−0.092***	0.035	−3.924	H8
Adherence to Tech	→	Intention	1.018***	0.021	53.955	H9
Adherence to Natural	→	Intention	0.132***	0.033	4.717	H10

of the five significant dimensions, practitioners will be better informed to make investment decisions, keeping in mind the negative relationships and how to improve their efficiency and effectiveness.

While our study included all on-line consumers as respondents, practitioners can target specific groups based on factors, such as group cohesiveness or a sense of belonging, to prioritize engagement, loyalty, satisfaction, and intention towards 3D foods. This approach is particularly effective with consumer segments demonstrating technology readiness and aligns with customer acceptance. While lifestyle choices are a priority for consumers, retailers can employ strategies to address the negative effects of adherence to necessity and 3D-Food choices, if they want to consider 3D-food products as a lifestyle choice.

Practitioners often rely on communication strategies to influence consumer behaviour. They could employ the SRT concepts for leveraging goals and outcomes for food choices. As this food incurs less waste, consumer's attitudes towards promotions and choice can be altered. The SRT lends itself to understanding the dominant beliefs and cultural systems essential for disseminating 3D-printed food information. Thus, from a retail strategic perspective, using marketing communication efforts for mitigating the risk, along with showing scientific evidence can be directed to selective cohorts. This will enable practitioners to derive more tangible outcomes. Since the results demonstrate the highest beta value for technology adherence and have a direct positive significance to 3D-printed food choice, practitioners can use a positioning strategy to capture consumer co-creation of tech-savvy 3D- food products. These positioning strategies can significantly impact practitioners' competitiveness and performance.

6. Study 2. Future consequences (CFC), associated with 3D-printed foods

6.1. Introduction

While the previous study on Social Representation Theory (SRT) offers valuable insights into the current societal meanings and consumer perceptions of 3D-printed foods, it primarily captures how consumers make sense of new technologies in the present. However, emerging food innovations like 3D printing are inherently future-focused, with much of their value, application, and impact projected into the years ahead. Therefore, understanding time orientation on how consumers think about and evaluate the future implications of 3D-printed foods is essential. This is particularly important for novel technologies, since new technologies are revolutionizing industries, as these are likely to be food for the future. Shifting consumer concern from immediate to future time consequences can present a remarkable target for their future involvement, designed to advocate 3D food promotion (Dassen et al., 2015). Including time orientation thus enhances the study's depth, enabling a more comprehensive understanding of both immediate and forward-looking factors that influence consumer behavior toward 3D-printed foods.

Despite some clusters of the population finding 3D-printed foods unacceptable and unsafe for consumption (Manstan and McSweeney, 2020), research shows that attributes such as content, assumed sensory qualities and the appreance are considered necessary for food promotion (Lupton and Turner, 2018). 3D-printed foods are innovative and there is limited research regarding consumer's acceptance of these foods (Manstan and McSweeney, 2020). Due to limited research, it would be useful to determine an individual's consideration of future (CFCs) consequences as against immediate outcomes. Researchers recognize a need for an integrative approach to provide a meaningful interpretation of future consequences and the relationship with trait-based across specific areas (Kooij et al., 2018).

The study objectives are to address the call made by researchers on CFC time orientation constructs (Joireman and King, 2016) and to provide a better understanding of the present 3D-printed foods. The research proposes a conceptual model and investigates how consumers regard consumption of 3D foods under future consequences (such as technology that is still advancing), as trade-offs between immediate consumption (e.g., curious to eat 3D printed foods, considering them in their daily repertoire). Time orientation will assist in increasing the explanatory power of the model (Dassen et al., 2015).

Secondly, we aim to advance the findings of Study 1, we examine future acceptance and the mediating effects of healthy (naturalness) and hedonic (enjoyment) consumption values. These values can be viewed as trade-offs between time forecast and acceptance of 3D foods, likely to provide new theoretical and empirical insights (Olsen and Tuu, 2017). Lastly, we extend our investigation beyond acceptance by exploring the moderating effects of sensory-sensitive consumers within a multigroup setting. This approach is aimed at segmentation, leading to more effective strategies. Together, these efforts contribute to advancing knowledge and filling gaps within the 3D-printed food area, while also highlighting practical applications.

6.2. Theoretical background

Strathman et al. (1994)and his associates defined CFC as "the extent to which people consider the potential distant outcomes of their current behaviours and the extent to which they are influenced by these potential outcomes" (p. 743). They consider the immediate and the future consequences by proposing the construct termed consideration of future consequences (CFC), where an individual considers distant as opposed to immediate results of likely behaviors.

According to Strathman et al. (1994), people vary in how they think about future outcomes. Some individuals naturally focus on long-term benefits and are willing to give up immediate rewards, like pleasure or convenience, in exchange for future gains such as better health or status. Others, however, prioritize short-term benefits, even if it means ignoring future consequences. When it comes to 3D-printed food, people may view it through either a future-focused lens, a present-focused one, or both at the same time (Joireman et al., 2016).

Consideration of Future Consequences (CFC) has been widely studied and has shown strong relevance across a range of personal and societal behaviors (Joireman and King, 2016). Individual differences in CFC are known to predict important behaviors, especially those related to self-control (Joireman et al., 2016). Over time, CFC research has addressed key issues such as how to best measure the concept, its underlying structure, and how it applies to specific areas—particularly health-related decisions (Joireman and King, 2016). Importantly, both immediate and future-oriented thinking need to be considered, as these two dimensions predict different types of behavior. Moreover, researchers suggest that CFC is best understood and measured in relation to specific behaviors rather than as a general trait (Van Beek et al., 2013).

Olsen and Tuu (2017) examined how time orientation influences convenience food consumption, highlighting a significant relationship between Consideration of Future Consequences (CFC) and food-related behaviors, particularly health-conscious and organic food choices (Dassen et al., 2015; Olsen and Tuu, 2017). Their framework aligns with prior studies that distinguish between CFC-future and CFC-immediate orientations (Dassen et al., 2015). These temporal dimensions—whether individuals prioritize immediate or future outcomes—play a crucial role in predicting behaviors related to food consumption and physical activity (van Beek et al., 2013). Time orientation impacts health-related behaviours as well as the consumption of food (Tortora and Ares, 2018). Results indicate that future efforts must prioritize effectively communicating the significant health benefits of 3D food printing (Lanz et al., 2024).

6.2.1. Hypothesis development

Furthermore, research highlights that consumer empowerment, personalization of 3D food structures, the maturity of the technology, and its perceived appropriateness all contribute to greater acceptance of

3D-printed foods. When consumers are actively involved in the food production process, they feel more empowered. This engagement can enhance satisfaction and perceived control (Parizel et al., 2016), particularly when immediate benefits such as pleasure are anticipated. Additionally, studies on individual differences in time perspective suggest that future time orientation is a strong predictor of positive attitudes, engagement, and sustainable behaviours (Joireman and King, 2016). Building on this, we apply the two-factor framework of time orientation, CFC-future and CFC-immediate (Joireman et al., 2016) to better understand how perceptions of 3D-printed foods are shaped not only by current representations but also by expectations of future outcomes. This approach allows us to extend the discourse on consumer acceptance by integrating both immediate gratification and long-term benefit perspectives.

Given that the success of 3D-printed foods relies mainly on customer acceptance (Caulier et al., 2020), we expect that both CFC–future and CFC–immediate are likely to have a positive association with customer acceptance. It will also take time for this technology to reach its optimum, and we can expect that CFC's future orientation will potentially have a positive impact on consumer acceptance. Accordingly, the hypotheses are proposed:

H1a. CFC-immediate orientation has a direct positive effect on hedonic values.

H1b. CFC-immediate orientation has a direct positive effect on customer acceptance of 3D-printed foods.

H1c. CFC-immediate orientation has a direct positive effect on healthy values.

H2a. CFC-future orientation has a direct positive effect on hedonic values.

H2b. CFC-future orientation has a direct positive effect on customer acceptance of 3D-printed foods.

H2c. CFC-future orientation has a direct positive effect on healthy values.

6.2.1.1. Hedonic value. Hirschman's (1984) work suggests that hedonic value recognizes novel experiences at a cognitive and/or emotional level. Hedonic consumption is perceived as being individually driven and specific products serving as a means to a pleasurable end (Alba and Williams, 2013). Others consider hedonic experiences as being associated with arousal, pleasure, and emotion that is instinctive, while others view them as fantasies, feelings, and fun (Hirschmann and Holbrook, 1982). Attributes of 3D-printed food attributes such as health, fun, creativity, and natural content were found significant (Lee, et al., 2021). Hedonic benefits were found to positively influence willingness to pay (Califano and Spence, 2024).

Researchers also suggest the hedonic characteristics of food are pleasure, taste, and good sensory appeal, often characterized by their high sugar, fat, and salt. There are also some queries due to disgust and sanitation based on employing a printer to produce the 3D printed food (Lupton and Turner, 2017). Arguably, the critical motivator of consumers' attitudes toward 3D-printed food is the hedonic value. Furthermore, consumer values of eating out are separated into two factors, hedonic and utilitarian. Hedonic eating values are likely to increase the demand for 3D-printed foods, leading consumers to seek novel experiences on both cognitive and emotional levels.

Based on the regulatory focus theory, hedonic eating values are posited as mediators in the relationship between Consideration of Future Consequences (CFCs) and convenience foods (Higgins et al., 2001). The mediating role of hedonic eating values was examined from a time forecast, showing their influence on convenience foods through a mediating relationship (Olsen and Tuu, 2017). Before 3D printing food influences the food industry, consumer acceptance is required (Manstan et al., 2021). We can specifically posit that hedonic eating values will positively mediate the relationship between both CFC-future and CFC-immediate and customer acceptance, as per prior findings. Accordingly, we hypothesize as follows:

H3a. Hedonic eating values positively affect consumer acceptance of 3D-printed food.

H3b. Hedonic eating values mediate the relationship between CFC-immediate and consumer acceptance of 3D-printed food.

H3c. Hedonic eating values mediate the relationship between CFC-future and consumer acceptance of 3D-printed food.

6.2.1.2. Healthy values. Based on the regulatory focus theory, healthy eating values are also indicated as mediators in the relationship between CFCs and convenience foods (Higgins et al., 2001). The mediating role of healthy eating values was considered from a time perspective and their influence on convenience foods showed a mediating relationship (Olsen and Tuu, 2017). Since prior research provides support for mediation, we can specifically posit that healthy eating values will positively mediate the relationship between both CFC-future and CFC-immediate with customer acceptance.

Many researchers believe that moving the time focus from immediate benefits toward future outcomes is critical for enduring a healthy choice alternative (Hall and Fong, 2007). Studies have been conducted in several areas indicating when individuals have a future forecast, they are more than likely to exercise frequently (Adams and Nettle, 2009). Health values inspire consumers' interest in healthy eating and arouse hedonic and positive expectations. Understanding the concept of what constitutes healthy trends so future orientation can improve changes in health behaviour intervention and 3D-printed foods are likely to become conducive to a healthier lifestyle.

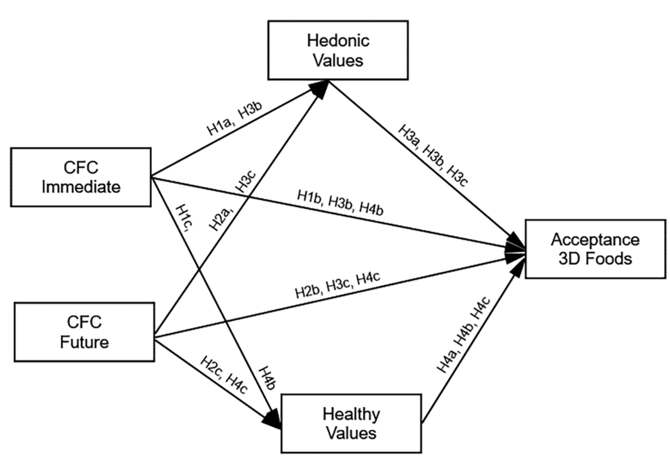
Allowing consumers to consider the design, and co-designing of products by involving in the production and adding the nutrient composition can lead to a higher expectation of healthy eating values, based on the above discourse, it is proposed:

H4a. Healthy eating values have a positive effect on consumer acceptance of 3D-printed foods.

H4b. Healthy eating values mediate the relationship between CFC-immediate orientation and consumer acceptance of 3D-printed foods.

H4c. Healthy eating values mediate the relationship between CFC-future orientation and consumer acceptance of 3D-printed foods.

Accordingly, we hypothesize the following model:



7. Methodology

The scale measures were taken from Olsen and Tuu (2017) who adopted hedonic eating values from Babin et al. (1994). Similarly, healthy eating values were derived from utilitarian consumption values and further adapted from several studies (Babin et al., 1994; Voss et al., 2003). Both these were measured by asking the question 'It is important to me that the foods I eat …'. The scales for CFC-immediate and CFC-future used the 12-item scale of Strathman et al. (1994) and were further refined. The moderating variable considered sensory sensitivity scales adopted from Steptoe et al. (1995), while visual sensitivity was taken from Barrena and Sanchez (2013), all were anchored on a Likert-scale of 1= strongly disagree and 7 strongly agree, apart from the food acceptance scale which is measured by 1= not at all and 7= absolutely very much.

A two-step approach was used; the measurement model examined the fit of the observed variables to the latent variables, whereas the structural model examined the hypothesized relationships (Arbuckle, 2011). Thus, using AMOS 28, we conducted a confirmatory factor analysis (CFA), to test whether the factors that were hypothesized supported the data well (Hair et al., 2017). Convergent and discriminant validity were also tested (Churchill and Iacobucci, 2002). The internal consistency of measures is indicated in Table 3. It shows that composite reliability (CR) is above 0.70, and for the average variance extracted (AVE), all values are above 0.50, both are within the recommended levels and confirm convergent validity (Hair et al., 2017).

Table 3
Study 2 - factor loadings, AVE and CR.

CFC-future AVE 0.50 CR 0.80	
I think it is more important to perform a food consumption behavior with important distant consequences	0.576
I am willing to sacrifice my immediate happiness or wellbeing in order to achieve future outcomes	0.615
Often I engage in a particular food consumption behavior in order to achieve outcomes	0.799
I consider how things might be in the future, and try to influence those foods with my day to day behavior.	0.82
CFC-immediate AVE 0.59 CR 0.90	
Since my day-to-day work has specific outcomes, it is more important to me than food consumption	0.623
I only act to satisfy immediate concerns, figuring that I will take care of future problems.	0.887
I think that sacrificing now is usually unnecessary since future outcomes can be dealt with…	0.776
I generally ignore warnings about possible future food problems because I think the problems…	0.668
My convenience is a big factor in the decisions I make or the actions I take.	0.722
My behavior is only influenced by the immediate (i.e., a matter of days or weeks) outcomes of my actions.	0.845
I only act to satisfy immediate concerns, figuring the future will take care of itself.	0.823
Hedonic Values AVE 0.53 CR 0.77	
It is important to me that foods I eat… give me exciting feelings when eating	0.676
It is important to me that foods I eat… are fun to eat	0.765
It is important to me that foods I eat… help me escape from my daily routines	0.746
Health Values AVE 0.71 CR 0.90	
It is important to me that foods I eat… give me a good health status	0.893
It is important to me that foods I eat… help me to control my weight	0.87
It is important to me that foods I eat… help me to avoid health issues	0.865
It is important to me that foods I eat… do not increase my weight	0.74
Acceptance AVE 0.77 CR 0.90	
I intend to have 3D-printed foods in the near future	0.899
I am interested in having 3D-printed foods	0.933
I favourably evaluate 3D-printed foods	0.795

7.1. Analysis

The analysis of the measurement model fit statistics indicated a satisfactory fit between the measurement model and the data (x2 = 382.861, df = 179, x2 /df = 2.139, CFI = 0.91, TLI = 0.902, RMSEA = 0.075). The x2 /*df* values are close to 1, showing a reasonable fit, while TLI and CFI values are above 0.9, representing appropriate-fitting models (Hair et al., 2017), RMSEA value appears to be less than 0.8, indicating a fair fit (Hair et al., 2017). Finally, both the relative fit index (RFI) and the incremental fit index (IFI) are below the benchmark of 0.95 (Byrne, 2010).

We further conducted the matrix multitrait-multimethod (HTMT) ratio as proposed by Henseler and Ringle (2015) where the ratio with a 0.85 cut-off needs to be considered as standard and this provides the most appropriate assessment for discriminant validity (Voorhees et al., 2016). In conducting our analysis, we found that all values are well within the threshold levels, which are regarded as 0.850 for strict and 0.900 for liberal discriminant validity met (Henseler et al., 2015). No warnings were declared for discriminant validity. The matrix multitrait-multimethod (HTMT) ratio with a 0.85 cut-off should be perceived as standard (Henseler et al., 2015). This demonstrates the best assessment for discriminant validity (Voorhees et al., 2016).

7.2. Findings

The findings of this analysis show that the path model estimates, and the Goodness of fit indices show that the model is of a reasonable fit. The Path estimates indicated (χ2 (1.007) *df* 1; the root mean squared error of approximation [RMSEA]=0.068; the confirmatory fit index [CFI]= 0.1.00; Tucker– Lewis index [TLI]=1.00, NFI 0.99; GFI 0.99 and AGFI 0.97. The model shows GFI, AGFI, CFI = 0.99; TLI, NFI are within the recommended level (Byrne, 2013).

The combined model path analysis as per Fig. 2 and shown in Table 4 three hypotheses were not significant H1c, H1b, and H4a. The following hypothesis was significant: H1a: CFC-immediate orientation has a direct positive effect on hedonic values ($\beta = 0.50$; $p < .001$); H2a: CFC-future orientation has a direct positive effect on hedonic values ($\beta = 0.32$; $p < .001$); H2c: CFC-future orientation has a direct positive effect on healthy values. ($\beta = 0.35$; $p < .001$) for which healthy values were slightly higher than hedonic values. Furthermore, H2b: CFC-future orientation has a direct positive effect on customer acceptance of 3D-printed foods ($\beta = 0.69$; $p < .001$), and similarly, H3a: Hedonic eating values have a positive effect on consumer acceptance of 3D-printed food ($\beta = 0.14$; $p < .001$).

To confirm mediation effects, a bootstrapping procedure of 5000 bootstrapping samples was generated in AMOS, selecting a bias-corrected bootstrapping method with 95 % confidence intervals to

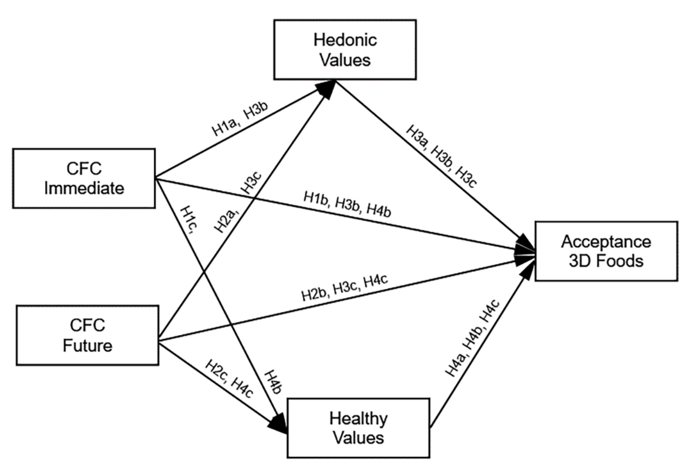


Fig. 2. Conceptualised model.

Table 4
Study 2 - estimates of the model.

			Estimate	S.E.	C.R.	P
Immediate	→	Hedonic	0.502	0.05	9.125	***
Immediate	→	Healthy	−0.12	0.085	−1.783	0.075
Future	→	Hedonic	0.323	0.06	5.882	***
Future	→	Healthy	0.359	0.103	5.344	***
Hedonic	→	Acceptance	0.141	0.109	2.443	0.015
Immediate	→	Acceptance	0.028	0.091	0.529	0.597
Future	→	Acceptance	0.694	0.105	13.449	***
Healthy	→	Acceptance	0.028	0.063	0.583	0.56

examine their significance. A statistical significance is inferred when zero is not contained in the 95 % confidence interval of the represented estimates. The results of the bias-corrected bootstrap test confirm the following (see Table 5). Healthy values mediation between CFC-immediate and CFC-future on acceptance for 3D- printed foods were not supported while the only two that were supported were H4b: Hedonic eating values mediate the relationship between CFC-immediate and consumer acceptance for 3D-printed food – supported and full mediation while H4c: Hedonic eating values mediate the relationship between CFC- Future and consumer acceptance for 3D-printed food were supported and showed a partial mediation.

7.3. Measurement invariance

To assess measurement invariance, it is recommended that configural, metric and scalar invariance tests are required to be conducted before testing for casual path invariance (Byrne 2013). It helps to meaningfully compare scores and have confidence in observed item differences (Steenkamp and Baumgartner, 1998). It is an estimated sequential process of comparing nested models (Byrne and Stewart, 2006). Through multigroup confirmatory factor analysis, configural weak factorial invariance was used to study model equivalence differences between cohorts (Steenkamp and Baumgartner, 1998). This was followed by metric or strong factorial invariance restrictive test whereby all factor loading is equally constrained between groups. The chi-square changes between the configural and metric model show evidence of equivalence, for example, the test of invariance resulted in a significant value in the change in χ^2 (37.5, Δ *df* = 21, *p, .01*). Since $\Delta\chi^2$ is criticized due to sensitive sample size, the Δ CFI (0.007) and ΔRMSEA (0) are below the 0.01 recommended cut-off level as suggested by Cheung and Rensvold, (2002). Thus, it is evident that with a degree of confidence, the model applies across cohorts and shows measurement invariance.

The research considers sensory appeal plays a key role in the enjoyment and satisfaction of the physical attributes of the experience in the way we connect with food to obtain that culinary experience. It stimulates the need to consume these foods and the experience behind them. In making food choices, sensory appeal appears to be a significant factor for European consumers and New Zealand consumers (Prescott et al., 2002). A sensory appeal can act as effective appetite stimulation, and attract food choices, and is challenging to consistently print appealing 3D- foods with sensory appeals (Scheele et al., 2022). Thus, food sensory evaluation is critical, and it is important for developing food products, marketing, and consumer acceptance.

Hierarchical cluster analysis is a method used to investigate relatively homogenous clusters based on objects founded on measured traits. Scales taken from Steptoe et al. (1995) and adapted to suit this study are the two scales that measure sensory preference based on *sensory sensitivity*: 3D-food must have taste, smell, texture and appeal, while *visual sensitivity* – it is important that 3D-foods look delightful to eat. Ward's method is popularly used as it provides informative findings through a high agglomerative coefficient and cluster sizes that are relatively evenly distributed (Tabachnik and Fidell, 2007). The study employed the use of hierarchical cluster analysis to identify the perceived importance of sensory preference that involved two scales sensory sensitivity and visual sensitivity anchored on two seven-point Likert scales. Ward's method and Euclidian distances were used to establish cluster numbers by examining the dendrogram and cluster coefficients that indicated a two-cluster solution. One-way ANOVA was used to test the significant statistical differences between the two cohorts showing differences between those that are high sensory (n = 95) and those that are low sensory sensitivity group (n = 106).

While highly sensory-sensitive food consumers found 3D-printed food acceptance and time-orientated significant, except for a negative influence on healthy values indicating with time, healthy values will also increase. In Table 6, in the case of low sensory-sensitive food consumers CFC immediate orientation was positively significant with hedonic values ($\beta = 0.54; p < .001$) and was higher than the high sensory-sensitive food consumers (β = 0.44; p < .001); Similarly, with low sensory sensitive food consumers it was found that for CFC-future orientation was positively significant with 3D-printed food acceptance (β = 0.76; p < .001) and was higher than high sensory sensitive food consumers ($\beta = 0.47; p < .001$). Furthermore, with low sensory-sensitive food consumers for CFC-future orientation with hedonic values (β = 0.27; p < .001) and healthy values both were positively significant (β = 0.31; p < .05) and lower than high sensory-sensitive food consumers for hedonic values (β = 0.41; p < .05) and healthy values (β = 0.45; p < .001). The chi-square was significant for CFC-future orientation with the 3D- printed food acceptance.

Table 5
Study 2 - standardised total, direct and indirect effects.

	Future	Immediate	Health	Hedonic
Health	0.359*** [.21, 0.49]	−0.12 [−0.24, 0.01]	0	0
Hedonic	0.323*** [.19, 0.43]	0.502*** [.38, 0.60]	0	0
Acceptance	0.749*** [.67, 0.81]	0.096 [−0.02, 0.09]	0.028 [−0.07, 0.12]	0.141* [.02, 0.26]
	Future	Immediate	Health	Hedonic
Health	0.359*** [.21, 0.49]	−0.12 [−24, 0.01]	0	0
Hedonic	0.323*** [.19, 0.43]	0.502***[.38, 0.60]	0	0
Acceptance	0.694*** [.58, 78]	0.028 [−0.07, 0.12]	0.028 [−0.74, 0.12]	0.141* [.02, 0.26]
	Future	Immediate	Health	Hedonic
Health	0	0	0	0
Hedonic	0	0	0	0
Acceptance	0.056* [.00, 0.11]	0.068* [.00, 0.14]	0	0

8. Theoretical implications

Our research makes three important theoretical contributions. Firstly, the present study considered the two-factor structure of time-related CFC-future and CFC-immediate on 3D-printed food consumption, given that there is an imperative need to research the contributions of CFC-future and CFC-immediate (Joireman et al., 2016; Olsen and Tuu, 2017). It answers research calls for using time-related situations (Van Beek et al., 2013), thus strengthening the validity by comparing the respective results.

Secondly, the study broadens the existing perspectives of both health and hedonic eating values. These mediating variables shed light on critical factors regarding health-related values and hedonic values. In previously held studies, the importance of healthy eating values was considered important with 3D printed foods, there is a violation of previously held studies or inconclusive findings when compared to previous results. CFC-immediate consequences were not significant in the combined model, where only hedonic eating value fully mediates the relationship between CFC-immediate and acceptance of 3D-printed foods. Hedonic eating values partially mediate the consequences of time-related future orientation acceptance of 3D-printed foods. While

Table 6
Study 2 - standardised estimates for combined model & sensory segments.

			Combined Model	S. E.	t-value	β (Low) Sensory	S.E.	t-value	β (High) Sensory	SE	t-value	Δ χ2
IM	→	HED	0.502***	0.05	9.125	0.544***	0.066	6.871	0.444***	0.07	5.944	0.344
IM	→	HY	−0.12	0.085	−1.783	−0.083	0.111	−0.83	−0.244**	0.12	−2.797	2.137
FU	→	HED	0.323***	0.06	5.882	0.279***	0.082	3.519	0.415***	0.08	5.568	1.696
FU	→	HY	0.359***	0.103	5.344	0.313**	0.137	3.132	0.454***	0.14	5.218	2.156
HED	→	ACC	0.141*	0.109	2.443	0.111	0.163	1.387	0.293***	0.15	3.68	2.079
IM	→	ACC	0.028	0.091	0.529	−0.045	0.129	−0.59	0.145***	0.12	2.006	3.234
FU	→	ACC	0.694***	0.105	13.45	0.767***	0.144	11.22	0.471***	0.15	6.212	10.845**
HY	→	ACC	0.028	0.063	0.583	0.018	0.098	0.284	0.163***	0.09	2.39	1.814

supportive of the literature, theoretically, it shows that hedonic values have a higher tendency to contribute to the prediction of consumer acceptance of these foods (Escalante-Aburto et al., 2021).

Finally, while the results make a theoretical contribution to the literature on time-related consequences of CFC-immediate and CFC-future 3D-printed foods, it also explores the moderating role between high and low-sensory-sensitive consumers, whereby, in comparison of the beta-values for high-sensory sensitivity consumers, both time-related consequences of CFC-immediate and CFC-future orientation were significant. In contrast to the supported moderating effect of low sensory sensitivity consumers, time-related consequences for immediate and future orientation for hedonic values were supported. However, only CFC-future orientation was significant for healthy values and acceptance.

9. Managerial implications

Several implications for practitioners and policymakers can be suggested. First, the study identifies a specific model that is predictive of behaviour forecasts (Olsen and Tuu, 2017). This is important because 3D-printed food technologies are likely to disrupt the retailing channels by decentralizing production. Second, as new business models emerge, understanding time orientation as to when to market and psychological variables can provide an insightful understanding of consumers' shopping behaviour and more effective strategies for involving food enthusiasts. This research shows that time orientation can provide practitioners involved with a further understanding of 3D-printed foods forecasts to hedonic and healthy eating values. It demonstrates that consumers require a focus on hedonic values forecasted for the immediate or the short term. This allows them to respond to consumer preferences, direct marketing efforts, and monitor diffusion trends much more efficiently to stay ahead of the competition. For future orientation forecasts, speed to market is of the essence here, and the speed at which this innovation occurs would depend on the 3D-printed food innovation characteristics. Since it is in the early stages of development, using Rodger's diffusion theory, practitioners can address the adoption model. Thirdly, although not significantly influenced by the CFC-immediate, CFC-future is contingent on the consumer's time orientation.

We recognize that health-related foods have been a major consideration for retailers with them responding to several issues such as front-of-the-label packaging systems to help shoppers identify healthier alternatives (Newman et al., 2014). Secondly, presenting a framework to increase sales of healthy foods (Wansink, 2017). With some of these issues in mind, retail practitioners should engage in the potential viability of addressing 3D-printed food technologies from a healthy perspective.

For instance, with this technology, user innovation is not limited, and consumers can increasingly engage in co-creation activities. Consumers can co-create with practitioners for specific information they would like on labeling to make healthy decisions. Retailers are in control of leveraging 3D-printed food technology to promote their flagship brands.

Fourth, practitioners can overcome customer skepticism regarding 3D-printed foods by directly targeting highly sensory-sensitive customers to purchase these foods since not only time orientation of CFC-immediate and CFC-future forecasts were significant for this group, but also hedonic and healthy eating values were found significant. Creating promotions for highly sensory-sensitive consumers to influence their stage of the purchase journey. They need to identify which types of platforms are most effective, use influencers to effectively promote their brand ambassadors, and offer different value-based propositions. To encourage low sensory-sensitive consumers to accept 3D-printed foods under the CFC-immediate orientation, practitioners need to educate consumers, as many consumers have rather low initial knowledge about 3D-printed food (Brunner et al., 2018).

10. General discussions

10.1. Discussions (survey 1)

Among the five factors related to the social representation of foods in the presence of perceived risk, only enjoyment did not emerge as a significant factor for intention to choose 3D-printed food. Perceived risk beliefs act as psychological resistance to all except H2, which revealed a negative relationship. Perceived risk must be considered because it appears to be a significant factor influencing consumer attitudes and behaviors toward food innovation, particularly 3D-printed foods.

Suspicion towards novelties showed a significant negative relationship with the intention to choose 3D-printed food. Resistance stemming from suspicion of novelties can be construed as a form of food-related anxiety (Beardsworth and Keil, 1997). This suspicion is strongly correlated with food neophobia and is consistently demonstrated as a salient dimension in social representations of food (Huotilainen et al., 2006). In our study, this dimension could be associated with doubts, resistance, and suspicion, specifically toward 3D-printed foods. This may suggest that consumers who experience anxiety toward unfamiliar food technologies may use avoidance as a coping mechanism (Wagner and Kronberger, 2001). Interestingly, other studies have also reported that the direct effect of adherence to suspicion on food choice intentions is not always significant (Lee et al., 2021). The observed negative effect in our findings may reflect that consumers with a preference for familiar foods are generally more risk-averse, potentially influenced by cultural factors, such as a resistance to change and heightened skepticism toward unfamiliar or unconventional food innovations.

Adherence to naturalness demonstrated a significant positive influence. This factor signifies the importance of nature, signals the importance of organic or healthy foods. Health can be closely related to naturalness and consumers' choices are notably influenced by considering the importance of naturalness (Roman et al., 2017). There is a greater affinity toward naturalness than toward synthetic food additives, which are perceived as potential risks (Siegrist and Sütterlin, 2017). Naturalness has consistently shown a positive relationship with consumer preference (Groot, 2018). The value consumers place on naturalness is also determined by their level of trust in the product or brand (Ross et al., 2022). This aligns with the commonly held heuristic that "natural is better," which often guides consumer decision-making (Scheele et al., 2022). However, some consumers may see 3D-printed food as innovative but not necessarily 'unnatural' if it can offer health or sustainability benefits, and thus positively influence 3D-food choices.

Several authors argue that 3D-printed foods represent not only an innovation but an urgent necessity (Tejada-Ortigoza and Cuan-Urquizo, 2022). Adherence to necessity showed a positive significance. Some envision 3D food printers becoming as commonplace as traditional kitchen appliances (Tran, 2016). Their necessity is further facilitated by their potential to support texture-modified diets for individuals with specific medical needs (Lorenz et al., 2022). However, this advancement may face resistance from individuals who strongly value traditional food norms, as they may perceive 3D-printed foods as a deviation from essential and familiar dietary practices. Adherence to technology has mixed results in the literature, showing adoption and rejection rates (Cardello, 2003). Our research shows adherence to technology has a positive significance to 3D printed food choice. Consumers who are comfortable with technology may have greater trust in the safety, quality, and benefits of 3D-printed foods. They may perceive fewer risks associated with 3D-printed foods compared to those who are less familiar with or sceptical about technological innovations in food production.

10.2. Discussion survey 2

The time-related 3D-printed food forecast was used to examine the mediating and sensory-sensitive roles of consumers. Strathman et al. (1994) initiated the consideration of future consequences (CFC) through which people consider the future of distant versus immediate consequences of potential behaviors, which were tested in this research. The research employed prior subscales to design a conceptual model for time orientation and its effects on Future (CFC-future) and Immediate (CFC-immediate) 3D-printed food acceptance. Mediating values and sensory sensitivity moderating values were also considered.

Our results show that CFC-immediate orientation had no significant relationship with acceptance of 3D-printed foods; however, hedonic values fully mediated CFC-immediate orientation and acceptance of 3D-printed foods. This is an interesting finding and receives much support in the literature. This research shows that Hedonic values also have a direct relationship with consumers' acceptance of 3D foods. Of caveat, researchers show that while characteristics of hedonic value are perceived to be a key choice by a majority of consumers, healthy eating values are often pursued (Dassen et al., 2015). Others have contended that during the consumption process, individuals utilize both hedonic and utilitarian values (Okada, 2005), and retail practitioners can persuade customers to choose from hedonic vs. utilitarian (healthy). There could be a situation when consumers are likely to consume 3D-printed foods for hedonic values if, at the same time, they can explain healthy eating values (Okada, 2005).

CFC-immediate orientation had no significant association with healthy values, this was a surprising result as 3D printing foods can personalize nutrition and can have significant health benefits (Manstan and McSweeney, 2020); one reason could be that consumers also differentiate between being Health Vigilant, Health Predisposed, or Health Disinterested (Wansink, 2017). They suggest that even though these values may be opposing, consumers are likely to consider them when making choices regarding 3D-printed foods, forming more generalist forecasts. Healthy values mediating influence on CFC-immediate and future orientation as well as consumer acceptance for 3D-printed foods had no significance while, while hedonic values mediating CFC-immediate and future orientation and consumer acceptance for 3D-printed food were significant, and there was full mediation and partial mediation on this relationship, respectively.

11. Future research and limitations

Future studies could consider the Theory of Planned Behavior and intention to choose 3D-printed food products (D'Souza, 2022). It is also important to explore customers' purchase decision-making process from a social learning perspective, which will help to leverage these foods.

Some limitations can be reported in both studies. Causation cannot be inferred as the data were cross-sectional. For causal modelling procedures, larger samples can be targeted. Combining additional constructs from various new food literature will improve the predictive power of the framework for practitioners. Constructs used for both studies consisted of multi-items which provided more robust and generalizable findings to complement our findings. Future research can also extend selective variables to enhance the robustness of our findings.

Given their greater readability, CFCs can be regarded as a better measure of time orientation. As 3D-printed food evolves, researchers may want to extend the number of items that measure CFC-immediate and CFC-future time orientation within specific segments without compromising on the readability of these sub-scales.

This study is likely to be the first to provide insights on the time-related empirical evidence significance of CFC-future and CFC-immediate orientation on hedonic and health values for explaining acceptance of 3D-printed food.

Ethics

Ethics approval sought through application number HEC23375 from La Trobe University.

CRediT authorship contribution statement

Clare D'Souza: Writing – original draft, Methodology, Funding acquisition, Data curation, Conceptualization. **Vanessa Apaolaza:** Methodology, Data curation, Conceptualization. **Patrick Hartmann:** Writing – original draft, Methodology, Data curation. **Outi Niininen:** Writing – review & editing, Visualization, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix: Demographics (Study 1, $N = 411$; Study 2 $N = 201$)

GENDER	Study 1 %	Study 2 %
Male	48.5	48.3
Female	51.5	51.2
Other	0	0.5
EDUCATION LEVEL		
Primary school	1.2	0.5
High school	24.8	20.4
TAFE/Technical certificate or diploma	31.9	28.4
University degree	30.2	37.3
Post-graduate degree or higher	11.4	12.4
Other (please specify)	0.5	1
AGE		
18–24	10.9	11.4
25–32	17	17.4
35–44	20.2	19.4
45–54	19	18.9
55–64	16.1	15.9
65+	16.8	16.9
EMPLOYMENT		
Employed full time	36.3	43.3
Employed part time	17.5	14.4
Self Employed	7.5	6.5
Unemployed	8	3
Retired	20.4	19.4
Student	1.9	6
Homemaker	8.3	7
Other	0.5	0.5
INCOME		
0-$24,000	9.7	10.4
$25,000-$49,000	25.5	20.4
$50,000-$74,000	22	19.9
$75,000-$99,000	20.5	19.9
$100,000 or greater	14.8	21.4
Prefer not to say	7.5	8
STATE		
Australian Capital Territory	9.7	2.0
New South Wales	25.5	37.3
Northern Territory	22	.5
Queensland	20.5	14.4
South Australia	14.8	8.5
Tasmania	7.5	2.0
Victoria	22	25.9
Western Australia	20.5	9.5
REGIONAL		
Metro	74 %	69.7
Regional	26 %	30.3

Data availability

The data that has been used is confidential.

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