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Food safety management systems: The role of cognitive and cultural biases in determining what is 'safe enough'

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ABSTRACT

Background: Food safety management systems (FSMS) are designed and implemented to control, and where possible eliminate, the potential food safety hazards associated with a product, and how food is produced, to ensure compliance with food safety legislation, retailer standards and/or private third-party certification standards. However, the design, validation, implementation and verification of FSMS can be subject to both conscious and unconscious bias that inform risk management and risk acceptance.

Scope and approach: The aim of this structured review is to firstly consider existing hazard analysis and risk assessment approaches to developing and implementing FSMS, and approaches to defining what is "safe enough' and, secondly to explore the role of cognitive and cultural biases in decision-making.

Key findings and conclusions: Cognitive and cultural biases can influence food safety assessment, FSMS design and perceptions, management and acceptance of food safety risk. A better understanding of their influence and how this informs scientific and lay approaches to hazard analysis and food safety risk assessment could provide more insight into how regulators, food business operators, staff and consumers assess and accept food safety risk.

1. Introduction

Food safety management systems (FSMS) are designed, validated, implemented and verified with the aim of controlling, and where possible eliminating, any potential food safety hazards associated with a product and methods of production to ensure compliance with food safety legislation, retailer requirements and/or private third-party certification standards. Multiple actors are involved in the management of food safety from field to fork, including farmers, the organisations that process, transport or store food, food service and food retail, and ultimately the consumer. Definitions of food safety reflects the potential of an agent to cause harm or adverse effects, which can be acute, occurring within a few hours or days of ingestion or contact with the agent, or chronic, as with carcinogens, where the health consequences for individuals can take decades to become apparent (Manning, 2017).

Hassauer and Roosen (2020) state that two types of assessments are necessary to determine the status of being 'safe food': firstly, the presence or absence of a food safety hazard which can be determined using a hazard assessment approach such as hazard analysis critical control point (HACCP), and secondly, the probability and severity of an adverse effect, which is established using a risk assessment approach. This differentiation between hazard assessment and risk assessment and the types of criteria on which such assessments are based has been considered across the food science literature (Wallace et al., 2014; Barlow et al., 2015; Manning et al., 2020). Food safety assessment tools such as HACCP use a defined approach, (seven principles of HACCP), to assess the likelihood of a food safety hazard occurring and the potential severity of its impact for a given product and its method(s) of production (Siegrist & Hartmann, 2020). Whilst applying HACCP principles involves an evidence-based hazard analysis, the decisions made during the analysis may be influenced by heuristics. Indeed, it is often lay people within food business operations (FBOs) rather than food safety experts who decide the likelihood and severity associated with different food safety events in food supply chains (Manning et al., 2019). These likelihood-based predictions, Manning et al. (2019) argue, are influenced by a range of personal and cultural biases and worldviews, or ways of 'seeing the world' (Masuda & Garvin, 2006; Siegrist & Árvai, 2020; Thaivalappil et al., 2023); which are based on an individual's or teams sensed proximity towards a given food safety event (Higashi et al., 2023). It is too simplistic to suggest that either experiential systems thinking or analytical systems thinking (Table 1) sit discretely in either the realms of the lay person or the expert specifically (Slovic et al.,

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Table 1
Comparison of two methods of thinking (Adapted from Slovic et al., 2004).

	Experiential systems thinking	Analytical systems thinking
1	Holistic	Analytical
2	Affective - pleasure-pain orientated	Logical – reason orientated
3	Associations inform connections	Logical connections
4	Behaviour mediated by "vibes" from past experiences	Behaviour mediated by conscious appraisal of events
5	Encodes reality in concrete images, metaphors and narratives	Encodes reality in abstract symbols, words and numbers
6	More rapid processing: orientated towards immediate action	Slower processing: orientated towards delayed action
7	Self-evidently valid "experiencing is believing"	Requires justification via logic and evidence

2004), especially when considering the activities of the HACCP Team (Codex, 2022).

Decision-making behaviour is affected by the dynamic aspects of the context in which the decisions are being made e.g., time pressure, level of uncertainty associated with the information available, feedback received on the effect of particular previous actions, and the trade-off between the cost and risk of an intervention and the risk associated with the status quo (Kerstholt, 1994). Heuristics are a type of cognitive bias that reduce complex mental tasks to simpler cognitive processes that are achievable for individuals to undertake (see seminal work Slovic et al., 1982), especially in situations where there are high levels of uncertainty and unpredictability. The cognitive dimension is important here, as many individuals working within FBOs will make decisions that are partly driven by logic, following the structured approach of the seven HACCP principles, but are also influenced by consciously acknowledged heuristics (e.g., affective feelings such as sympathy or antipathy, or liking or disliking), and heuristics operating unconsciously (e.g., for seminal work on priming effects see Kahneman, 2011). Consequently, the FBO managers' experiences, skills and expertise, indeed those of the whole HACCP Team, and the senior executives that provide resources for the operationalisation of the FSMS, are crucial antecedents and mediators of not only the risk-based decisions being made but also, how they individually, and collectively, attitudinally and behaviourally respond and frame business success and failure in the context of food safety (Amankwah-Amoah & Debrah, 2010; Higashi et al., 2023).

One suggestion is that a more holistic, systemic approach to delivering food safety may be more effective especially where different stakeholders have varied perceptions of, and degrees of willingness to accept, food safety risk (Houghton et al., 2008). The literature also highlights the need to consider both direct causal and wider contributory factors that can lead to a food safety incident (see Oleo et al., 2024; Soon-Sinclair et al., 2024). The promissory narrative of food that is sold or being prepared as 'being safe' is reframed with contexts such as being "safe for everything we have tested for; safe for everything we know about." Indeed, some have suggested that dominant cultural biases can strongly influence risk assessments, shaping what those making decisions, often on behalf of others, determine is 'safe enough' (Rayner & Cantor, 2018). Similarly, cognitive biases may affect the decisions made by individuals tasked with assessing risk (Montibeller & Von Winterfeldt, 2015). As a result of these biases, even when businesses are fully compliant with their FSMS, there is always a residual level of food safety risk, since decisions around what is considered 'safe enough' can be influenced by subjective factors (Oleo et al., 2024; Zwietering et al., 2021). This paper focuses on how to contextualise how 'safe enough' is determined in a range of food production contexts and provides examples to illustrate the argument that is put forward.

The aim of this structured review is to firstly consider existing hazard analysis and risk assessment approaches to developing and implementing FSMS, and in particular approaches to defining what is acceptable as being "safe enough' and, secondly to explore the role of cognitive and cultural biases on food safety-related decision-making. Seeking to address this aim provides the novel contribution of this paper. The paper is structured as follows: Section 1 is the introduction; Section 2 explores how conventional and relational thinking influence food-related risk assessment and management, and Section 3 explores cultural and cognitive biases in the context of food safety risk assessment. Section 4 provides a critical reflection on the findings and Section 5 concludes the paper and positions four research questions for future research.

2. Conventional thinking or relational thinking in food safety assessment and management

Scientific or technical decision-making tools are based on rules, logic, or mathematical calculation, and derive a prescribed measurement of risk through using rational criteria and analysis. However, rational-based decision-making is bounded by factors including uncertainty, imperfect data, lack of knowledge of potential alternatives, and an inability to quantify the impact or potential consequences, i.e. there is a bounded rather than perfect rationality that contextualises such decision-making (Manning et al., 2019; Simon, 1979). Efficient decision-making, judgments and predictions require reliable information about events and future outcomes that are often uncertain. Some argue that a divergence in risk perceptions between experts, other stakeholders and the wider general public is due to differences in levels of rationality, knowledge, education, levels of stress and a lack of understanding by the general public of complex scientific and technical information (Phillips-Wren & Adya, 2020). Therefore, one viewpoint is that if individuals just listened to experts and/or were given more information, more 'education,' then they would improve their personal decision-making, ultimately reaching the same conclusions as the experts (van der Vossen-Wijmenga et al., 2022) i.e. they would hold the accepted beliefs or views that are considered to be true, often described as 'conventional wisdom.'

2.1. Conventional thinking and relational thinking in risk assessment and risk management

Conventional wisdom aligns with accepted, or acceptable, risk profiles and is only contested, challenged, confounded or re-evaluated when new evidence emerges. This is evident in academic fields associated with harms, such as the wider medical field, where new theories or expositions may, over time, become accepted knowledge and conventional wisdom. Conventional thinking can overlook the human response to a perceived harm and how that human relational response then reshapes the harm itself, as was shown, for example, in the Covid-19 pandemic when the virus itself responded to the human behaviours that occurred producing new variants of concern (Eyster et al., 2023). As Eyster et al. state, it is not only humans that have agency, there are also many interdependent agents (see Nash, 2005), that continually co-create each other and the world in which they exist, and to ignore this creates 'false certainty.' This means that if the analytical and predictive modelling of a given microbiological harm does not firstly, keep pace with the relational response of the humans affected and secondly, the impact of the relational response to the pathogen on humans' behavioural response, then the modelling approach will quickly lose its predictive power. Indeed, Afzal et al. (2022) argue modelling that informs policy has limitations as "some aspects like political and societal issues and cultural and ethical standards" are hard to characterise and multiple assumptions can be incorporated within these models where data is not available/is uncertain or where data is available but there is a risk of data bias which could impact on the efficacy of the model.

Reductionist methods, Eyster et al. (2022, p.464) argue are useful tools (e.g. the HACCP approach at food business operator (FBO) level) for "operationalising relational thinking as long as temporary 'reductions' coexist with an ongoing reflection and adaptation about which relationships [between interdependent agents] should be targeted, at which spatial and temporal scales, and how these decisions are shaped by our relationships with our study systems." Operationalised relational thinking has been determined in this research as food being determined as 'safe enough.' How safe is safe enough?' is not a new question in the risk assessment and psychology literature. The concept of 'safe enough' and how it can be determined has been a theme of the literature for over half a century (Fischhoff et al., 1978). However 'safe enough' is being reconsidered in more recent literature in terms of reducing and valorising food waste and by-products (Socas-Rodríguez et al., 2021); heavy metals in insect based products (Gori et al., 2025); and cultured meat (Siddiqui et al., 2022). Reflexive governance structures, for example, where artificial intelligence (AI) could be used to make autonomous decisions associated with food safety management, could be of value in determining multi-stakeholder perceptions of 'safe enough,' and it is important scientifically, and ethically critical, to embed governance aspects within risk assessment, risk management and risk acceptance processes (Manning et al., 2023). Whilst this paper is not focused on responsible innovation per se, exploring the role of heuristics in anticipatory and reflexive cognitive processes is of interest, as well as how they inform the framing of 'safe enough.'

When considering application of AI more generally Lazar and Nelson (2023, p. 138) state that "a sociotechnical approach emphasizes that no group of experts (especially not technologists alone) should unilaterally decide what risks count, what harms matter, and to which values safe AI should be aligned." This argument can be extended to consideration of all food safety hazards and potential food-related harms. Rather, it would be better to position that individuals make risk ranking decisions using cognitive processes that can be conscious or unconscious, biased or unbiased, and it is the nuances of these processes that inform the actions and outcomes of risk assessment and the determination of risk acceptance. In this context, conventional thinking emerges in different forms especially when relationships between different agents are fluid and dynamic (Eyster et al., 2023). Eyster et al. (2023, p. 459) argue that:

> "When the prediction space and observation space are similar, conventional thinking may be sufficient …. However, conventional thinking may fail when applied to a different relationship. And such relationships are changing quickly (e.g. due to climate change, COVID-19). Misunderstandings can be mitigated by acknowledging both the relational basis of observations and the uncertainty related to extrapolating conventional understandings without considering changing relationships."

As an explanatory example, climate change and its predicted impact on food safety is complex due to the range of hazards that could arise, emerge or change and the interconnections between the different factors of influence (Maggiore et al., 2020). Additionally, there is a high level of uncertainty regarding the changing nature of relationships between multiple agents.

A changing climate will require changes to accepted good aquaculture practices, good veterinary practices (GVP), good agricultural practices (GAP), good manufacturing practices (GMP) and good hygienic practices (GHP) (Jacxsens et al., 2010; Tirado et al., 2010; Uyttendaele et al., 2015). Jacxsens et al. (2010) suggest that mitigation of climate related food safety hazards is hampered by a lack of effective control measures and quality assurance (QA) guidelines, lack of scientific data for risk assessments on emerging pathogens, a lack of insight into the effectiveness of FSMS and a lack of scientific underpinning of existing FSMS. Tirado et al. (2010) identify a range of adaption strategies including intersectoral coordination, integrated surveillance and monitoring, data and information exchange, risk assessment and predictive modelling, improved detection methods and use of new technologies, investing in scientific and technical capabilities, good practices, risk management guidance, emergency preparedness, contingency planning, early warning and emergency response. What kinds of hazards could emerge, will they be more likely and more severe? Existing literature has considered impact on the dairy supply chain (Van der Spiegel et al., 2012); drought and evapotranspiration causing higher concentration of contaminants and pathogens in surface water (Jacxsens et al., 2010); flooding causing contamination of soils (Kirezieva et al., 2015), especially heavy metals such as arsenic (Tirado et al., 2010); increased incidence of parasites, viruses and fungi that are harmful to animals, plants and public health (Maggiore et al., 2020); changes to levels of anti-nutrients in plants e.g. oxalate, phytate, tannin, saponin or phenols; and greater mycotoxin production (Lennon, 2015; Tirado et al., 2010). These changing factors will test conventional thinking on food safety and prevention, and mitigation of food safety risk. This fluidity of the scope of food safety hazards, their likelihood and potential severity informs how we undertake hazard analysis and risk assessment in this context? How will new conventional and relational governance emerge?

Relational governance extends beyond transactional, contractual and market-based governance and encompasses governance through relationships, trust, social interaction and cooperation (Claro et al., 2003; Nguyen & Jolly, 2020). Relational governance has been previously explored in the food literature (Han et al., 2011; Nguyen & Jolly, 2020), but this research considers cognitive and cultural biases and heuristics in particular. Ahlqvist et al. (2020) provides examples of relational governance mechanisms that build trust and social engagement with a specific issue including.

- establishing teams, working groups and committees;
- mechanisms for co-creation and shared decision-making; and
- processes for information sharing and problem solving.

The interaction between conventional and relational governance within FSMS development and implementation can be explained through consideration of risk assessment approaches and design of verification activities. In terms of risk assessment, scoring or rating systems based on conventional thinking often appear objective, as they provide quantitative guidelines for interpreting risk ratings. However, the number-based ratings assigned during risk assessment are inherently subjective and it is likely that individuals assign these ratings based on different criteria. These approaches are often repetitive in nature, with previous risk assessments serving as examples or templates resulting in anchoring, as individuals may base new risk ratings on old ratings, rather than objectively assessing the risk themselves in the given contemporary context (Qiu et al., 2024). Rules of thumb guides too are based on conventional thinking and can be subject to cultural bias such as confirmation bias or availability bias (Table 2).

Checklist based verification (audit systems) may be technically correct and demonstrate the level of compliance or non-compliance with FSMS requirements and certification criteria, but they are open to a range of biases such as sampling bias, anchoring bias and omission bias. Thus, aspects of food safety issues may not be identified within an inspection or audit simply because they are not on the list

Table 2
Examples of risk based heuristic tools that can be applied to food safety risk assessment (Adapted from Kahneman & Tversky, 1982; Peters et al., 2004; Manning & Soon, 2014).

Risk assessment approaches	Type of potential bias
Checklist based audit systems	Prescribed checklists based on conventional wisdom and existing normative standards can create sampling bias, omission bias and checklist myopia. The approach can also create anchoring bias where only specific documents or data are assessed.
Rules of thumb	Guides based on accepted practices that have evolved over time can be influenced by the affect bias, what is considered good practice, availability bias and confirmation bias.
Scoring or rating systems	Numerical bias as a result of weighting systems used. Numerical bias, Probability bias, Anchoring to rating provided in examples and previous assessments.

(Flores-Miyamoto, Reij, & Velthuis, 2014). As the climate-change related example herein shows with emergent hazards or dynamic aspects of risk, where likelihood and/or severity of the risk may change, a more holistic approach to food safety is required.

2.2. Risk assessment and risk management: a techno-social process

Risk is rarely determined in isolation from social relationships and emotions. In social representations, a risk can be associated to an emotion as part of the communication process e.g. linking climate change to food safety, or to emotions of worry, fear or anger i.e. fear appeals. Fear appeals are a "*discursive practice used to accelerate the implementation of greenhouse mitigation policies*" using signals of peril, Armageddon, crisis or catastrophe (Janković & Schultz, 2017, p. 29). Fear appeals depend on firstly, individuals and communities believing that a threat is serious and salient, and secondly, that those individuals and communities also believe there is something they can do themselves (self-efficacy) to mitigate, adapt to, or eliminate the threat (Hunter & Röös, 2016), e.g. not purchase and/or consume the product. Despite the widespread use of fear appeals, Smith and Leiserowitz (2014) indicated that worry as an emotion was the strongest predictor of support for policies or action, more so than fear, perhaps because fear is an immediate and more transient emotion, and it can interfere with and reduce cognitive and analytical processing of risk information. Alternatively, worry as an emotion, they suggest, motivates cognitive and analytical processing of risk information and ultimately recalibration. Thus, in terms of risk assessment there can be a contested space between acting on scary warnings intended to persuade, and rational precautions framed by the degree of certainty that surround them (Ruiter et al., 2001). Considering the risk communications surrounding Covid-19, Stolow et al. (2020, p. 531) stated

> "*Fear appeals, also known as scare tactics, have been widely used to promote recommended preventive behaviours. We contend that unintended negative outcomes can result from fear appeals that intensify the already complex pandemic and efforts to contain it … … We are concerned that fear appeal approaches for COVID-19 may not only be ineffective at changing behaviour, but additionally harmful by exacerbating already existing stressors of the pandemic, thus leading to a backlash of unanticipated, negative, reactionary behaviours.*"

In the food context, the use of fear appeals has been linked to the production and sale of genetically modified organisms (GMOs). Indeed, with regard to genetically modified foods, studies suggest that fear and anger play different roles where fear was associated with health-related concerns with consumption of the food itself, and anger was associated with concerns over the operations of the 'market' (Immonen & Luomala, 2017).

Studies have considered the interaction of fear appeals and food safety identifying that fear appeals influence the effectiveness of food recalls and purchase intention i.e. fear perception of the use of chemical pesticides influences purchase intention for organic food (Chou et al., 2020), what Zhang and Zhou (2019) describe as the interaction between fear appeals and perceptions of the efficacy of protective behaviours. Social representations drive collective meaning-making and common cognitions producing social bonds that unite organisations and groups based on dialogues, discourse, emotions, attitudes and judgments (Höijer, 2011). In the context of food safety, social representations may bound and inform the application of HACCP principles, the implementation and verification of the FSMS and the associated individual and collective decision-making that occurs (Manning et al., 2019). Perceptions of these interactions between principles, FSMS and the socio-technical interactions of food safety culture and food safety climate frame our understanding of food-related risk management, in the present and how these perceptions have evolved over time (Manning et al., 2019; Sharman et al., 2020).

Whilst risk assessment may appear objective, in reality all forms have a large component of subjective judgment (see seminal work of Slovic et al., 1981). Slovic (1999) differentiates between experts, who tend to characterise risk as "real" using objective, analytical and rational criteria, and the general public, who perceive risk in terms of subjective, value based, hypothetical, intuitive and irrational criteria. This divergence often leads to polarised viewpoints with regard to risk perceptions, risk acceptance and risk management strategies. Lay people, rather than experts often rely more on cues from experiences and observations rather than being informed by scientific evidence especially when risk communication strategies are weak.

Psychological, social, and institutional factors influence risk perceptions and associated behaviour(s) through a network of socially mediated formal or informal communication channels (Masuda & Garvin, 2006). These channels can act to amplify or to attenuate perceived risk. Risk amplification is the socio-political activity that amplifies the risk perception from the viewpoint of experts who may deem the hazard to be low risk to a point where there is raised awareness and concern within wider society (Kasperson et al., 2003). Risk signals are filtered through social amplification stations such as individuals, institutions, the media or non-governmental organisations (NGOs) who can amplify or attenuate (reduce) risk signals (Masuda & Garvin, 2006).

Peters et al. (2004) argue that whilst in business, risk and benefit are often positively correlated i.e. the greater the risk the greater the return, conversely they are negatively correlated in the minds of the public suggesting that an affect heuristic plays a role in risk assessment i.e. a combination of what people think and what they feel. Therefore, risk assessment and resultant reactions could be based, via an affect heuristic, on perceptions of which stakeholder(s) is set to benefit and which is liable to take the risk e.g. a new technology might be seen by the general public as providing the greatest benefit to business and corporations and the highest risk to consumers especially where there is associated uncertainty in terms of safety information, but for corporations the technology could be perceived as low risk in terms of investment opportunities and economic return. This puts pressure on regulatory authorities being asked to approve such novel technologies (Gu et al., 2023). Whilst some culturally and cognitive orientated risk assessment biases have been considered in this section, the next section considers these in more depth.

3. Cultural and cognitive biases in the context of food safety risk assessment

3.1. Cultural biases

Research suggests that cultural aspects such as gender are of influence. Males tend to judge risk as smaller and less problematic than females with white males consistently ranking risk lower i.e. having higher risk acceptance than other demographic groups, leading to a description of "the white-male effect on risk perception and the white male response" (Slovic, 1999). Kahan et al. (2007) proposed that the "white male effect" might primarily derive from the congruence between hierarchical and individualistic worldviews, and a position of extreme risk skepticism or insensitivity to risk. Finucane et al. (2000) in their study concluded that white males were more hierarchical and individualistic and less fatalistic and egalitarian, more trusting of technological hazards and less trusting of government. Trust, therefore, is an important heuristic that mediates perceptions of benefit and risk (Siegrist & Hartmann, 2020). Albeit that this research was twenty-five years ago and cultural framings of what it is to 'be a white male' may have evolved, industry sectors that predominantly employ this demographic group as senior executives may as a result see a differentiation in how risk acceptability is assessed and mitigated at senior executive level where it is predominantly 'white male' compared to a more diverse wider society. Contemporary research on the role of gender in mediating individuals' risk approaches to Covid-19 found females perceived risks as higher than males but that women had better coping mechanisms in Pakistan (Rana et al., 2021), and Spain (Rodriguez-Besteiro et al., 2021). Although other studies found gender had less influence compared to other variables such as education in Germany (Rattay et al., 2021) and in China (Ding et al., 2020). Kahan et al. (2007) found that risk perception(s) reflects a form of *motivated cognition* through which individuals seek to deflect any potential threats to the roles and positions they occupy, the identities they hold, and societal organisational structures i.e. they are motivated to reject contested social norms that could threaten them and their status. Identity-protective cognition, they assert, considers that the individual making decisions as being part of a group will drive their sense of esteem or status and so challenging group beliefs (conventional thinking) may threaten personal standing within that group and infers a reduction in social perceptions of their competence the potential of becoming an 'outlier.' Thus where an individual can reason, analyse, appraise information and determine risk in line with group norms this drives ongoing self-preservation and on-going group membership, status and group survival. Thus, a dominant group heuristic can be formed which influences how information is processed and how the associated risk profile is derived, amplified or attenuated. Dake (1991) states that cultural biases, such as hierarchism, fatalism, individualism and egalitarianism are predictive of risk ranking and risk taking at the societal level. This suggests an association between cultural bias and wider social relations but van der Linden (2015) positions that considering the values that are held is a better approach (see Owoloja & Manning, 2024 for a wider exposition). Cultural biases that influence risk judgments have been synthesized as part of this research (Table 3) and four in particular were drawn together by Johnson and Swedlow (2019) see Fig. 1. Cultural theory considers the influence of two social dimensions group aspects of "us and them" and grid aspects of the degree to which behaviours are prescribed and decisions are bounded.

Searching for research published in the last five years that had considered the four cultural biases put forward by Dake in association with hazard analysis, and food safety risk assessment identified no

Table 3
Cultural bias that influences risk judgment (Adapted from Slovic, 1999; Leiserowitz, 2003; Peters et al., 2004; Kahan et al., 2007).

Cultural factors	Definition
Affect	Feelings of good or bad
Communitarianism	Feelings of depending on others and promoting values of solidarity as opposed to the individual.
Data source	Feeling that sources of bad news have more credibility than sources of good news.
Dread/fear	Feeling of the extent of perceived lack of control, and perceived catastrophic potential and the inequitable distribution of risk and benefit.
Egalitarianism	Feeling that there should be equality of power and wealth, with limited prescription and social boundaries and this influences judgment.
Emotivism	Consideration of right and wrong as a subjective, emotional response. Affect can be seen as positive or negative towards a given risk.
Fatalism	Feeling that as an individual you have very little control over a given risk i.e., they lack autonomy. This worldview has notions of determinism and preordination.
Hierarchism	Feeling that decisions about a given risk should be left to experts. This worldview has notions of position, power, command and obedience.
Individualism	Feeling that there should be individual benefit, and this influences judgment. A form of egoism i.e. that a person is self-made, free to behave as they want. This reflects that a risk assessment outcome should be agent-relative i.e. of value to the individual
Prescriptivism	Consideration that you should do what I require you to do.
Technological Enthusiasm	Feeling that technology is important to reduce risk
Unknown	Feeling as to the extent to which the issue is perceived to be unobservable, unknown new or delayed in producing harmful effects.

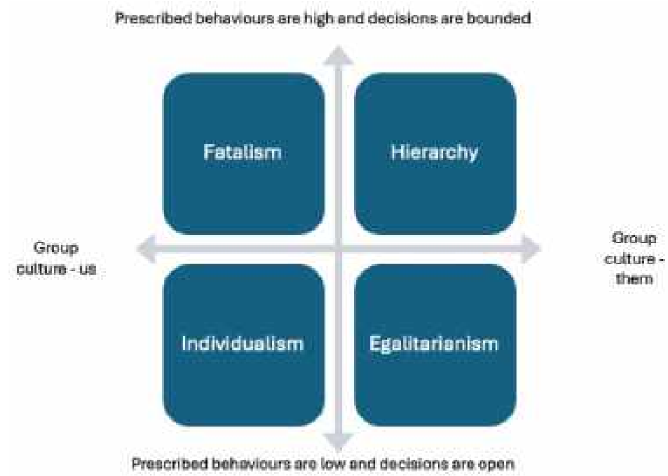

Fig. 1. Interaction of cultural biases (Adapted from Johnson & Swedlow, 2021).

explicitly focused work in this area. In summary, cultural biases i.e. the tendency to judge others, their attitudes and their behaviours in terms of one's own cultural assumptions and values will frame what is determined as safe enough in a given context.

3.2. Cognitive biases

With the crucial role of hazard analysis, the development of FSMS, and the undertaking of risk assessment, analysis, and effective management, further exploration is needed into how cognitive biases influence both positive and negative outcomes, particularly which types of biases affect specific contexts (James et al., 2023). Cognitive biases impact risk perception and decision making, but to date there is limited research specifically examining their impact on food safety-related risk perception (Shan et al., 2019). Cognitive biases have the potential to distort perceptions and associated attitudinal and behavioural responses to a given event or information (Gifford, 2011). The likelihood of cognitive biases impacting a food safety-related risk assessment decision is influenced by aspects such as *uncertainty* - assuming risk is not substantial due to uncertainty about information; *numbness* - assuming risk is not a factor due to a sense of limited immediacy; *discounting* - undervaluing distant or future risks; *optimism* - risk perception based on an optimistic outlook; and *ignorance* - not knowing that a problem even exists (Gifford, 2011). Thus dread, catastrophic potential, controllability, equity, and longevity (risk to future generations) are criteria of influence when humans individually, or collectively, assess risk (see seminal work of Slovic, 1999; Peters et al., 2004). Heuristics influence risk perceptions and risk assessment, but there is limited evidence to show when, where and how they are applied (Siegrist & Árvai, 2020), especially with regard to food safety. Thus, cognitive processes influence the application of food safety assessment tools, such as HACCP, and the extent to which their effectiveness is optimised (Thaivalappil et al., 2018).

Biases and heuristics can be considered as being "decision rules, cognitive mechanisms, and subjective opinions people use to assist in making decisions" (Busenitz & Barney, 1997, p.12). Whilst heuristics are often used to reduce complex mental tasks to simpler processes, their application influences the validity of those cognitive processes and can also drive deep and persistent biases (Slovic et al., 1982). Heuristics are often used during cognitive appraisal to form judgements on a complex situation. Affect refers to the positive or negative feelings that a person holds towards an external stimulus, whether cognitive or experiential, and constitutes a key component of cognitive appraisal (Peters et al., 2004). However, it is worth noting that cognitive appraisal includes more than just valence; it often involves broader emotion-based assessments associated with fear, dread, anger or happiness. Karasawa (1995) suggested five intuitive, automatic dimensions of cognitive appraisal: *causation* (responsibility and agency via self, others or chance); *coping* (ability to control and ability to adjust), *importance* (including relevance), *pleasantness* (positive or negative affect), and *predictability* (expectedness or certainty) – see also Table 1.

Individuals use the availability heuristic as a cue to determine likelihood or frequency of an event if it is easy to recall or imagine (Pachur et al., 2012; Slovic et al., 1982) i.e. *it is known*. Therefore, it could be argued that repeated reflection and consideration of a given hazard, even if it is hypothetical and there is no evidence it could occur, or the consideration is aligned with an emotive narrative, could as a process in itself make individuals imagine the hazard as more easily actualised and thus by inference believe the likelihood of it occurring to be higher than it actually is in reality. This means that via the availability heuristic some food safety risks could be seen as particularly familiar or salient, regardless of their actual likelihood or the severity if they did occur (Siegrist & Árvai, 2020). This would suggest that for hypothetical or very rare events, perceived risk could be biased, and the HACCP team could over-estimate the likelihood of occurrence, whereas the likelihood of events which are more difficult to recall or imagine occurring may be under-estimated (Slovic et al., 1982), perhaps influenced by optimistic bias (James et al., 2023). The availability heuristic demonstrates the role of experience as a cognitive determinant of how risk is perceived and ranked. Thus environment, culture and the experience derived as a result will all bias risk perception (James et al., 2023). Indeed, misleading personal experiences may promote either a misplaced heightened sense of fear or dread, or alternatively a misleading false sense of security with respect to the availability heuristic (Slovic et al., 1982). Therefore, availability as a heuristic could, for example, lead to an individual's over-estimation of food safety risk associated with the presence of pesticides, even if it is present at parts per billion in a given food, or alternatively, under-estimate the health risk of diabetes or heart disease associated with ingredients in the said food that are present in much higher proportions, or contamination with pathogens (Yu et al., 2018).

Representativeness reflects the degree of generalisation drawn from a limited sample set, whether constrained by size or specific characteristics, which may or may not accurately reflect the broader population. This heuristic is used by people when resources (time, knowledge, people etc.) are limited and a more systematic sampling approach is not possible. This has been described as the knowledge deficit model (Siegrist & Árvai, 2020). The heuristic relies on previous experience in similar situations to interpret how the data from a sample population can be extrapolated to the whole population, for example, annual pesticide residue testing for products that are received at the factory every week of the year. Assessing representativeness relies on using cognitive filters such as similarity, stereo typicality, or commonality to evaluate the relevance of past experiences, whether direct or indirect. Again, this paper will not include an exposition on different types of sampling strategies, but these do have implications in terms of the representativeness of the findings.

The anchoring and adjustment heuristic involves focusing a decision on an initial reference point, such as a rating provided in a previous risk assessment, which can influence the accuracy of subsequent judgements and beliefs (James et al., 2023). Once beliefs are established through this process, they often become resistant to change, even in the face of contradictory evidence. Instead, the new evidence is often dismissed as unreliable, erroneous or unrepresentative rather than the established belief system being revised (Fischhoff et al., 1982; Slovic et al., 1982). Slovic et al. (1982) describe the heuristic of overconfidence, for example in established belief systems, as being "pernicious" and where an individual may have too much confidence in their ability to make judgments or decisions. This is often driven by a cognitive inability to be precise, to be guided by relevant data or to judge the validity of the assumptions made. Further, experts may be overconfident, believing that they have never experienced, nor would never personally experience, the effect should the hazard present itself in the future.

Existing research has considered the interaction of cognitive bias and food safety assessment including optimistic bias in the context of food producers (de Andrade et al., 2019; James et al., 2023; Joomun et al., 2024), and food consumers (Batista et al., 2024; das Neves et al., 2024). These cognitive biases are summarised in Table 4. Optimistic bias tends to make individuals believe that the risk is less likely than in reality (James et al., 2023; Siegrist & Árvai, 2020). James et al. (2023) in their research extended the range of biases they considered to include: anchoring effect, confirmation bias, habit, illusion of control, omission bias, optimistic bias, outcome bias, and self-serving bias and call for further research in this area.

In summary, multiple heuristics, in particular the affect heuristic, availability heuristic (related to tasks, subjects and explanations), representativeness heuristic, anchoring and adjustment of explanations and overconfidence in the context of food safety, will influence effective risk management approaches and perceptions of what is safe or unsafe, and what is likely or unlikely to occur. Whilst there is the potential for risks to not be identified at all by the HACCP Team (missed hazards), it is aspects such as not having a suitable technical resource, not considering the risk of cross-contamination, nor adequately understanding the significance or likelihood of hazards occurring in a given context or having insufficient resources to implement the FSMS designed that leads to weak FSMS (Manning et al., 2019; Wallace et al., 2014).

4. Discussion

Compromises or trade-offs are central to risk-based decisions associated with the level of resources available and their influence on the design and implementation of FSMS. Examples of such trade-offs include weighing the cost versus the potential risk, cost versus time

Table 4
Types of cognitive biases associated with food safety assessment and food control (Adapted from: Cogan, 2015; De Andrade et al., 2019; James et al., 2023).

Bias	Description
Anchoring effect	Individuals rely on an initial piece of information or data more than information that follows.
Availability	The availability heuristic demonstrates the role of experience as a cognitive determinant of how risk is perceived and ranked (Fischhoff et al., 1982). Thus environment, culture and the experience derived as a result will all bias risk perception.
Confirmation bias	Individuals use information that confirms their existing beliefs and perceptions and ignore other evidence which could be contrary.
Habit	The frequency, regularity or routineness of a practice or activity of an individual(s) which then due to its regularity informs the behaviour of the future and their perception of the likelihood of risk.
Illusion of control	Individuals tend to overestimate how much the controls they have in place (the FSMS) deliver safe food even if this is in fact governed purely by chance.
Numerical bias	Individuals are impacted by numerical bias where the methods used to gather and analyse data creates a bias. Examples include sampling bias, selection bias and representativeness.
Omission bias	Individuals perceive a food safety risk associated with a specific action more negatively and potentially as more harmful than a food safety risk associated with an omission.
Optimistic bias	Individuals underestimate the likelihood of a negative event occurring so ignore or downplay risk warnings or are less motivated to take precautions necessary to assure/ensure safe food.
Outcome bias	Individuals perceive a food safety risk based on the outcome rather than the quality of the decision at the time it was made. This could also be described as hindsight bias.
Self-serving bias.	Self-serving bias makes individuals overly confident in their assessment of the likelihood of a negative event occurring as they believe they are better and more skilled that others and less likely to use optimistic bias.

(Monghasemi et al., 2015); benefit versus harm (O'Connor et al., 2003); speed of response versus accuracy (Franks et al., 2003; Häubl & Trifts, 2000), effort required versus accuracy (Häubl & Trifts, 2000); and effectiveness of intervention versus safety (Kim & Lee, 2022). Some values are more resistant to trade-offs than others. Albeit in a more general risk assessment scenario, than food safety research specifically, prospect theory has been used to analyse the framing of decisions by risk assessors. Prospect theory predicts that framing a choice/decision in terms of potential gains and losses may "create a shift in the preference of decision-makers" driving risk-assessors to focus on weaknesses rather than preventive measures (Uyar & Paksoy, 2020). Kemel and Paraschiv (2018, p. 163) provided insight into the differences between consumer preferences and cost-benefit analysis recommendations concluding that "decisions involving human lives are characterised by less elevated probability weighting in the loss domain and higher loss aversion compared to decisions involving money." Hazard identification, determination of appropriate control measures, undertaking risk assessment and then developing and implementing FSMS has been based on a set of 'accepted' conventional and relational approaches. These include the 'group' use of HACCP principles, risk ranking (likelihood and severity) using risk matrices, decision trees and templates for FSMS development (Codex, 2022). This techno-social approach requires consensus among stakeholders as to how hazard analysis and risk assessment procedures and methodologies should be designed, harmonised and consistently implemented often in situations where there is limited data and uncertainty levels are high (Barlow et al., 2015). However, Wallace et al. (2014) identified weaknesses within FBOs, including gaps in individual knowledge of food safety hazards and errors in the application of hazard analysis and structures risk evaluation methods. Monaghan et al. (2017) too differentiate between an assessment of risk with qualitative or semi-quantitative methods and a formal risk assessment, often undertaken by regulators that follows a fully quantitative approach. Further, they argue, it is qualitative assessment of risk that is applied by FBOs, especially at primary production level, where the presence of pre-requisite programmes such as GAP are considered in terms of control of food safety hazards, but where the evidence base on which FBOs rely to undertake such assessments needs to be much better developed. Cultural and cognitive biases can influence qualitative, semi-quantitative and fully quantitative approaches to assessment of risk and risk assessment, and this will be influenced by the what, where, when, who and how of the approach as well as the why and what if, of the reflective aspects of hazard identification and assessment of risk.

At the FBO level, the level of knowledge, availability of physical and financial resources to support the implementation of the FSMS and the management engagement with food safety goals will all influence the effectiveness of ensuring food that is produced is consistently safe. Aligning and integrating individual FBO FSMS across a supply chain will deliver an effective chain of custody and verification ecosystem to assure food safety. Most research has focused on intra-organisational food safety culture rather than developing supply chain level integrated culture, thus cultural and cognitive biases within one FBO could conflict with other FBOs in the same supply chain. For example, risk appetite may vary between FBOs and willingness to accept a level of food safety risk within a cost/benefit trade-off e.g. improved sustainability impacts, or application of AI in food safety decision-making. Cooper et al. (2021) reflect on the interaction between accountability and accuracy-efficiency trade-offs especially how accountability is defined in the event of an incident. They argue "*the precautionary principle advises extreme caution around new innovations when there is substantial unknown risk [placing] the burden of proof on risk-creating actors to provide sufficient evidence that they are not producing significant risk of harm*" and demonstrating they are making appropriate and informed decisions given the risk landscape (Cooper et al., 2021, p. 2). The need to reduce the impact of cultural and cognitive biases on individual FBO FSMS and ensure greater compliance has been addressed in the US by Section 204(d) of the FDA Food Safety Modernisation Act (FSMA) which prescribes from January 2026 the records that FBOs must maintain containing Key Data Elements (KDEs) and associated Critical Tracking Events (CTEs) whereby information must be provided to the FDA within a mutually agreed timeframe (FDA, 2024). However, such approaches in themselves, being prescriptive embed aspects of cultural bias especially with regard to the regulator's framing of what records demonstrate that food is safe-enough. There are technological aspects to be overcome in terms of improved interoperability of data sharing and working through the interactions between conventional and relational thinking between FBOs and regulators.

Is it possible to build bias resilient FSMS and design bias-resistant risk assessment processes? As these processes are so underpinned by complex economic and politico-social drivers, and the nexus of conventional and relational thinking how does this inform definition of what is safe enough? These questions are worthy of further empirical research.

5. Concluding thoughts

The aim of this structured review is to firstly consider existing hazard analysis and risk assessment approaches to developing and implementing FSMS, and approaches to defining what is "safe enough' and, secondly to explore the role of cognitive and cultural biases in decision-making. The research has highlighted that the degree of objectivity in food safety risk assessment can be influenced by a number of heuristics, cognitive and cultural biases that impact on efficacy. Competing stakeholders' worldviews and the lack of consensus with regard to what food safety is, the range of criteria that stakeholders use (e.g. scientists or the general public) to determine whether a food is believed to be safe or not, especially when there is contradictory evidence, means there is a collective negotiation, and sometime renegotiation to 'evaluate what is, and what is not, safe food" (Hassauer & Roosen, 2020). It is important to recognise that most individuals within organisational HACCP teams are members of the general public and not scientists per se. Thus, they will analyse hazards from a layperson's perspective. Determining acceptable levels of risk can be challenging when the constructs of acceptability and tolerability have both scientific and social aspects. This means that a given food may be deemed as scientifically safe by some and deemed as not safe enough by others. The challenge too is that as scientific knowledge evolves what was deemed as 'safe' at one point in the past as new understanding emerges on what it is to be safe, will be revised. For example, as the limit of detection reduces in analytical tests as they become more specific, a chemical residue which was previously undetected will now be identified. The inherent safety status of the food has not changed, but the information that can be provided about the food is now richer, and more nuanced. Changing perceptions of quality, and indeed safety levels of a particular agent, can create a situation where overregulation or under regulation of an aspect of food safety occurs. Four further research questions have emerged from this research for future empirical work.

RQ1: Can an improved understanding of cultural biases assist a more reflexive approach to assessing the socio-cultural context of hazard analysis and risk assessment to then inform how existing HACCP approaches can be optimised when FBOs develop, and implement FSMS?
RQ2: What criteria determine what constitutes 'safe enough' in the context of food safety for different stakeholders and how are these standards set, and where necessary revised?
RQ3: How might cognitive biases influence hazard analysis and risk assessment in the development of FSMS?
RQ4: Can FSMS and food safety risk assessment be bias free?

In summary, cognitive and cultural biases can influence assessment of food safety hazards and perceptions, management and acceptance of food safety risk. A better understanding of their level and pathways of influence and how this informs scientific and lay approaches to FSMS design and implementation and risk assessment could provide more insight into how regulators, food business operators, staff and consumers assess, mitigate and accept food safety risk.

Data availability

No data was used for the research described in the article.

References

Afzal, A., Saleel, C. A., Bhattacharyya, S., Satish, N., Samuel, O. D., & Badruddin, I. A. (2022). Merits and limitations of mathematical modeling and computational simulations in mitigation of COVID-19 pandemic: A comprehensive review. *Archives of Computational Methods in Engineering, 29*(2), 1311–1337.

Ahlqvist, V., Norrman, A., & Jahre, M. (2020). Supply chain risk governance: Towards a conceptual multi-level framework. *Operations and Supply Chain Management, 13*(4), 382–395.

Amankwah-Amoah, J., & Debrah, Y. A. (2010). The protracted collapse of Ghana Airways: Lessons in organizational failure. *Group & Organization Management, 35*(5), 636–665.

Barlow, S. M., Boobis, A. R., Bridges, J., Cockburn, A., Dekant, W., Hepburn, P., Houben, G. F., König, J., Nauta, M. J., Schuermans, J., & Bánáti, D. (2015). The role of hazard-and risk-based approaches in ensuring food safety. *Trends in Food Science & Technology, 46*(2), 176–188.

Batista, S. A., Stedefeldt, E., dos Santos, E. B., Nakano, E. Y., Ginani, V. C., & Botelho, R. B. A. (2024). Understanding and evaluating risk perception, knowledge, and food safety self-reported practices of public-school students in Brazil. *Food Research International, 196*, Article 115027.

Busenitz, L. W., & Barney, J. B. (1997). Differences between entrepreneurs and managers in large organizations: Biases and heuristics in strategic decision-making. *Journal of Business Venturing, 12*(1), 9–30.

Chou, F. S., Wang, C. C., Lai, M. C., Tung, C. H., Yang, Y. J., & Tsai, K. H. (2020). Persuasiveness of organic agricultural products: Argument strength, health consciousness, self-reference, health risk, and perceived fear. *British Food Journal, 122*(4), 1289–1304.

Claro, D. P., Hagelaar, G., & Omta, O. (2003). The determinants of relational governance and performance: How to manage business relationships? *Industrial Marketing Management, 32*(8), 703–716.

Codex (Codex Alimentarius Commission). (2022). Hazard analysis and critical control point (HACCP) system and guidelines for its application. *Codex Alimentarius Commission Food Hygiene Basic Texts*. Available at: https://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCXC%2B1-1969%252FCXC_001e.pdf.

Cogan, J. A. (2015). The uneasy case for food safety liability insurance. *Brooklyn Law Review, 81*, 1495–1553.

Cooper, A. F., Levy, K., & De Sa, C. (2021). Accuracy-efficiency trade-offs and accountability in distributed ML systems. In *Proceedings of the 1st ACM Conference on equity and access in Algorithms, mechanisms, and Optimization* (pp. 1–11).

Dake, K. (1991). Orienting dispositions in the perception of risk: An analysis of contemporary worldviews and cultural biases. *Journal of Cross-Cultural Psychology, 22*(1), 61–82.

das Neves, C. P., Eves, A., Rodrigues, K. L., de Mello, J. F., Gandra, T. K. V., & Gandra, E. A. (2024). Applying the theory of planned behavior with optimistic bias to understand food safety behaviors of young and middle-aged highly educated Brazilian consumers. *Food Control, 163*, Article 110551.

de Andrade, M. L., Rodrigues, R. R., Antongiovanni, N., & da Cunha, D. T. (2019). Knowledge and risk perceptions of foodborne disease by consumers and food handlers at restaurants with different food safety profiles. *Food Research International, 121*, 845–853.

Ding, Y., Du, X., Li, Q., Zhang, M., Zhang, Q., Tan, X., & Liu, Q. (2020). Risk perception of coronavirus disease 2019 (COVID-19) and its related factors among college students in China during quarantine. *PLoS One, 15*(8), Article e0237626.

Eyster, H. N., Satterfield, T., & Chan, K. M. (2023). Empirical examples demonstrate how relational thinking might enrich science and practice. *People and Nature, 5*(2), 455–469.

FDA. (2024). FSMA final rule on requirements for additional traceability records for certain foods. Available from: https://www.fda.gov/food/food-safety-modernization-act-fsma/fsma-final-rule-requirements-additional-traceability-records-certain-foods. (Accessed 18 November 2024).

Finucane, M. L., Slovic, P., Mertz, C. K., Flynn, J., & Satterfield, T. A. (2000). Gender, race, and perceived risk: The 'white male' effect. *Health, Risk & Society, 2*(2), 159–172.

Fischhoff, B., Slovic, P., & Lichtenstein, S. (1982). Lay foibles and expert fables in judgments about risk. *The American Statistician, 36*(3b), 240–255.

Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S., & Combs, B. (1978). How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. *Policy Sciences, 9*, 127–152.

Flores-Miyamoto, A., Reij, M. W., & Velthuis, A. G. J. (2014). Do farm audits improve milk quality? *Journal of Dairy Science, 97*(1), 1–9.

Franks, N. R., Dornhaus, A., Fitzsimmons, J. P., & Stevens, M. (2003). Speed versus accuracy in collective decision making. *Proceedings of the Royal Society of London B Biological Sciences, 270*(1532), 2457–2463.

Gifford, R. (2011). The dragons of inaction: Psychological barriers that limit climate change mitigation and adaptation. *American Psychologist, 66*(4), 290–302.

Gori, A., Armani, A., Pedonese, F., Benini, O., Mancini, S., & Nuvoloni, R. (2025). Heavy metals (Pb, Cd, Ni) in insect-based products for human consumption sold by e-commerce in the EU market: Occurrence and potential health risk associated with dietary exposure. *Food Control, 167*, Article 110781.

Gu, Y., Li, X., & Chan, E. C. Y. (2023). Risk assessment of cultured meat. *Trends in Food Science & Technology, 138*, 491–499.

Häubl, G., & Trifts, V. (2000). Consumer decision making in online shopping environments: The effects of interactive decision aids. *Marketing Science, 19*(1), 4–21.

Höijer, B. (2011). Social representations theory. *Nordicom review, 32*(2), 3.

Han, J., Trienekens, J. H., & Omta, S. O. (2011). Relationship and quality management in the Chinese pork supply chain. *International Journal of Production Economics, 134*(2), 312–321.

Hassauer, C., & Roosen, J. (2020). Toward a conceptual framework for food safety criteria: Analyzing evidence practices using the case of plant protection products. *Safety Science, 127*, Article 104683.

Higashi, S. Y., Caleman, S. M. D. Q., Manning, L., De-Aguiar, L. K., & Monteiro, G. F. A. (2023). Factors influencing Brazilian sugar and ethanol refineries' failure. *RAUSP Management Journal, 58*, 55–68.

Houghton, J. R., Rowe, G., Frewer, L. J., Van Kleef, E., Chryssochoidis, G., Kehagia, O., Korzen-Bohr, S., Lassen, J., Pfenning, U., & Strada, A. (2008). The quality of food risk management in Europe: Perspectives and priorities. *Food Policy, 33*(1), 13–26.

Hunter, E., & Röös, E. (2016). Fear of climate change consequences and predictors of intentions to alter meat consumption. *Food Policy, 62*, 151–160. https://doi.org/10.1016/j.foodpol.2016.06.004

Immonen, A. M., & Luomala, H. T. (2017). Different shades of displeasure: When fear and anger lead to opposite consumer responses to GM foods. *British Food Journal, 119*(12), 2740–2752.

Jacxsens, L., Luning, P. A., Van der Vorst, J. G. A. J., Devlieghere, F., Leemans, R., & Uyttendaele, M. (2010). Simulation modelling and risk assessment as tools to identify the impact of climate change on microbiological food safety–The case study of fresh produce supply chain. *Food Research International, 43*(7), 1925–1935.

James, H. S., Segovia, M., & Giwa-Daramola, D. (2023). Food safety and cognitive biases: What we know, what we need to know, and why. *British Food Journal, 125*(10), 3717–3733.

Janković, V., & Schultz, D. M. (2017). Atmosfear: Communicating the effects of climate change on extreme weather. *Weather, Climate, and Society, 9*(1), 27–37. https://journals.ametsoc.org/doi/10.1175/WCAS-D-16-0030.1.

Johnson, B. B., & Swedlow, B. (2021). Cultural theory's contributions to risk analysis: A thematic review with directions and resources for further research. *41*(3), 429–455.

Joomun, A. B., Wallace, C. A., Aumjaud, B., & Ramful-Baboolall, D. (2024). Food safety culture and climate prevailing in micro and small food manufacturing enterprises in Mauritius and Rodrigues. *International Journal of Food Science and Technology, 59*(2), 685–702.

Kahan, D. M., Braman, D., Gastil, J., Slovic, P., & Mertz, C. K. (2007). Culture and identity-protective cognition: Explaining the white-male effect in risk perception. *Journal of Empirical Legal Studies, 4*(3), 465–505.

Kahneman, D. (2011). *Fast and slow thinking*. New York: Allen Lane Penguin Books.

Kahneman, D., & Tversky, A. (1982). The psychology of preferences. *Scientific American, 246*(1), 160–173.

Karasawa, K. (1995). Cognitive antecedents of emotions. *Japanese Psychological Research, 37*(1), 40–55.

Kasperson, J. X., Kasperson, R. E., Pidgeon, N., & Slovic, P. (2003). The social amplification of risk: Assessing fifteen years of research and theory. In N. Pidgeon, R. E. Kasperson, & P. Slovic (Eds.), *The social amplification of risk* (pp. 13–46).

Kemel, E., & Paraschiv, C. (2018). Deciding about human lives: An experimental measure of risk attitudes under prospect theory. *Social Choice and Welfare, 51*, 163–192.

Kim, Y. D., & Lee, J. S. (2022). IoT-based fumigation for insect repellent in food storages: Breaking the trade-off between efficiency and safety. *Sustainability, 14*(3), 1129.

Kirezieva, K., Jacxsens, L., van Boekel, M. A., & Luning, P. A. (2015). Towards strategies to adapt to pressures on safety of fresh produce due to climate change. *Food Research International, 68*, 94–107.

Lazar, S., & Nelson, A. (2023). AI safety on whose terms? *Science, 381*(6654), 138-138.

Leiserowitz, A. A. (2003). Global warming in the American mind: The roles of affect, imagery. *Worldviews in risk perception, policy preferences and behavior*. Doctoral dissertation, University of Oregon.

Lennon, J. J. (2015). Potential impacts of climate change on agriculture and food safety within the island of Ireland. *Trends in Food Science & Technology, 44*(1), 1–10.

Maggiore, A., Afonso, A., Barrucci, F., & Sanctis, G. D. (2020). Climate change as a driver of emerging risks for food and feed safety, plant, animal health and nutritional quality. *EFSA Supporting Publications, 17*(6), 1881E.

Manning, L. (2017). Categorizing food-related illness: Have we got it right? *Critical Reviews in Food Science and Nutrition, 57*(9), 1938–1949.

Manning, L., Birchmore, I., & Morris, W. (2020). Swans and elephants: A typology to capture the challenges of food supply chain risk assessment. *Trends in Food Science & Technology, 106*, 288–297.

Manning, L., Brewer, S., Craigon, P. J., Frey, J., Gutierrez, A., Jacobs, N., Kanza, S., Munday, S., Sacks, J., & Pearson, S. (2023). Reflexive governance architectures: Considering the ethical implications of autonomous technology adoption in food supply chains. *Trends in Food Science & Technology, 133*, 114–126.

Manning, L., Luning, P. A., & Wallace, C. A. (2019). The evolution and cultural framing of food safety management systems—where from and where next? *Comprehensive Reviews in Food Science and Food Safety, 18*(6), 1770–1792.
Manning, L., & Soon, J. M. (2014). Developing systems to control food adulteration. *Food Policy, 49*, 23–32.
Masuda, J. R., & Garvin, T. (2006). Place, culture, and the social amplification of risk. *Risk Analysis, 26*(2), 437–454. https://doi.org/10.1111/j.1539-6924.2006.00749.x
Monaghan, J. M., Augustin, J. C., Bassett, J., Betts, R., Pourkomailian, B., & Zwietering, M. H. (2017). Risk assessment or assessment of risk? Developing an evidence-based approach for primary producers of leafy vegetables to assess and manage microbial risks. *Journal of Food Protection, 80*(5), 725–733.
Monghasemi, S., Nikoo, M. R., Fasaee, M. A. K., & Adamowski, J. (2015). A novel multi criteria decision making model for optimizing time–cost–quality trade-off problems in construction projects. *Expert Systems with Applications, 42*(6), 3089–3104.
Montibeller, G., & Von Winterfeldt, D. (2015). Cognitive and motivational biases in decision and risk analysis. *Risk Analysis, 35*(7), 1230–1251.
Nash, L. (2005). The agency of nature or the nature of agency? Environmental *history*, 10 (1), 67–69http://www.jstor.org/stable/3985846 .
Nguyen, T. A. T., & Jolly, C. M. (2020). Global value chain and food safety and quality standards of Vietnam pangasius exports. *Aquaculture reports, 16*, Article 100256.
O'Connor, A. M., Légaré, F., & Stacey, D. (2003). Risk communication in practice: the contribution of decision aids. *BMJ, 327*(7417), 736–740.
Oleo, D. D. D., Manning, L., McIntyre, L., Randall, N., & Nayak, R. (2024). The application of systematic accident analysis tools to investigate food safety incidents. *Comprehensive Reviews in Food Science and Food Safety, 23*(3), Article e13344.
Owoloja, A., & Manning, L. (2024). Organisational integrity: Definitions, perceptions and the relationship with organisational performance. In M. Kaptein (Ed.), *A research handbook on organisational integrity*. Cheltenham: Edgar Elgar.
Pachur, T., Hertwig, R., & Steinmann, F. (2012). How do people judge risks: Availability heuristic, affect heuristic, or both? *Journal of Experimental Psychology: Applied, 18*(3), 314.
Peters, E. M., Burraston, B., & Mertz, C. K. (2004). An emotion-based model of risk perception and stigma susceptibility: Cognitive appraisals of emotion, affective reactivity, worldviews, and risk perceptions in the generation of technological stigma. *Risk Analysis, 24*(5), 1349–1367.
Phillips-Wren, G., & Adya, M. (2020). Decision making under stress: The role of information overload, time pressure, complexity, and uncertainty. *Journal of Decision Systems, 29*(sup1), 213–225.
Qiu, Z., Liu, Q., Li, X., & Zhang, Y. (2024). Why do workers generate biased risk perceptions? An analysis of anchoring effects and influential factors in workers' assessment of unsafe behaviour. *Safety and Health at Work, 15*(3), 300–309.
Rana, I. A., Bhatti, S. S., Aslam, A. B., Jamshed, A., Ahmad, J., & Shah, A. A. (2021). COVID-19 risk perception and coping mechanisms: Does gender make a difference? *International Journal of Disaster Risk Reduction, 55*, Article 102096.
Rattay, P., Michalski, N., Domanska, O. M., Kaltwasser, A., De Bock, F., Wieler, L. H., & Jordan, S. (2021). Differences in risk perception, knowledge and protective behaviour regarding COVID-19 by education level among women and men in Germany. Results from the COVID-19 Snapshot Monitoring (COSMO) study. *PLoS One, 16*(5), Article e0251694.
Rayner, S., & Cantor, R. (2018). How fair is safe enough? The cultural approach to societal technology choice 1. In *The institutional dynamics of culture, volumes I and II* (pp. 848–855). Routledge.
Rodriguez-Besteiro, S., Tornero-Aguilera, J. F., Fernández-Lucas, J., & Clemente-Suárez, V. J. (2021). Gender differences in the COVID-19 pandemic risk perception, psychology, and behaviors of Spanish university students. *International Journal of Environmental Research and Public Health, 18*(8), 3908.
Ruiter, R. A., Abraham, C., & Kok, G. (2001). Scary warnings and rational precautions: A review of the psychology of fear appeals. *Psychology and Health, 16*(6), 613–630.
Shan, L., Wang, S., Wu, L., & Tsai, F. S. (2019). Cognitive biases of consumers' risk perception of foodborne diseases in China: Examining anchoring effect. *International Journal of Environmental Research and Public Health, 16*(13), 2268.
Sharman, N., Wallace, C. A., & Jespersen, L. (2020). Terminology and the understanding of culture, climate, and behavioural change–Impact of organisational and human factors on food safety management. *Trends in Food Science & Technology, 96*, 13–20.
Siddiqui, S. A., Khan, S., Murid, M., Asif, Z., Oboturova, N. P., Nagdalian, A. A., Blinov, A. V., Ibrahim, S. A., & Jafari, S. M. (2022). Marketing strategies for cultured meat: A review. *Applied Sciences, 12*(17), 8795.
Siegrist, M., & Árvai, J. (2020). Risk perception: Reflections on 40 years of research. *Risk Analysis, 40*(S1), 2191–2206.
Siegrist, M., & Hartmann, C. (2020). Consumer acceptance of novel food technologies. *Nature Food, 1*(6), 343–350.
Simon, H. A. (1979). Rational decision making in business organizations. *The American Economic Review, 69*(4), 493–513.
Slovic, P. (1999). Trust, emotion, sex, politics, and science: Surveying the risk-assessment battlefield. *Risk Analysis, 19*(4), 689–701.
Slovic, P., Finucane, M. L., Peters, E., & MacGregor, D. G. (2004). Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk, and rationality. *Risk Analysis, 24*(2), 311–322.
Slovic, P., Fischhoff, B., & Lichtenstein, S. (1982). Why study risk perception? *Risk Analysis, 2*(2), 83–93.
Slovic, P., Fischhoff, B., Lichtenstein, S., & Roe, F. J. C. (1981). Perceived risk: Psychological factors and social implications [and discussion]. In *Proceedings of the royal society of London A: Mathematical, physical and engineering sciences* (Vol. 376). The Royal Society. April 1764),17-34.
Smith, N., & Leiserowitz, A. (2014). The role of emotion in global warming policy support and opposition. *Risk Analysis, 34*(5), 937–948.
Socas-Rodríguez, B., Álvarez-Rivera, G., Valdés, A., Ibáñez, E., & Cifuentes, A. (2021). Food by-products and food wastes: Are they safe enough for their valorization? *Trends in Food Science & Technology, 114*, 133–147.
Soon-Sinclair, J. M., Nayak, R., & Manning, L. (2024). An AcciMap approach to analyse the Chinese melamine milk scandal. *British Food Journal*. https://doi.org/10.1108/BFJ-02-2023-0161
Stolow, J. A., Moses, L. M., Lederer, A. M., & Carter, R. (2020). How fear appeal approaches in COVID-19 health communication may be harming the global community. *Health Education & Behavior, 47*(4), 531–535.
Thaivalappil, A., Waddell, L., Greig, J., Meldrum, R., & Young, I. (2018). A systematic review and thematic synthesis of qualitative research studies on factors affecting safe food handling at retail and food service. *Food Control, 89*, 97–107.
Thaivalappil, A., Young, I., Lam, S., & Papadopoulos, A. (2023). Enhancing quality of qualitative evidence in food safety and food security. *Food and Humanity, 1*, 28–31.
Tirado, M. C., Clarke, R., Jaykus, L. A., McQuatters-Gollop, A., & Frank, J. M. (2010). Climate change and food safety: A review. *Food Research International, 43*(7), 1745–1765.
Uyar, T., & Paksoy, M. (2020). Framing effect in safety risk probability assessment: A prospect theory approach. *The International Journal of Aerospace Psychology, 30*(3–4), 119–129.
Uyttendaele, M., Liu, C., & Hofstra, N. (2015). Special issue on the impacts of climate change on food safety. *Food Research International*, (68), 1–6.
van der Linden, S. (2015). The social-psychological determinants of climate change risk perceptions: Towards a comprehensive model. *Journal of Environmental Psychology, 41*, 112–124.
van der Spiegel, M., Van der Fels-Klerx, H. J., & Marvin, H. J. P. (2012). Effects of climate change on food safety hazards in the dairy production chain. *Food Research International, 46*(1), 201–208.
van der Vossen-Wijmenga, W. P., Zwietering, M. H., Boer, E. P., Velema, E., & den Besten, H. M. (2022). Perception of food-related risks: Difference between consumers and experts and changes over time. *Food Control, 141*, Article 109142.
Wallace, C. A., Holyoak, L., Powell, S. C., & Dykes, F. C. (2014). HACCP–the difficulty with hazard analysis. *Food Control, 35*(1), 233–240.
Yu, H. Y., Neal, J. A., & Sirsat, S. A. (2018). Consumers' food safety risk perceptions and willingness to pay for fresh-cut produce with lower risk of foodborne illness. *Food Control, 86*, 83–89.
Zhang, X., & Zhou, S. (2019). Clicking health risk messages on social media: Moderated mediation paths through perceived threat, perceived efficacy, and fear arousal. *Health Communication, 34*(11), 1359–1368.
Zwietering, M. H., Garre, A., Wiedmann, M., & Buchanan, R. L. (2021). All food processes have a residual risk, some are small, some very small and some are extremely small: Zero risk does not exist. *Current Opinion in Food Science, 39*, 83–92. https://doi.org/10.1016/j.cofs.2020.12.017