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The use of smart biosensors during a food safety incident: Consumers' cognitive-behavioural responses and willingness to pay

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Abstract

Intelligent and active packaging could allow consumers to control cognitive reactions linked to the risk of consuming food products contaminated by microbiological pathogens and thus mitigating negative consequences of food safety incidents. However, despite advances in technology, consumers' reactions and willingness to pay for active and intelligent packaging in the absence and presence of food safety incidents remain somewhat unexplored. To fill such a gap this study incorporates protection motivation theory (PMT) within a contingent valuation survey conducted in the UK to explore consumers' behavioural responses to risk communication in the absence and presence of a food safety incident. These responses were moderated by the possibility of buying hypothetical meat products marketed with biosensors informing consumers of the presence of bacteria post-purchase. A singular approach was developed to identify the following four behavioural responses of the PMT's cognitive mediating process: no response, fear, low response and danger control. Results indicate that the theoretical components of PMT play a different role in the absence and presence of food safety incidents. Respondents who receive risk information are willing to pay more than other participants to adopt precautionary behaviour and that purchasing behaviour varied across these four cognitive-behavioural responses. Governmental institutions, the food industry and retailers should consider working together to reassure consumers by investing in technology that may help consumers to mitigate fear during a food safety incident, but also to develop appropriate risk communication strategies that should focus more on the cognitive-behavioural outcomes analysed in this study.

KEYWORDS

biosensors, contingent valuation, food safety scares, protection motivation theory, risk cognition, risk communication

1 | INTRODUCTION

Food safety is a complex interdisciplinary field that finds its roots in agricultural science, chemistry, engineering, food science, microbiology and risk analysis. Scientific principles of these different disciplines are brought together to develop methods and technologies that from farm to fork can prevent illnesses and injuries to human beings when food is produced, handled, processed, stored, marketed and consumed

(Schmidt & Rodrick, 2003; WHO & FAO, 2016). However, despite advances in science and technology millions of people fall ill from either microbiological or chemical contamination every year and thousands die because they consume unsafe food especially in developing countries (WHO, 2015). In addition, in developed countries markets are continuously hit by food safety incidents caused by outbreaks of foodborne pathogens such as *Escherichia coli*, *Campylobacter*, *Salmonella*, *Norovirus*, which seriously affect the life of people who consume contaminated food products (FAO, 2016). As a result, when food safety incidents hit markets, it is critical to inform consumers about the likelihood of being harmed by a certain hazard, the severity of the damage caused by the contaminant to their health and the response that they can put in place to reduce the risk of consuming contaminated food products (Cope et al., 2010; Frewer, 2000).

In these contexts, risk communication (e.g., wording, sources of information, channels) is paramount to regaining consumer confidence after a food safety scare (Cope et al., 2010; Nocella et al., 2014). Public health messages can effectively inform the target audience about the real hazards to which they are exposed in order to avoid or minimize the health risks (Cerroni et al., 2019; Lofstedt, 2006). Consumers' confidence can be regained by using effective risk communication that reduces the gap between real and perceived risks (Cerroni et al., 2013; Hansen et al., 2003). This gap can also be reduced by adopting new technology that reduces the risk of food safety incidents like smart biosensors provided on food packaging to alert consumers about the presence of harmful bacteria (Augustin et al., 2009). Smart biosensors belong to a class of active and intelligent packaging commonly referred to as 'smart tags' that apply a range of different technologies (Realini & Marcos, 2014), and have the potential to provide consumers with more accurate information about food safety measurements than an estimated expiration date (Müller & Schmid, 2019).

However, smart tags remain largely unused and little research has been conducted to investigate consumers' acceptance of such new technology (Li et al., 2020) especially regarding the use of biosensors during a food safety incident (Erdem, 2015). Investigating factors that influence consumer demand for this innovative food packaging can have important implications for the improvement of food safety standards of highly perishable products that can be contaminated by bacteria such as meat and fish. Insights about willingness to pay (WTP) for smart biosensors can provide marketers and policy makers with useful information about the optimal level of food safety in which the additional costs of a higher level of safety are equal to their marginal benefits (Traill & Koenig, 2010). In order to fill such a gap this study aims at investigating how protection motivation theory (PMT) explains consumers' acceptance and WTP for meat products marketed with biosensors under different risk communication scenarios. Such an investigation also contributes to the scanty literature of PMT in the context of food safety (Chen, 2016; Mullan et al., 2016; Scarpa & Thiene, 2011) and to the examination of the influence of risk communication on the cognitive processes generated by food scares. As a result, the following research questions will be explored:

i. Do the items that characterize the PMT's latent dimensions remain stable in the absence and presence of risk?
ii. Are the scores of PMT's latent dimensions associated to threat and coping appraisal during a food safety incident higher than those observed in absence of risk?
iii. Is the number of consumers willing to buy meat products marketed with smart biosensors during a food safety incident higher than that observed in absence of risk?
iv. Are consumers' willing to pay a premium for meat products marketed with smart biosensors in different risk communication scenarios?
v. How does WTP for smart biosensors vary across various behavioural responses in different risk communication scenarios?

The remainder of this paper is organized as follows. Section 2 will discuss risk evaluations, PMT and its application to food safety studies in order to introduce the theoretical framework and hypotheses of the current study. Section 3 will explain the survey and statistical methods adopted. Section 4 will present and discuss results. Section 5 will draw conclusions.

2 | LITERATURE PRESENTATION AND THEORETICAL BACKGROUND

2.1 | Evaluation of risk in the context food safety

To better understand people's behaviour when they face a situation of danger, researchers have attempted to measure how lay people perceive risk (subjective risk) and related psychological components in several ways taking into account both emotional and cognitive reactions (Brewer et al., 2007; Kuttschreuter, 2006; Kuttschreuter & Gutteling, 2003; Loewenstein et al., 2001; Rosenstock, 1974; Slovic et al., 2004). There are different notions of subjective risk, but all concepts assume that people can assess the severity and probability of possible outcomes under a situation of risk even if erroneously because their evaluations are not objective since risk is the outcome of social processes (Hansson, 2010; Loewenstein et al., 2001; Slovic, 1987; Slovic, 2016). Perceived risk can be measured in different ways asking participants to rate their concern or express severity, fear, feelings of anxiety or perceived probability about negative outcomes (Haase et al., 2013; Hohl & Gaskell, 2008; Levy et al., 2008; Liao et al., 2009; Shahabi Ahangarkolaee & Gorton, 2021; Sönmez & Graefe, 1998). In the context of food, people's perceived risk, given the same objective level of risk and consequences, can increase or decrease in relation to how several factors linked to a certain hazard can influence their risk perception (WHO & FAO, 2016). The influence of factors such as perceived naturalness, perceived controllability, scientific knowledge, familiarity, severity of consequences, immediacy of consequences, intentional exposure, perceived distribution of risks and benefits and ethical and moral concerns, provide an idea of the complexity of the evaluation of these reactions.

People's reactions to undertaking a protective behaviour under different situations of danger can also be explored using several theories that fall under the umbrellas of expectancy value models[1] and fear appeal models such as the health belief model, the parallel response model (Leventhal, 1970), the PMT (Rogers, 1975 and 1983) and the extended parallel process model (Witte, 1992; Witte & Allen, 2000). However, fear appeal models, as in this study, are appropriate when researchers want to understand and explain how effective risk communication is in influencing a protective decision-making process (Ruiter et al., 2014; Tannenbaum et al., 2015). These models allow researchers to assess how people react to risk communication taking into account how they perceive the threat and whether they are capable of coping with danger by adopting protective behaviour (Milne et al., 2000; Peters et al., 2013). Furthermore, in expectancy value models the perceived effectiveness of taking a precautionary action is not considered (Floyd et al., 2000) and the operationalization of theoretical framework components, summing products obtained multiplying beliefs by evaluations of items of different psychological constructs, is more cumbersome than fear appeal models.

Fear appeal models have been applied to explore and predict pro-environmental behaviour and various health related behaviours, such as reducing alcohol use and smoking, enhancing healthy lifestyles, enhancing diagnostic health behaviours and preventing diseases caused by unsafe sex or non-communicable diseases such as obesity, high blood pressure and so on (Bui et al., 2013; Cox et al., 2004; Helmes, 2002; Kothe et al., 2019; Milne et al., 2000). More recently, PMT has also been implemented to evaluate the intention both to adopt protect behaviour against cybercrimes (Meso et al., 2013; van Bavel et al., 2019) and to receive the COVID19 vaccine (Kim et al., 2021; Li et al., 2021). However, in the context of food safety these affective and cognitive reactions to different hazards and risk communication messages have generally been investigated employing different scales of risks (Lobb, 2005; Schafer et al., 1993; Setbon et al., 2005) and only a few studies have employed the extended parallel model (Quilliam et al., 2018) or the PMT to explore how the cognitive process generated by food scares is influenced by risk communication (Scarpa & Thiene, 2011, Chen, 2016, Mullan et al., 2016).

2.2 | Theoretical framework

PMT finds its roots in the health belief model that focused on the cognitive processes mediating attitudinal and behavioural change (Prentice-Dunn & Rogers, 1986). Subsequently, this conceptual framework was extended to a more general theory of persuasive communication, which focused on the cognitive processes of mediating behavioural change towards an adoption of a protective behaviour (Rogers, 1983). PMT is generally used to understand and explain the health decision-making process generated by fear-arousing appeals whose outcomes can help marketers and policy makers to create social marketing campaigns that can persuade individuals to adopt the protective behaviour (Bui et al., 2013; Floyd et al., 2000; Kothe et al., 2019; Milne et al., 2000). In this study, we focus on PMT in order to have a conceptual understanding of how the different elements of this conceptual framework can influence consumers' motivation to purchase safe meat products under different risk situations. This protective behaviour is captured by consumers' acceptance and WTP[2] for meat marketed with smart biosensors.

Figure 1 shows that the PMT cognitive process is triggered by information coming from environmental (communication and observational learning) and intrapersonal sources (socio-demographic characteristics and prior experience). Communication conveyed and framed by media often signals danger such as negative health outcomes due to a food safety scare (Brady et al., 2009; Chang, 2012; Fleming et al., 2006; Wåhlberg & Sjöberg, 2000) caused by outbreaks of foodborne pathogens such as *Campylobacter*, *Escherichia coli*, *Listeria* and *Salmonella* that contaminate different food products in various countries around the world (WHO, 2015; WHO & FAO, 2016). The scope of these messages is to simulate situations of fear among participants in order to evaluate psychological reactions (Frank & Schvaneveldt, 2016; Frewer et al., 1996).

To investigate how different risk messages regarding a food safety incident affect consumers' WTP for meat products marketed with smart biosensors, three different versions of a contingent valuation (CV) survey were developed: (i) the no risk information (NRI); (ii) the low risk information (LRI) and (iii) the high risk information (HRI). In our paper, the risk under investigation relates to health outcomes of a food-safety incident caused by *Escherichia coli* in meat-based products, while the risk reducing behavioural response (motivation to protect) is the purchasing of food marketed with biosensors made with nanotechnology. As shown in Figure 1, the cognitive mediating process consists of two information evaluation processes: threat appraisal (TA) and coping appraisal (CA) (Bui et al., 2013; Kothe et al., 2019). The first process deals with people's assessment of threats and has been explained by Witte (1992) as "an external stimulus variable that exists regardless of a person's conscious perception of its presence'. Threat is usually evaluated by perceived vulnerability (or susceptibility) and perceived severity. Perceived vulnerability is represented by personal prediction of the chance of contracting a disease (i.e., the probability of food poisoning), while severity is the perceived seriousness of a disease (i.e., health issues due to food poisoning). Fear and threat are characterized by a positive relationship. Fear increases when perceived severity and perceived susceptibility to a threat increase. However, if fear is low, perceived threat will play a minor role in the cognitive process (Witte, 1992; Witte & Allen, 2000).

The second cognitive process is coping appraisal and assesses the efficacy of the recommended adaptive behaviour in reducing or avoiding health risks (Bui et al., 2013; Kothe et al., 2019). Coping appraisal also consists of two components: response efficacy and self-efficacy. Response efficacy is the individual's expectation regarding the capacity of the recommended adaptive behaviour to reduce or remove the threat (e.g., ability of biosensors to reduce the risk of food poisoning), while self-efficacy is the personal ability to execute the recommended adaptive response successfully (e.g., personal ability

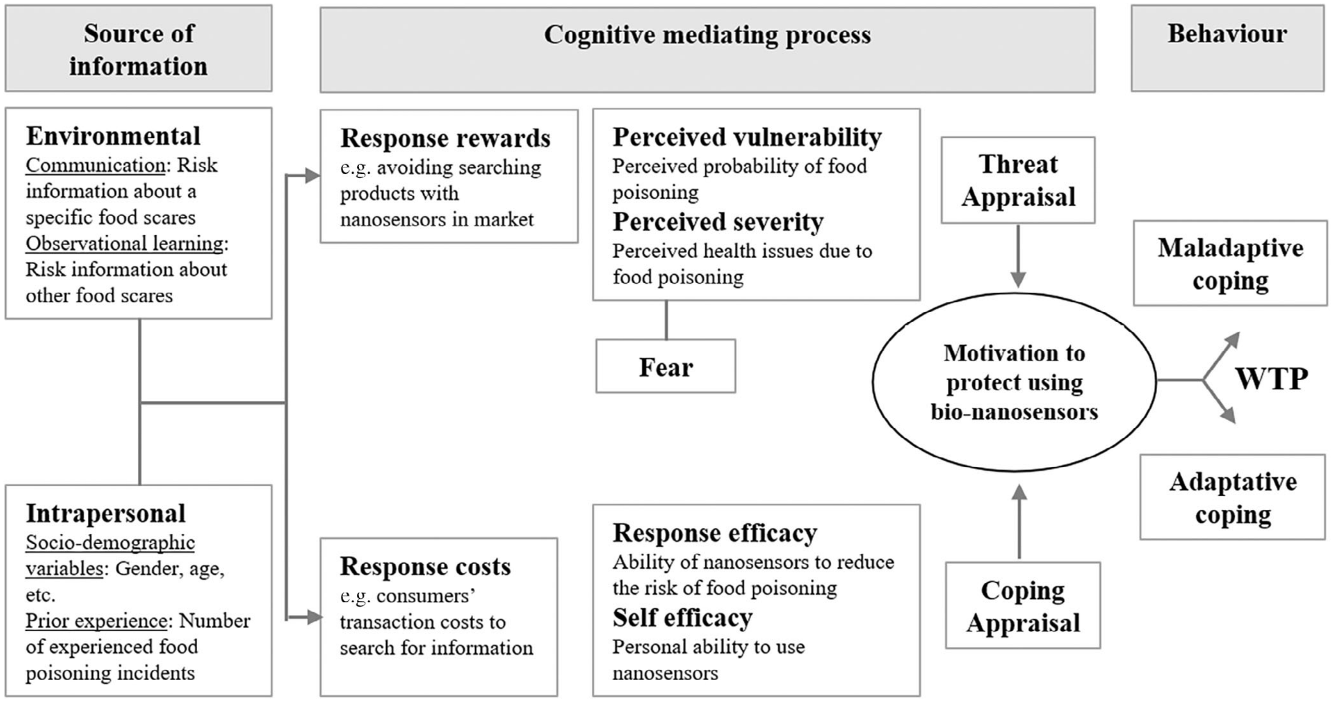

FIGURE 1 The conceptual framework of PMT adapted to our empirical application

to use biosensors) (Boer & Seydel, 1996). The PMT conceptual framework also includes rewards associated with maladaptive responses and costs associated with adaptive responses, which were integrated in a later revision of PMT (Maddux & Rogers, 1983). Rewards can be either intrinsic or extrinsic and represent the benefits of not following persuasive information (e.g., avoiding searching products with smart sensors in the marketplace). Costs are instead represented by any physical or psychological disadvantages following the persuasive recommendation (e.g., information transaction costs faced by consumers). Studies conducted to explore the impact of fear-arousing communication on the acceptance of the proposed adaptive behaviour show that increases in the perceived level of fear and perceived response efficacy increase the intentions to select the adaptive response (Floyd et al., 2000; Sutton, 1982).

In the food-safety literature, Scarpa and Thiene (2011) found that when participants doubted that the recommended behaviour (purchasing organic food) could reduce health risks (low perceived response efficacy), they enacted fear control (no behavioural change) instead of risk control (performing the recommended behaviour). In contrast, consumers' acceptability of the recommended behaviour increased when they perceived such behaviour to be effective in reducing health risks, that is, high perceived response efficacy. PMT was also used to determine the efficacy of four food-handling behaviours: cooking food properly, reducing cross-contamination, keeping food at the correct temperature and avoiding unsafe foods. Findings showed that self-efficacy was the most consistent factor influencing respondent's uptake of these food-handling recommendations (Mullan et al., 2016). Finally, an extended version of PMT was implemented to investigate consumers' intentions to make safer food choices. The extended PMT included the public's perceived food risk management quality and perceived product safety liability of food providers involved in food safety scandals alongside standard elements of the PMT. These new factors as well as perceived vulnerability and perceived self-efficacy contributed to behavioural change (Chen, 2016).

2.3 | Cognitive-behavioural responses of PMT and hypotheses

To create cognitive-behavioural responses we borrow the hypotheses developed by Witte and Allen (2000) for the extended parallel process model on how different combinations of levels of threat and coping appraisal (elements included also in PMT) influence people both for the adoption of the proposed protective behaviour and for WTP for meat marketed with biosensors. According to Witte and Allen (2000), these different combinations can generate the following four behavioural responses: *no response*, *fear control*, *low response* and *danger control* (Figure 2).

As illustrated in Figure 2, *no response* occurs when individuals score low on both dimensions of this conceptual framework. They do not feel at risk and do not consider coping with the danger. People belonging to this segment appear to be indifferent to risk messages and do not change their behaviour and their WTP for smart biosensors should be very close to zero in the absence or presence of risk. *Fear control* arises when people score high on threat appraisal and low on coping appraisal. Thus, even if people are scared by the food safety incident, they do not believe that available information and/or

FIGURE 2 Behavioural outcomes of the PMT cognitive process

		Threat appraisal (TA)	
		Low TA	**High TA**
Coping appraisal (CA)	**Low CA**	*No Response* (*No behavioural change*) People do not feel at risk and do not consider coping with the danger anyway.	*Fear control* (*Maladaptive coping behaviour*) People are scared but they do not believe they will cope with the danger.
	High CA	*Low Response* (*Adaptive coping behaviour*) People are not so scared but they believe that they will cope with the danger.	*Danger control* (*Protective behaviour*) People are determined to take protective action to avoid or reduce the threat.

resources (e.g., smart biosensors) can help them to cope with the food safety scare and thus, also in this case, their WTP should be very close to zero in the absence or presence of risk. This group is likely to adopt maladaptive coping behaviour, which is inferior to adaptive action. *Low response* happens when people score low on threat and high on coping appraisal. People belonging to this segment are not particularly afraid of foodborne outbreaks. However, they could implement adaptive coping behaviour because they believe that available information and/or resources can help them to cope with the food safety incident and therefore their WTP for the adoption of protective behaviour is likely to be positive especially in a situation of risk. Finally, *danger control* occurs when people score high on both threat and coping constructs. People placed in this segment are determined to take on protective behaviour to reduce or eliminate health risks of food borne pathogens in meat products and thus their WTP for smart biosensors should be positive and higher than that observed in the previous groups.

Therefore, to answer our research questions we state the following research hypotheses.

> **Hypothesis A** (HA): In the absence of risk, the importance of the items that characterize the PMT's latent dimensions is different from the significance of those that identify PMT's constructs in presence of risk.

> **Hypothesis B** (HB): Participants' scores of the threat and coping appraisal dimensions in a situation of risk are higher than those observed in absence of risk.

> **Hypothesis C** (HC): The percentage of participants who are willing to buy meat marketed with smart biosensors in a situation of risk is higher than that observed in absence of risk.

> **Hypothesis D** (HD): Consumers' willingness to pay for smart sensors in a situation of risk is higher than that observed in absence of risk for all behavioural outcomes of the PMT cognitive process illustrated in Figure 2.

3 | METHODS

To investigate the extent to which different risk messages regarding a food safety incident affect consumers' motivation to make safer choices by purchasing meat products with smart biosensors, we designed a quasi-experimental contingent valuation (CV) survey. The survey aimed to gather information about all elements of the PMT framework illustrated in Figure 1, namely, sources of information, cognitive mediating processes and purchasing behaviour.

3.1 | Sources of information

PMT distinguishes environmental from intrapersonal sources of information. Environmental information can be exogenously provided in the form of risk communication or acquired via 'observational learning'. To investigate how different risk messages regarding a food safety incident affect consumers' WTP for meat products marketed with smart biosensors, a sample of the population of British consumers was split into three groups as described above. Each group received a different risk message: (i) in the NRI group, respondents did not receive any news on the food-safety incident; (ii) in the LRI group, respondents were informed that there was a moderate health risk due to a food-safety incident and (iii) in the HRI group, respondents were informed that there was a severe health risks due to a food-safety incident. This design allows researchers to explore whether different elements of PMT affect consumers' response to different threatening messages.

In the NRI treatment, participants were not provided with any information regarding the number of people hospitalized or who had died because of food poisoning caused by an *E. coli* outbreak in the United Kingdom. In the LRI treatment group, the message reported that '…following the *E. coli* outbreak only 10 people in the UK had been admitted to hospital and that there will be a 50% chance that the number of contaminated chickens in your supermarket will be 10 out of 100'. In the HRI treatment group, respondents were informed that '…in the days following the scare more information will be available from mass media. They report that following this outbreak 100 people in the UK had been admitted to hospital and 10 people had died after having consumed food that was probably contaminated. Media also report that there would be a 50% chance that the number of contaminated chickens in supermarkets would be 20 out of 100.'

Respondents were also asked to report both which media they generally used and trusted most to follow food-safety information and their personal experience with food safety incidents. Both groups also received information regarding how to cope with risk as illustrated in the next section.

3.2 | The operationalization of the cognitive mediating process

Considering the lack of research on the exploration of individuals' cognitive-behaviour towards reactions to food safety incidents using PMT, the items of the various PMT components were developed following examples of wording provided both in review papers and studies investigating health aspects of food (Cox et al., 2004; Henson et al., 2010; Milne et al., 2000; Scarpa & Thiene, 2011; Wurtele & Maddux, 1987) and adapting them to the context of this investigation. In the survey, all the elements of the PMT cognitive mediating process (Figure 1) were measured on a five-point Likert scale other than vulnerability which was measured on a five-point itemized rating scale ranging from 'extremely unlikely' to 'extremely likely'. Perceived vulnerability was measured using three questions capturing: (i) respondents' beliefs regarding the likelihood of eating meat products contaminated by *E. coli*, (ii) being hospitalized because of food poisoning due to *E. coli* and (iii) dying because of food poisoning due to *E. coli*. Perceived severity was measured by asking respondents to express their level of agreement on the following statements: (i) eating meat contaminated by *E. coli* can cause temporary health problems such as nausea, vomiting etc., (ii) eating meat contaminated by *E. coli* can seriously damage health and (iii) health problems caused consuming meat contaminated by *E. coli* can reduce life expectancy. Fear was measured eliciting respondents' level of concern regarding: (i) the safety of meat they usually buy, (ii) the safety of meat they usually cook and (iii) the safety of meat they usually eat.

Response efficacy captured information related to two protective risk-reducing tools: the 'five keys to safer food' poster and smart biosensors in food packaging. The 'five keys to safer food' poster was developed by the WHO in 2001 (https://www.who.int/foodsafety/publications/consumer/en/5keys_en.pdf) with the scope of educating consumers to minimize food-born risks. Its core messages are: (i) keep clean; (ii) separate raw and cooked; (iii) cook thoroughly; (vi) keep food at safe temperatures and (v) use safe water and raw materials. Figure 3 illustrates the information that was presented to respondents regarding how smart biosensors were developed and how they work.

Perceived response efficacy was evaluated asking respondents to express their level of agreement on the following statements: (i) the application of the 'five keys to safer food' removes the risk of eating meat products contaminated by *E. coli*; (ii) food products containing biosensors can remove the risk of eating meat products contaminated by *E. coli* and (iii) unchanged colour of biosensors definitely shows that meat products are free from *E. coli* contamination.

Three questions were also used to investigate respondents' perceived self-efficacy. These questions explored whether they believed that they were capable of: (i) performing the 'five keys to safer food', (ii) finding supermarkets selling meat products packaged with smart biosensors and (iii) noticing the smart biosensor colour change to detect the presence of *E. coli* in meat products.

The cost associated with the adaptive response was measured using a CV, a widely used technique employed in non-market valuation studies. This technique required the development of hypothetical market scenarios where respondents had to express their maximum WTP for whole chicken (1 kg) marketed with smart biosensors.[3] WTP was elicited using a two-step payment card. During the first step, respondents had to express their intention to buy the whole chicken the day after a food scare on a four-point scale: (i) I would certainly buy; (ii) I would probably buy; (iii) I would probably not buy and (iv) I would certainly not buy. In the second step, participants who did not intend to buy these products had to indicate the reasons for which they were not willing to buy meat products packaged with biosensors. The inclusion of this question was important to discriminate protest responses towards a price increase. Instead, participants who stated their intention to buy these products were redirected to the payment that allowed them to state their maximum WTP from a range of monetary values as if they were shopping around comparing different prices for a certain good (Bateman et al., 2005; Donaldson et al. 1997).[4] Respondents were asked to state the maximum additional amount of money (in £) that they were willing to pay for the whole chicken (1 kg) packaged with smart biosensors. They were informed that a whole 1 kg chicken marketed without smart biosensors was on sale at £ 6.00. The payment card contained prices ranging from £0.05 to £3.00 in £0.05 increments. They also had the option to 'pay more than £3.00'. If this option was chosen, they were asked to specify their maximum WTP. Before responding, they were reminded that spending more on this product would leave them with less money to buy or pay for other goods and services (Bateman et al., 2005).

3.3 | Modelling PMT latent dimensions and WTP for biosensors

Despite being a well-established conceptual framework, the validation of PMT latent dimensions via factor analysis was necessary to test our hypothesis and to work out the latent scores used in the econometric analysis. Thus, the PMT's latent dimensions included in the

Nanotechnology is a new technology that uses very small particles. These nanoparticles are a thousand times smaller than the size of a particle of sand. One of the potential applications of nanotechnology in the food sector is in the development of new packaging materials such as biosensors that can increase the safety of the food that we consume.

Packaging containing biosensors is capable communicate to consumers whether a bacterial infection develops in the food that they have purchased. Essentially these nanosensors are stickers that change their colour or flash a light when pathogens develop in the food that you store at home. Pictures below show how these nanosensors can communicate consumers the presence of E. coli in meat products.

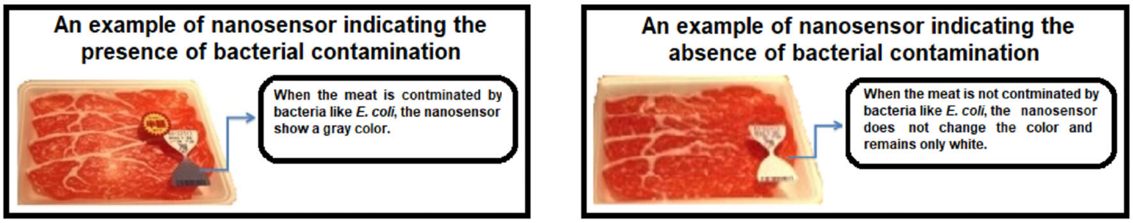

FIGURE 3 Biosensors indicating presence/absence of bacterial contamination

econometric investigation were captured performing a factor analysis for each treatment group investigated in this study. The viability of factor analysis was evaluated according to the significance of the χ^2 value obtained for the Bartlett test of sphericity and the value of the Kaiser-Meyer-Olkin measure of sampling adequacy (≥0.6). Latent dimensions were retained when the eigen values of the extracted values were >1 and the total variance explained by extracted PMT dimensions was >60% (Malhotra, 2010). PMT's dimensions were extracted using the varimax rotation method to keep the orthogonality between the latent constructs of the cognitive process undertaken by participants in three different simulated markets. This was an important aspect to avoid problems of multicollinearity that might arise when using these factors in subsequent econometric analysis of consumers' WTP for biosensors.

The scores of the identified PMT latent dimensions were calculated through the following general form equation:[5]

$$F_j = \beta_1 I_1 + \beta_2 I_2 + \ldots + \beta_n I_{1n} \tag{1}$$

In Equation (1), F is the identified PMT factor (latent construct), j is an index ranging from one to n latent dimensions, the β_n represent the factor loadings on the identified components of the rotated matrix and the I_n are the raw scores assigned by respondents to the items of the PMT conceptual framework when they filled in the questionnaire. Thus, hypothesis A was assessed evaluating whether the j PMT latent dimensions identified in the absence or presence of risk were similar or different as follows:

$$HA_0: PMT_{j,NRI} = PMT_{j,RI};$$
$$HA_1: PMT_{j,NRI} \neq PMT_{j,RI}.$$

Hypothesis B was verified running an independent sample t-test on the weighted j PMT latent dimension scores identified with and without risk as follows:

$$HB_0: F_{j,NRI} \geq F_{j,RI};$$
$$HB_1: F_{j,NRI} < F_{j,RI}.$$

Hypothesis C was tested via a chi-square test comparing the proportion of participants who were willing to buy meat marketed with biosensors in absence of risk ($\mathbf{P_{NRI}}$) with that observed in presence of risk ($\mathbf{P_{RI}}$) as follows:

$$HC_0: P_{NRI} \geq P_{RI};$$
$$HC_1: P_{NRI} < P_{RI}.$$

To test Hypothesis D, the identified PMT's latent dimensions were used in the econometric analysis of consumers' WTP a premium price for meat products marketed with smart biosensors. Given the left censored nature of our dependent variable ($y^* = WTP$), tobit regression models were estimated for our different treatment groups (Tobin, 1958). In the set of our independent variables, we included the four PMT latent dimensions identified via factor analysis: copying appraisal (*CA*), fear (*FEAR*), perceived severity (*PS*) and perceived vulnerability (*PV*). In addition, we checked for the following socio-demographic variables: (i) *FEMALE* indicating whether respondents are female or not; (ii) *EDU_HS*, *EDU_UG* and *EDU_PG* indicating whether respondents, respectively, obtained a high school diploma (or lower level of education), an undergraduate degree or a postgraduate degree; (iii) *AGE_1*, *AGE_2*, *AGE_3* and *AGE_4* indicating whether respondents were, respectively, younger than 24 years of age, were between 25 and 44, were between 45 and 64, or were older than 64; (iv) *HH_SIZE* indicating the size of the household; (v) *EMP* indicating whether respondents are employed or not; (vi) *WELL_D*, *WELL_M* and *WELL_G* indicating whether respondents self-reported level of wellbeing was difficult, modest or good. Furthermore, the model also included the following shopping habits of respondents: (i) *PRICE* indicating the price per kilo that respondents generally pay for whole chicken; (ii) *EXP* indicating the number of times respondents have experienced illness due to food poisoning and (iii) *KNOW* indicating if respondents have ever heard about nanotechnologies before the study.

Finally, the distributions of the estimated participants' WTP were compared across the four possible behavioural responses ('no response', 'low response', 'fear control' and 'danger control') presented in Figure 2.

These four responses were generated standardizing the individuals' scores (*i*) of the *j* PMT latent dimensions, using the following approach:

$$Z_{i,j} = \left(F_{i,j} - \overline{F}_{i,j}\right)/s\left(F_{1,j}\right). \tag{2}$$

In Equation (2), $Z_{i,j}$ is the standardized score of the latent dimension *j* for individual *I*; $F_{i,j}$ is the calculated score of the latent dimension *j* for individual *i*; $\overline{F}_{ij}$ is the average of the sample's calculate scores and $s\left(F_{1,j}\right)$ is the standard deviation of the sample's calculate scores. Negative standardized scores ($Z_{i,j} < 0$) identify low levels of threat and copying appraisal, while non-negative scores ($Z_{i,j} \geq 0$) correspond to high levels. Combinations of low and high scores allowed to segment respondents across the four Witte's cognitive-behavioural responses illustrated in Figure 2.

Expected WTP values were predicted from Tobit model estimations and compared across respondents of the four cognitive-behavioural responses *k* and across treatment groups *q* using independent sample t-tests. Thus, hypothesis D was tested in the following way:

$$HD_0: WTP_{k,q} \geq WTP_{k-1,q-1};$$
$$HD_1: WTP_{k,q} < WTP_{k-1,q-1}.$$

3.4 | Sampling and data collection

Sampling and data collection were conducted by the Qualtrics market research company. The final sample size consisted of 627 with each treatment group consisting of 209 respondents. Respondents were randomly assigned to treatment groups. The final sample and each treatment group were representative of the reference population in terms of gender and age. The study received ethical approval from the Ethics Committee of the University of Reading. The survey was piloted at the beginning of February 2015 with 60 respondents and ended in April 2015.

4 | RESULTS

Results presented in this section focus on the influence of Witte's (1992) four possible categories of behavioural responses (i.e., no response, fear control, low response and danger control) on premium prices that respondents were willing to pay for meat packaged with biosensors when information on a health hazard due to food contamination was provided and when it was not provided. Analyses comparing respondents' WTP across the three treatment groups (NRI, HRI and LRI) showed that there were no statistically significant differences in PMT latent dimensions and WTP between LRI and HRI. These results suggest that respondents react to any message signalling risk, independently of the magnitude of the risk presented in the message. Therefore, in this section, only results from analyses comparing NRI and 'risk information' (RI) groups are presented. The latter include subjects from the LRI and HRI groups.

4.1 | Socio-economic characteristics and shopping habits of respondents

The socio-economic characteristics of the sample are very similar across the NRI and RI treatment groups. In both groups, 50% of respondents were female, 14% were under the age of 25, 42% were aged between 25 and 44, 26% between 45 and 64 and 18% older than 64. These distributions match the composition of the British population in 2013 (Office for National Statistics, 2015). In terms of education, 52% of respondents had a high school diploma, 30% had an undergraduate degree and 18% a postgraduate degree. Approximately 14% of respondents declared that their financial situation (household income) was difficult, 50% said that it was modest, and 36% answered that it was reasonably good or even better. Nearly 60% of respondents were employed, 17% retired, 10% looking after the home, 7% unemployed and 6% students. Conventional chicken products were the most preferred (52%), followed by free range (32%) and organic products (16%), and about 90% of participants stated that they purchase 1 kg of chicken for <£ 6.

4.2 | Latent dimensions of the NRI and RI cognitive mediating process

Table 1 illustrates the descriptive statistics of the 15 variables (items) used to identify PMT latent dimensions by treatment group: *FEAR*, *PS* (perceived severity), *PV* (perceived vulnerability), self-efficacy (*SELF*) and *RESP* (response efficacy).

The latent dimensions of PMT identified via factor analysis were: *CA*, *FEAR*, *PS* and *PV* with the SELF and RESP components enclosed in CA. These results were supported by the significance of the Bartlett's test of sphericity of the NRI (approximate $\chi^2 = 1398$; $df = 105$; $p = 0.0001$) and RI (approximate $\chi^2 = 2587$; $df = 105$; $p = 0.0001$) groups. In both groups, the null hypothesis that in the population there is absence of correlations among PMT items was rejected. This was also confirmed by the Kaiser–Meyer–Olkin measure of sampling adequacy which is well above the minimum threshold of 60% for the NRI (72%) and RI (74%) treatment groups.

Table 2 shows the results of the rotated component matrix. The four latent dimensions that were extracted for NRI and RI groups explained 64% and 62% of their total variance, respectively. Even if the order of extraction is not the same between the two groups, it is interesting to observe the consistency in terms of importance of the items of the PMT components in the two different contexts of risk information. Items load high on the four identified components more or less in the same way irrespectively of whether respondents were expressing their evaluations in the absence or presence of risk and thus our results support HA_0. Moreover, in NRI group, *CA* is the most important latent dimension characterizing respondents' cognitive process. *FEAR* is the second most important latent component, followed by *PS* and *PV*. On the other hand, in the RI group, *FEAR* becomes the most important latent dimension followed by *CA*, *PS* and *PV*.

TABLE 1 Descriptive statistics of PMT variables across treatment groups

PMT latent dimensions	Variables	Items	NRI mean[a]	RI mean[a]
FEAR	$Fear_1$	I am very concerned about the safety of the meat I buy usually.[b]	3.11 (1.23)	3.68 (1.12)
	$Fear_2$	I am very concerned about the safety of the meat I cook usually.[b]	3.14 (1.32)	3.60 (1.20)
	$Fear_3$	I am very concerned about the safety of the meat I eat usually.[b]	3.17 (1.27)	3.69 (1.17)
PS	Sev_1	Eating meat contaminated by bacteria such as *E. coli* can cause temporary health problems such as nausea etc.[b]	4.35 (0.73)	4.41 (0.72)
	Sev_2	Eating meat contaminated by bacteria such as *E. coli* can seriously damage health.[b]	4.04 (0.85)	4.18 (0.827)
	Sev_3	Health problems caused consuming meat contaminated by bacteria such as *E. coli* can reduce life expectancy.[b]	3.40 (1.03)	3.51 (1.01)
PV	$Vuln_1$	How likely or unlikely is that I eat meat products contaminated by *E. coli*.[c]	2.68 (1.11)	2.89 (1.11)
	$Vuln_2$	How likely or unlikely is that if I eat meat contaminated by *E. coli* I will be hospitalized.[c]	3.16 (1.07)	3.23 (1.06)
	$Vuln_3$	How likely or unlikely is that if I eat meat contaminated by *E. coli* I will damage permanently my health.[c]	2.48 (1.09)	2.59 (1.06)
SELF	$Self_1$	I am capable of performing the 'five keys to safer food' shown in the picture above.[b]	4.51 (0.63)	4.47 (0.67)
	$Self_2$	I am capable of finding supermarkets selling meat products containing biosensors in the packaging.[b]	3.64 (0.99)	3.65 (1.00)
	$Self_3$	I am capable of noticing the biosensor colour change to detect the presence bacteria in my meat products.[b]	4.29 (0.76)	4.30 (0.75)
RESP	$Resp_1$	I believe that the application of the 'five keys to safer food' removes the risk of eating contaminated meat products.[b]	4.01 (0.83)	4.03 (0.83)
	$Resp_2$	I believe that food products containing biosensors can remove the risk of eating contaminated meat products.[b]	3.91 (0.83)	4.03 (0.82)
	$Resp_3$	I believe that the unchanged colour of biosensors definitely shows that meat products are not contaminated.[b]	3.67 (0.90)	3.75 (0.91)

[a]In brackets standard deviations.
[b]Items measured on a five-point Likert scale ranging from 'completely disagree' to 'completely agree'.
[c]Items measured on a five-point rating scale ranging from 'Extremely unlikely' to 'Extremely likely'.

These results indicate that risk communication on health hazards delivered during a food safety incident triggered *FEAR* as the most import factor of the cognitive process. In contrast, when risk information was not provided CA is the most important latent component, indicating that respondents were primarily guided by their perceived efficacy of biosensors and their confidence in the adoption of WHO recommendations to protect themselves from food hazards.

The loading factors of the rotated matrix were used to calculate the scores of PMT latent dimensions as indicated in Equation (1). Table 3 shows that on the average *CA* is 17.86 and 17.34 in the NRI and RI scenarios, respectively, and this difference is significant to the independent sample *t*-test ($t = -2.66$; $df = 625$; $p = 0.08$). *FEAR* is higher when risk information is provided (NRI = 11.27, RI = 13.55) and this difference is significant to the independent sample *t*-test ($t = -7.84$; $df = 625$; $p = 0.001$). Risk communication appears to have a very limited effect on *PS* (NRI = 13.91, RI = 14.19), while it does influence *PV* substantially (NRI = 6.93, RI = 9.07) as shown by the results of the independent sample *t*-test ($t = 11.24$; $df = 625$; $p = 0.001$). In the light of these results, we reject partially HB because in a situation of risk only participants' scores of *FEAR* and *PV* are higher than those observed in absence of danger.

4.3 | WTP for biosensors and relative differences in behavioural responses

Most respondents were willing to buy meat marketed with biosensors in both groups (NRI = 83.3%, RI = 84.4%) and thus on the basis of the results of a chi-square test ($\chi^2 = 0.139$; $df = 1$; $p = 0.709$) we reject HC. However, the average WTP for the new technology was higher in the RI (£0.91, s = £0.72) than in the NRI group (£0.82, s = £0.68). These results suggest that even if the new technology attracts potential buyers in both groups, the provision of risk information leads participants to pay a higher premium price.

Table 4 shows the estimated parameters of the Tobit models for the two treatment groups. The estimated coefficients related to the

TABLE 2 PMT factors of the rotated component matrix of the two treatment groups

	NRI factors					RI factors			
PMT items	CA	FEAR	PS	PV	PMT items	FEAR	CA	PS	PV
$Resp_2$	0.825	0.004	0.128	0.058	$Fear_3$	0.939	0.078	0.084	0.051
$Self_3$	0.687	0.023	0.227	−0.294	$Fear_2$	0.918	0.058	0.125	0.066
$Self_2$	0.660	0.009	−0.120	0.151	$Fear_1$	0.900	0.081	0.129	0.062
$Resp_3$	0.654	0.132	−0.042	0.208	$Resp_2$	0.217	0.709	0.025	0.110
$Resp_1$	0.612	−0.034	0.047	0.020	$Resp_3$	0.220	0.703	−0.111	0.214
$Self_2$	0.551	0.016	0.380	−0.400	$Self_3$	−0.081	0.667	0.366	−0.124
$Fear_3$	0.040	0.950	0.075	0.120	$Resp_1$	−0.046	0.667	−0.106	−0.059
$Fear_2$	−0.012	0.930	0.054	0.179	$Self_2$	0.040	0.560	0.104	0.100
$Fear_1$	0.089	0.914	0.050	0.160	$Self_1$	−0.133	0.511	0.495	−0.194
Sev_2	0.090	0.051	0.850	0.165	Sev_2	0.166	0.046	0.802	0.276
Sev_1	0.030	0.081	0.787	−0.046	Sev_1	0.190	0.005	0.742	−0.063
Sev_3	0.039	0.018	0.691	0.385	Sev_3	0.076	0.009	0.604	0.543
$Vuln_3$	0.117	0.109	0.209	0.849	$Vuln_3$	0.157	0.091	0.094	0.878
$Vuln_2$	0.262	0.191	0.274	0.721	$Vuln_2$	0.234	0.173	0.211	0.765
$Vuln_1$	−0.063	0.161	−0.011	0.288	$Vuln_1$	−0.072	−0.026	−0.048	0.317

TABLE 3 Comparison between NRI and RI descriptive statistics of PMT latent dimensions[a]

	NRI			RI		
PMT latent dimensions	Mean	Min	Max	Mean	Min	Max
CA	17.86 (2.44)	10.82	23.04	17.34 (2.24)	7.79	21.94
FEAR	11.27 (3.57)	4.39	17.78	13.55 (3.36)	4.41	18.94
PS	13.91 (2.06)	6.69	18.00	14.19 (1.96)	6.61	18.11
PV	6.93 (2.24)	1.65	12.89	9.07 (2.25)	2.77	14.71

[a]In brackets standard deviation.

variables indicating PMT latent dimensions suggest that the elements of the cognitive process have a different impact on participants' WTP for biosensors when risk information is provided (RI) or not (NRI). In the NRI group, the coefficient β_{CA} is positive and significant, while β_{FEAR} is not significant. These results indicate that, the higher the *CA* score, the higher the WTP for biosensors. More specifically, if the *CA* score increases by one, participants are WTP £0.17 more for products marketed with biosensors. These results suggest that, when respondents perceived biosensors to be effective in reducing the risk of food poisoning, they were willing to pay higher price premiums. The FEAR component, that is very low in the NRI group according to factor analysis, does not have an impact on WTP when the risk information is not provided.

On the other hand, in the RI group, results are substantially different. The coefficient β_{CA} does not influence WTP anymore, while β_{FEAR} becomes positive and statistically significant, suggesting that, the higher the FEAR score, the higher the WTP for biosensors. If the FEAR score increases by 10, participants are WTP £0.70 more for products marketed with biosensors. These results show that *FEAR* becomes an important cognitive dimension when risk information is provided, as already demonstrated by results obtained via the factor analysis.

It is also interesting to observe and compare the opposite signs of the threat appraisal elements in the two groups. In the NRI group, the β_{PS} and β_{PV} coefficients, respectively, show a positive and negative sign, while in the RI segment their signs are reversed. Estimation results suggest that, when the PS score increases by one, the WTP for biosensors increases by £0.18 in the no-risk scenario and decreases by £0.11 in the risk scenario. For the same reason, when the PV score increases by one, the WTP for biosensors decreases by £0.32 in the NRI group and increases by £0.20 in the RI group. From a psychological point of view, these results might be explained by the difference in the average FEAR score constructs observed for the two groups. The average FEAR score of the NRI participants is lower than that of RI respondents and thus in a situation of low fear and absence of risk communication participants are willing to pay less than a situation where they were prompted with risk messages and show high levels of fear.

TABLE 4 Determinants of WTP for biosensors[a]

Variables	NRI model *Beta values*	RI model *Beta values*
PMT constructs		
CA	**0.17** **(5.03)*****	0.01 (0.23)
FEAR	−0.03 (1.32)	**0.07** **(4.03)*****
PS	**0.18** **(3.98)*****	**−0.11** **(3.40)*****
PV	**−0.32** **(7.13)*****	**0.20** **(7.63)*****
Demographic and socio-economic characteristics		
FEMALE	0.04 (0.32)	−0.13 (1.50)
EDU_UG	0.14 (1.04)	0.05 (0.63)
EDU_PG	0.10 (0.48)	0.21 (1.52)
AGE_2	−0.04 (0.52)	**−0.20** **(2.16)****
AGE_3	−0.20 (1.46)	−0.14 (1.58)
AGE_4	0.19 (1.31)	−0.05 (0.65)
HH_SIZE	0.18 (1.33)	0.03 (0.30)
EMP	0.25 (1.43)	0.01 (0.07)
WELL_M	−0.21 (1.46)	−0.04 (0.44)
WELL_G	**−0.47** **(2.98)*****	0.10(1.04)
Shopping experiences		
PRICE	**0.10** **(2.06)****	**0.06** **(1.79)***
EXP	−0.06 (0.93)	0.02 (0.49)
KNOW	**−0.28** **(2.07)****	**0.18** **(2.06)****
Intercept	**−3.38** **(5.14)*****	**−1.16** **(2.95)*****
Model statistics		
Loglikelihood	−444.08	−659.94
Sigma	1.209***	0.973***
Mean WTP	−£0.35	£0.34
Median WTP	−£0.41	£0.32

[a]In brackets *z* values, *, ** and ***indicate significance at $p < 0.05$, $p < 0.001$ and $p < 0.0001$, respectively.

Furthermore, the coefficient β_{PV} is negative and statistically significant, indicating that, the more vulnerable respondents feel, the lower is their WTP. This result may be driven by the fact that respondents are confident that the use of biosensors reduces the probability of experiencing the negative health effects due to food contamination. On the contrary, in the RI group, their WTP increases, when they believe that they are more vulnerable to risk. In this case, results may be driven by the fact that information makes respondents feel more vulnerable, even if they are not confident that biosensors will be able to reduce the probability of experience the negative health outcomes due to food contamination.

Estimation results on socio-demographic and shopping habits are briefly discussed because these are only functional to the estimation of WTP that will be used to compare premium prices across the four possible behavioural responses of threat and copy appraisal cognitive strategies hereafter (as discussed by Witte, 1992). Socio-economic characteristics barely effect premium prices for biosensors in the treatment groups. Shopping habits appear to have a stronger influence on WTP. The coefficient β_{price} was positive and statistically significant in both scenarios, suggesting that, when the price (per kilo) generally paid for whole chicken increases, the price premium for biosensors increases. The coefficient β_{know} is negative in the NRI treatment group, while it is positive in the RI segment. Respondents who heard about biosensors developed using nano-technology were not willing to pay a premium for biosensors when risk information was not provided because they did not perceive the benefits of biosensors.

Furthermore, participants' cognitive and purchasing behavioural responses to take protective action were analysed using different approaches. First, we compare the percentage of the samples responding to health hazards according to each cognitive-behavioural response. Second, we visually compare WTP estimates using kernel density distributions. Third, we test HD working out whether differences across WTP estimates are statistically significant to independent sample *t*-tests.

The percentage of respondents belonging to the four behavioural groups is presented in Figure 4. For NRI, the smallest percentage of respondents reacted accordingly to the 'fear control' response (4.8%) and the largest to the 'no response' (36.8%) and 'low response' (32.1%). A large number of respondents was associated to the 'danger control' response too (26.3%). These results suggest that respondents' motivation to protect themselves from food hazard was quite high (58.4%) when risk information was not provided (danger control plus low response).

When information was provided, the largest groups of subjects reacted accordingly to the 'danger control' (33%) and 'no response' behaviour (30.4%). This suggests that psychological response is quite polarized: respondents react either very strongly or very weakly to food hazards when risk information is delivered. Also, the percentage of respondents whose psychological response is in line with 'fear control' is much higher when information is provided than when information is not available (24.2% against 4.8%). This indicates that fear becomes predominant when respondents were exposed to risk information. In contrast, the percentage of 'low responses' was lower when risk information was delivered (12.4% against 32.1%). Thus, in the risk scenario the number of participants willing to adopt precautionary behaviour (45.4%) is lower than NRI.

These findings seem to indicate that in both scenarios the number of people willing to adopt protective behaviour is relatively high and thus in line with consumers' acceptance of the new technology. However, also in this case when the proposed protecting behaviour is mediated by the price that participants have to pay for biosensors we observe interesting differences. In general, in the NRI group, the estimated price premiums for biosensors show negative peaks, while in the RI, price premiums for meat packaged with biosensors shows a clear peak at £0.39. Similar results were found in some studies investigating consumers' attitudes towards GM food (Collart & Interis, 2018; Hu, 2006) where negative WTP for innovative food can be explained by consumers' adoption of the precautionary principle or aversion to uncertainty. In this study, negative WTP for the new technology can be explained by the low level of observed fear in the RI scenario that does not induce consumers to pay for protection. This difference was explored more in detail comparing the density kernel distributions of price premium between the two treatment groups for each cognitive-behavioural response as illustrated in Figure 4.

The comparison of the estimated WTP distributions of these four segments shows that for the risk scenario there is always a unique WTP positive peak, while for NRI the peaks are all negative other than in the case of 'low response'. The highest WTP peaks were observed when a situation of 'danger control' (£0.76) and 'fear control' (£0.52) took over in the cognitive mediating process simulated by the food safety incident. Figure 4 also shows interesting differences between the estimated biosensors' WTP of the NRI and RI scenarios with the highest deltas observed for the 'fear control' ($\Delta = £1.18$) and 'danger control' ($\Delta = £0.97$) behavioural responses.

Differences in the expected value of these distributions were tested performing four independent sample *t*-tests. Results of the *t*-tests (Table 5) indicate that WTP for biosensors observed in NRI are statistically significantly higher than RI, other than for subjects associated with the 'no response'. These results indicate that when information is available, 'fear control' and 'danger control' induce consumers to adopt protective behaviour even if they have to pay more to protect themselves. Respondents whose reaction to health risk was weak (low response) displayed the opposite purchasing behaviour. They were willing to pay less for meat products packaged with biosensors when information was provided. These respondents

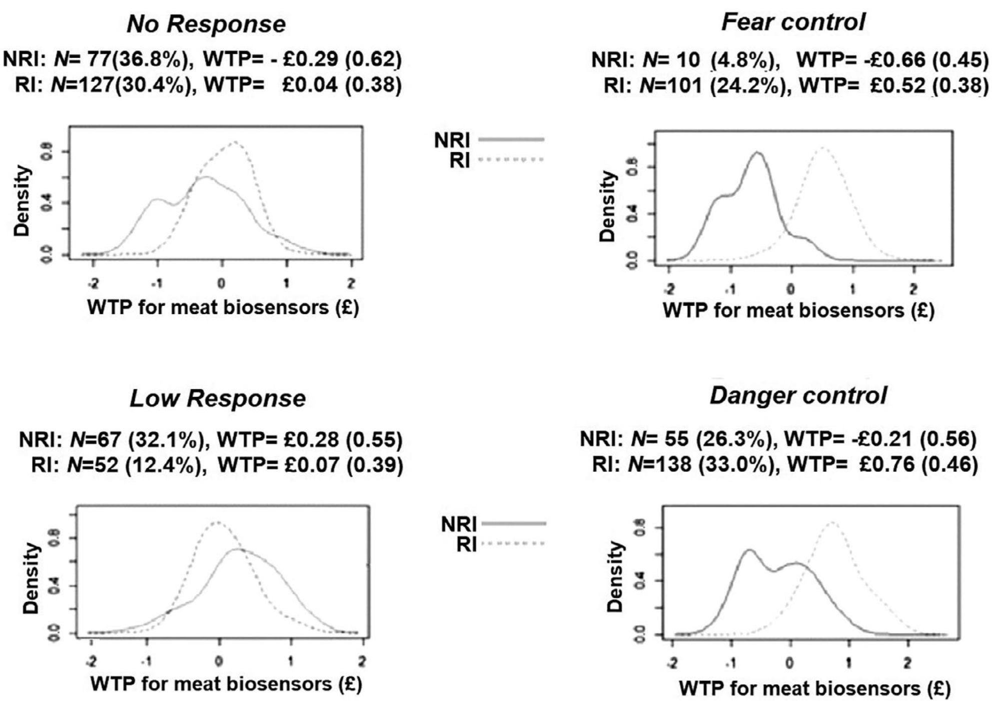

FIGURE 4 Comparison of biosensors' WTP estimates by cognitive-behavioural groups

TABLE 5 WTP differences by treatment groups and behavioural responses

Hypotheses	Behavioural responses	Sample size	*Degrees of freedom*	*t* statistic
H_0: $WTP_{NRI} = WTP_{RI} H_1$: $WTP_{NRI} \neq WTP_{RI}$	No response	204	202	−2.31**
H_0: $WTP_{NRI} = WTP_{RI} H_1$: $WTP_{NRI} \neq WTP_{RI}$	Low response	119	117	3.28***
H_0: $WTP_{NRI} = WTP_{RI} H_1$: $WTP_{NRI} \neq WTP_{RI}$	Fear control	111	109	−13.02***
H_0: $WTP_{NRI} = WTP_{RI} H_1$: $WTP_{NRI} \neq WTP_{RI}$	Danger control	193	191	−11.50***

Note: ** and ***indicate significance at $p < 0.001$ and $p < 0.0001$, respectively.

do not perceive the biosensors to be effective in mitigating the food hazard (low levels of coping appraisal) and therefore they were not motivated to pay more to protect themselves.

5 | DISCUSSION

5.1 | Theoretical contributions and implications

As far as we know, there are no studies that have explored how PMT elements affect WTP for food packaging technology that can help consumers to adopt protective behaviour at post-purchase level or during a food safety incident. Thus, this study extends previous research on how individuals relate to the risk of food safety scares in three ways. First, this is the only attempt to compare how the elements of PMT have an impact on the adoption of preventive behaviour in absence and presence of risk. Second, it incorporates elements of a fear arousal model (PMT) into a CV survey designed to elicit consumers' WTP for smart biosensors improving their post-purchase food-safety decisions. Third, to the best of our knowledge, this is the first study to test hypotheses developed by Witte's extended parallel processing model (Witte & Allen, 2000) on how different combinations of levels of threat and coping appraisals predict people's monetary responses to threatening messages.

The combination of the proposed model of fear appeal and contingent valuation technique has revealed interesting aspects of consumers' cognitive and purchasing behavioural responses to meat marketed with smart biosensors under different risk situations. The application of PMT has shown that the cognitive process of participants and their perceived risk of food hazards do not differ significantly when messages convey low or high levels of risks. In the case of food safety incidents, it is likely that fear and the elements of threat appraisal dominate the PMT cognitive process of consumers who are not capable of discerning between situations of low and high risks. This is a rather common finding in the literature (Hammitt & Graham, 1999; Smith & Desvousges, 1987; Viscusi et al., 1987) and it is well-known that laypeople struggle to understand low probabilities (Frederick & Fischhoff, 1998; Viscusi, 1998). Some studies have shown that people's insensitivity to the extent of risk reductions can be alleviated by visual aids (Corso et al., 2001).

Factor analysis has also confirmed the robustness of PMT as the items contributing to the structure of latent constructs do not change in the absence or presence of risk and therefore Hypothesis A was rejected. However, Hypothesis B was supported by our findings because when the latent scores related to a situation of risk were compared with a normal market situation, differences were observed in terms of the cognitive process. If we consider that according to PMT, increases in perceived severity, perceived vulnerability, response efficacy and self-efficacy significantly facilitate the adaptive behaviour (Floyd et al., 2000), our results indicate that the PMT elements that during a food safety scare rose significantly were fear and perceived vulnerability, while perceived severity remained more or less stable and coping appraisal decreased a little and significantly. This is an interesting result because it indicates that information delivered during food safety scares especially triggers the emotional reaction (fear) and cognitive elements of threat appraisal. PMT elements appear to influence consumers' WTP for smart biosensors in opposite ways in the two analysed scenarios. In a no risk situation, consumers' WTP is influenced by coping appraisal but not by fear, while the opposite outcome was observed in the risk scenario. It was also interesting to observe and compare the opposite parameters signs of threat appraisal elements in the two groups. Fear triggers a strong emotional reaction under the RI scenario and thus participants were willing to pay more to adopt protective behaviour. Therefore, policy makers and other stakeholders involved with risk communication could pay attention particularly to perceived vulnerability when they frame risk messages during a food safety incident caused by a food borne pathogen. This finding is in line both with theories of health behaviour that assume perceived vulnerability as the major motivational force behind precautionary behaviour (Weinstein, 1993) and with empirical studies providing evidence of positive relationships between perceived vulnerability and a wide variety of preventive behaviours in different health contexts (Jansen et al., 2021).

Furthermore, our results show that consumers' acceptance (willingness to buy) of meat marketed with biosensors was very high (about 85%) in both market scenarios and thus Hypothesis C was rejected. However, Hypothesis D was supported by our findings because the analysis of WTP significantly shows that when participants' protecting behaviour was mediated by the price of biosensors, the adoption of the protective behaviour was influenced by this value as the number of participants showing a positive willingness in the absence of risk was only 32.1%, while under a risk situation these estimates were always positive for the four cognitive-behavioural segments even if WTP was nearly zero for the 'no response' and 'low response' groups. These estimates also suggest that in the absence of risk all participants, other than those classified in the 'low response' segment, were not willing to pay for the proposed protective behaviour. Instead, in a situation of risk, fear has an impact on elements of threat appraisal and induce consumers to adopt protective behaviour even if they have to pay more to protect themselves. The highest WTP were observed for participants who were included in 'fear control' (£ 0.52) and 'danger control' (£ 0.76) groups in a situation of risk. The observation that the highest premium for biosensors was observed for the 'danger control' group confirms the solidity of PMT because the higher the TA and CA the higher the WTP to adopt protective behaviour.

Finally, the mismatch between the number of participants willingness to buy and willingness to pay for meat marketed with biosensors raises the question of how reliable and valid the willingness to buy is when the protective behaviour is measured using this measure alone. From a theoretical point view, our findings indicate that willingness to pay seems to be more appropriate than willingness to buy because the intention to perform a certain behaviour can also depend on non-motivational factors like the availability of requisite opportunities and resources like money (Fishbein & Ajzen, 2011;

Sheppard et al., 1988) especially for products that do not exist yet or else are still in a stage of infancy (niche markets).

5.2 | Implications for consumers, retailers and food processors

Consumers might benefit by buying meat marketed with biosensors. This new packaging would allow consumers not only to be assured of the absence of food borne pathogens at the point of purchase but also at post-purchase level. The possibility of consuming highly perishable products taking into account simultaneous information provided by shelf life and smart sensors could allow consumers to save shopping time and reduce food waste. This is because smart biosensors can help consumers to reduce perceived risk subjectivity on the basis of scientific evidence and thus to plan less frequent shopping and reduce waste of high perishable food when they might be unsure about their consumption in proximity of shelf-life expire. Biosensors could also become relevant during pandemic crises like COVID-19 because they can reduce perceived risk in the face of consumers' increasing uncertainty and pressuring demand for safety and thus they can offer marketers and other stakeholders to take advantage of ad hoc pricing strategies (Bresciani et al., 2021; Marozzo et al., 2022).

However, even if the adoption of new technology can impact significantly on food safety management systems and protect consumer health in global food supply chain its implementation still requires more investigation and future works (Nguyen & Li, 2021). Consumers appear to be unaware of smart tags as highlighted by research conducted within the EITFOOD SMART TAGS project (https://www.eitfood.eu/projects/smart-tags-for-improving-consumer-interaction-in-food-value-chain-2020). This is also evident from the literature available on smart packaging technology applied to food products which is rich from a scientific point of view (Yousefi et al., 2019), but still unexplored from a consumer and socio-economic point of view. It is likely that retailers, food manufacturers and other economic agents working along food supply chains find difficult to introduce this technology because if only few consumers are available to buy meat products with biosensors, they might face high marketing costs. There is a need of more cooperation on behalf of retailers and food manufacturers to increase consumers' awareness about the benefits of smart biosensors developing information campaigns and advertising the technology opportunely. In a situation without risk, 'coping appraisal was the most important factor because participants could count on consumers' abilities to adopt recommendations to protect themselves from meat contaminated by food borne pathogens. From this point of view, our results are encouraging because about 32% participants classified in the 'low response' segment were willing to pay £0.28 more for biosensors in a situation of no risk. Thus, considering that the cost of biosensors for large scale production is lower than our estimated premium price, companies investing on smart tags could be rewarded by differentiating their products from competitors because also in absence of risk there might be consumers who are willing to pay a premium price for smart biosensors.

5.3 | Limitations and future research directions

The discussion of theoretical and empirical findings provided with this study contributes to enrich different research areas (clusters 9, 1, 2 and 5) of the *International Journal of Consumer Studies* (Paul & Bhukya, 2021). As a result, these findings serve as a lens for future studies by other researchers who would like to employ PMT not only to investigate aspects of food safety but also other consumers contemporary issues involving pro-environmental and health related behaviours. Other studies could explore more in depth consumers' motivation to protect themselves within the four cognitive-behavioural groups of the PMT cognitive process when the intention to adopt the preventative behaviour is mediated by the availability of economic resources. Knowledge about the characteristics of these four groups can play an important role in understanding consumers' cognitive reactions towards different hazards and thus help both policy makers to frame and channel risk communication messages in a better way. In particular, stakeholders of the food industry could design ad hoc marketing strategies framing risk messages that could persuade more consumers to adopt precautionary behaviour. Such an approach could help stakeholders to mitigate the negative effects of food scares on purchasing behaviour of indicted products caused by social amplifications and alarming news delivered by mass media.

Our research is limited by the lack of studies that both employ fear appeal models in the context of food safety and explore consumers' acceptance and willingness to pay for smart packaging technology. Thus, there is also a need to conduct more studies on consumers' acceptance and willingness to pay for different smart packaging technologies that can improve the quality and safety of food products. Understanding consumers' attitudes and reactions to the introduction of new packaging technology such as freshness indicators, QR ink indicators, smart caps, radiofrequency indicators and so on, can help stakeholders to understand how to satisfy consumers' needs and make food supply chains more sustainable and trustworthy. The use of these innovative packaging labels can also help food regulators and standard/certification bodies to address problems of information failure by ensuring stakeholders not only about the safety of products traded and consumed but also providing clarifications of fraud vulnerability which can enhance traceability, trust and consumers' confidence along food supply chains (Rezazade et al., 2021).

6 | CONCLUSION

Consumers' emotional and cognitive reactions towards food safety issues are strongly influenced by how much government institutions and the food industry can do to guarantee the marketing of safe food (Wilcock et al., 2004). Governmental institutions, the food industry and retailers should work together to reinsure consumers by investing in technology that may help consumers to mitigate fear during a food safety incident, but also to develop appropriate risk communication strategies. Investing in new technology like smart biosensors can add value to food products both in a no risk situation and especially during a food safety incident. Consumer risk communication strategies instead should focus more on the cognitive-behavioural outcomes analysed in this study. While consumers belonging to danger control and fear control segments are determined to adopt protective behaviour and are willing to pay more than other segments, consumers belonging to other groups need appropriate risk communication campaigns to shift towards the same precautionary behaviour. In order to allow such a shift, policy makers should develop campaigns that educate the 'no response' consumers about risk and solutions and the 'low response' segment about risk. However, to adapt risk communication strategies to groups showing different cognitive-behavioural responses more interdisciplinary research needs to be conducted to identify psychographic characteristics of these segments of consumers in order to tailor the most appropriate risk communication strategies for them.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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ENDNOTES

[1] The Theory of Reasoned Action (Fishbein & Ajzen, 1975) and the Theory of Planned Behaviour (Ajzen, 1998) are the most popular expectancy value models (Fishbein & Ajzen, 2011). However, a discussion of these models is beyond the scope of this study.

[2] Consumers' WTP for improved meat safety standards has been evaluated in a few studies (Amfo & Ali, 2020; Erdem, 2015; Lim et al., 2013; Mørkbak et al., 2011), but a discussion of contingent valuation techniques used to estimate consumers' demand for goods and/or services that do not have a market yet is beyond the scope of this study (Bateman et al., 2002).

[3] Meat products with smart biosensors were not available in the United Kingdom when this survey was administered and are not available currently either.

[4] A discussion on strengths and limitation of the payment card compared with other payment vehicles such as single, bound, double bound etc., is beyond the scope of this paper. Interested readers can refer to the relevant literature (Bateman et al., 2005; Donaldson et al., 1997; Smith, 2003).

[5] In the equation, there is no intercept because the identified factors represent the axes of a multidimensional space whose intersection is at zero. For more information on factor analysis (Hair et al., 2008; Malhotra, 2010).

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