Title

Why don't the British eat locally harvested shellfish? The role of misconceptions and knowledge gaps

Authors

Nick Boase[1]*, Mathew P. White[1†], William H. Gaze[1] & Clare Redshaw[1]

[1]European Centre for Environment and Human Health, University of Exeter Medical School, Knowledge Spa, Royal Cornwall Hospital, Truro, Cornwall, TR1 3HD, UK.

*Corresponding author. Email: n.boase@exeter.ac.uk

[†]Email: mathew.white@exeter.ac.uk

Abstract

Although the UK consumes a substantial amount of shellfish, most is imported (e.g. prawns), while locally harvested molluscs and crustaceans (e.g. mussels, crab) tend to be exported. This study aimed to investigate whether a low rate of local shellfish consumption in the UK is due to misunderstandings or knowledge gaps about the potential health and environmental risks and benefits of consumption. Following the Mental Models Approach, the present paper reveals: 1) qualitative results from 26 stakeholder/public interviews which identified 10 key misunderstandings and knowledge gaps, including incorrect beliefs about health risks and a lack of knowledge about the relative environmental benefits compared to other foods (key misunderstandings included some parts of a crab are poisonous if eaten, and the majority of UK shellfish is farmed), and 2) quantitative results from a survey (n = 1,433) that explored the degree to which these misunderstandings and knowledge gaps may influence consumption intentions in the wider UK population. Survey results suggested the number of misunderstandings and knowledge gaps significantly predicted shellfish consumption intentions even after controlling for demographics, food related values, and past consumption behaviour. Path analyses revealed their impact on intentions was partially mediated via Theory of Planned Behaviour variables. Results could inform information campaigns supporting consumers to make more informed decisions regarding a group of foods that are potentially both healthy and relatively environmentally friendly.

Keywords: shellfish, consumers, knowledge, perceptions, mental models, Theory of Planned Behaviour

1. Introduction

Globally, billions of people rely on seafood as a protein source (Food and Agriculture Organisation of the United Nations, 2016). Shellfish is a key component of seafood and provides health and environmental benefits. For example, alongside protein, shellfish also provides nutrients such as poly-unsaturated fatty acids (linked to reduced cardiovascular disease risk, and important for neural development during infancy and childhood); selenium (necessary for immune and reproductive system functioning); and iodine (vital for thyroid hormone production; Givens & Gibbs, 2006; Larsen, Eilertsen, & Elvevoll, 2011; Nesheim & Yaktine, 2007; Weichselbaum, Coe, Buttriss, & Stanner, 2013). Environmentally, shellfish has a lower carbon footprint compared to other protein sources such as beef (Nijdam, Rood, & Westhoek, 2012). In addition to these benefits shellfish can, like many foods, also pose risks to consumers, including infections such as norovirus, and toxins from harmful algal blooms (Bellou, Kokkinos, & Vantarakis, 2013; Hinder et al., 2011; Westrell et al., 2010), and emerging contaminants such as microplastics (Vandermeersch et al., 2015). Despite these risks and because of the benefits, in many coastal nations shellfish production has a long history, and the UK is no exception.

Home to a modern active fishing fleet and aquaculture industry producing a variety of shellfish species, it would be expected shellfish is a staple food for UK consumers (Marine Management Organisation, 2016). However this is not the case: the UK Government's national food consumption data gives a mean conservative estimate of weekly expenditure on shellfish of £0.13 per person between 2010 and 2015, approximately one tenth of other animal protein sources such as pork (£1.35) and poultry (£1.16; Defra, 2017). The imbalance between production and consumption is explained by international trade, with crab, lobster and scallop exports worth £440 million in 2015. In contrast, imported prawns and shrimp are the shellfish predominantly consumed in the UK with 77,400 tonnes imported in 2015, worth £594 million (Marine Management Organisation, 2016). This study employed a mixed methods approach to investigate this production-consumption paradox, by investigating the factors affecting UK shellfish consumption.

Seafood consumption predictors in the literature include consumer demographics, behavioural factors, and knowledge. Whilst prior research often focussed on countries other than the UK, these three variables might influence UK perceptions. In general older, wealthier people consume more seafood (Olsen, 2003, 2004; Thong & Solgaard, 2017; Verbeke, Sioen, Pieniak, Van Camp, & De Henauw, 2005). For other demographic variables, such as gender and education, effects appear inconsistent. For example, a survey of

Portuguese bivalve shellfish consumers (n=1778) found men consumed shellfish more frequently than women (Anacleto, Barrento, Nunes, Rosa, & Marques, 2014), whereas the opposite pattern was observed amongst Belgian consumers (n=429; Verbeke et al., 2005). Additionally, education was positively associated with intention to consume shellfish for Belgian consumers, whereas the Portuguese survey found a negative association (Anacleto et al., 2014; Verbeke et al., 2005).

The psychological predictors of seafood consumption behaviour are complex and multi-faceted. For example, factors such as habit, tradition, familiarity, occasion and lifestyle have all been connected with seafood consumption (Birch & Lawley, 2014; Honkanen, Olsen, & Verplanken, 2005; Myrland, Trondsen, Johnston, & Lund, 2000; Olsen, 2004). Nevertheless, there are some common psychological factors associated with intention to consume seafood, and a framework often applied is the Theory of Planned Behaviour (TPB; Ajzen, 1991). This model posits an individual's behaviour is best predicted by their behavioural intention. In turn, their behavioural intention is influenced by three factors: their attitude, perceived social norm (social pressure to perform the behaviour), and perceived efficacy (ability to perform the behaviour; Ajzen, 1991). The TPB has been successfully used to investigate seafood consumption in several studies (Honkanen et al., 2005; Olsen, 2004; Verbeke & Vackier, 2005), but not yet in the UK. Positive attitudes are thought to be a particularly strong seafood consumption predictor, but with social norms and perceived efficacy also important (Carlucci et al., 2015). Olsen (2004) described attitude formation as being dependent on taste and other hedonic and sensory qualities (e.g. smell), with the notion of freshness particularly important. Verbeke & Vackier (2005) found all TPB factors were positively correlated with fish consumption in a sample of Belgian consumers. Another survey, of 1579 Norwegians, found past behaviour and habit explained greater variation in consumer intentions than attitude (Honkanen et al., 2005). In addition to the TPB, people's values, such as the importance of good quality food, are also important in shaping food consumption decisions (Hauser, Nussbeck, & Jonas, 2013). For shellfish consumption, quality was identified as the most important characteristic in a survey of 1648 Spanish consumers (Garza-Gil, Vázquez-Rodríguez, & Varela-Lafuente, 2016). In addition to psychological factors, other variables such as consumer knowledge are also relevant to understanding consumption.

A link between consumer knowledge and seafood consumption has been established (Pieniak, Vanhonacker, & Verbeke, 2013; Pieniak, Verbeke, Olsen, Hansen, & Brunsø, 2010; Pieniak, Verbeke, & Scholderer, 2010; Tudoran, Olsen, & Dopico, 2009). Generally, consumer knowledge and consumption are positively correlated (Pieniak, Verbeke, Olsen, et

al., 2010; Pieniak, Verbeke, & Scholderer, 2010). Pieniak et al. (2013) surveyed 3213 consumers from eight European countries including the UK. The study principally focussed on consumer knowledge of seafood production. This knowledge was mostly low, and varied significantly between countries. Southern European countries were generally better informed than countries such as Romania and the Czech Republic, which is perhaps not surprising given the latter countries' relative lack of coastal waters. In a separate recent international study, seafood stakeholders indicated concern at the perceived low level of knowledge amongst consumers (Tediosi et al., 2015). In addition to a lack of knowledge, another study identified misconceptions amongst Belgian consumers, for example nearly half (46%) incorrectly stated fish is a source of dietary fibre (Verbeke et al., 2005). Even where consumers possess correct knowledge, their behaviour is sometimes incongruous with what might be expected (Anacleto et al., 2014; Burger, 2000). For example, Portuguese consumers were aware of the risks from eating raw (or lightly cooked) bivalve shellfish from polluted areas, yet continued to do so (Anacleto et al., 2014).

One limitation of existing research is a paucity of studies relating specifically to shellfish consumption behaviour. For example, Carlucci et al., (2015)'s systematic review of consumer purchasing behaviour towards fish and seafood products identified 49 relevant papers, of which only two focussed exclusively on shellfish (Debucquet, Cornet, Adam, & Cardinal, 2012; Mueller Loose, Peschel, & Grebitus, 2013). The current study therefore contributes to filling this gap in our understanding by focussing specifically on shellfish consumption.

To investigate the factors affecting shellfish consumption in the UK, the current study applied the Mental Models Approach to Risk Communication (MMARC; Morgan, Fischhoff, Bostrom, & Atman, 2002). Developed during the 1990s, this well-regarded framework provides a structured means of identifying people's perceptions, misconceptions and uncertainties, and has been applied to a broad range of topics from flooding and wildlife, to food (Arvai, 2007; Hagemann & Scholderer, 2007, 2009; McComas, 2006; Ropeik, 2012; Wagner, 2007; Zaksek & Arvai, 2004, see also Boase, White, Gaze, & Redshaw, 2017 for a review). Central to this approach are mental models, which are people's underlying thoughts and ideas about a topic (Morgan et al., 2002). Importantly, mental models differ between individuals. Although 'experts' are generally considered to have a stronger technical understanding of many risk related topics, members of the public may also have a surprisingly sophisticated understanding of some risks, including food risks (Hansen, Holm, Frewer, Robinson, & Sandøe, 2003), and appreciate broader implications of some risks than the narrow focus of experts. This possibility notwithstanding, there is still sense in identifying knowledge gaps in

the public with the aim of supporting informed decision making. The key is to ensure one treats members of the public as having different knowledge that could be enriched through a reduction of misconceptions and uncertainties, rather than blandly asserting the superiority of experts.

Building on the MMARC framework, the present work comprised two parts. Study 1 involved interviews (n=26) with shellfish industry experts and stakeholders in the supply chain, and members of the public. Interviews were qualitative and semi-structured, and provided participants with the freedom to express their own ideas on the topic, rather than relying on a pre-conceived set of ideas developed by researchers. These perceptions were analysed in-depth, and key misconceptions, knowledge gaps and uncertainties were identified amongst experts and the public. Study 2 used a quasi-population representative survey of UK consumers (n=1,433), to establish the population prevalence of the knowledge gaps, misconceptions and uncertainties identified during the Study 1 interviews. Additionally, this second study measured the main TPB variables, with the aim of demonstrating the relative importance of these factors, alongside knowledge, in predicting people's shellfish consumption intentions. Study 2 concluded with the development of a predictive model to establish the antecedents of UK consumers' shellfish consumption. Of note, although the MMARC 'traditionally' focuses on risk perception, the current study also explored benefits perception and the trade-offs between risks and benefits.

2. Study 1

2.1 Introduction

This study was based in Cornwall, a coastal county in the south west UK, where an established fishing industry harvests a range of shellfish. As such, this area was well-suited to the study being in close proximity to many stakeholders from across the shellfish supply chain (Marine Management Organisation, 2016). Crucially the interviews asked only about shellfish harvested in the local area (e.g. crustaceans such as crab and lobster, and molluscs such as mussels and oysters) rather than shrimps and prawns that are largely imported from overseas. Residents of the county represent a diversity of professions and backgrounds (Cornwall Council, 2018). It is not expected the county's shellfish consumption and perceptions differ greatly to national levels. This is firstly because the UK Government's Family Food data indicates people in the south west UK (which includes Cornwall) consume similar shellfish quantities compared to other UK regions (Defra, 2017). Additionally, as the UK grocery retail sector is supermarket-dominated it is not expected that food to which

Cornish consumers are typically exposed is different to elsewhere in the UK (Jones, Comfort, & Hillier, 2004).

The aims of Study 1 were to identify:

- The barriers to, and especially any misconceptions or uncertainties about, shellfish consumption amongst stakeholders and the public
- The relative importance of risk-benefit perceptions, compared to other factors, in affecting people's shellfish consumption decisions

2.2 Materials and methods

There were 26 participants comprising of 12 stakeholders ('experts') and 14 members of the public (most from Cornwall in south west UK). Stakeholder participants were identified by researchers, and represented a range of roles within the shellfish supply chain including: fisher/producer (n=2); shellfish processor (n=2); distributor (n=5); retail/restaurant (n=3); and regulator (n=5).[1] Public participants represented a range of demographics and shellfish eating behaviours (8 male; 18-65 years; 8 were educated to degree level or above; 6 ate shellfish regularly, 5 ate it occasionally, and 3 never ate it). The principal means of recruiting public participants was via posters displayed in a variety of public locations.

Individual semi-structured qualitative interviews were conducted in person during 2013. Each interview was audio-recorded. Ethical approval was provided by the University of Exeter Research Ethics Committee and informed consent was provided by all participants. No incentive was provided. The interview schedule included prompts relating to health, the environment, sustainability and culture to elicit a broad range of ideas from participants (see Supplementary table 1). To define when a sufficient number of interviews had been conducted 'stop criteria' were applied, which comprised a combination of sample diversity and data saturation (Baker & Edwards, 2012; Francis et al., 2010; Morgan et al., 2002).

Interview recordings were transcribed verbatim, anonymised, and analysed using a coding framework, for which 89 codes were developed (hybrid inductive and deductive; Braun & Clarke, 2006; Fereday & Muir-Cochrane, 2006; Hollywood et al., 2013). Participants were given a unique reference in the format of either PBXX or EPXX, which indicated anonymised

[1] Whilst 12 stakeholder participants were interviewed, some had multiple roles (e.g. one participant was a processor and distributor) meaning the number of roles noted here was greater than 12.

public and stakeholder participants respectively. Codes were applied to each idea or opinion (mean per interview = 191) within the 26 transcripts. Blind double-coding on 13 interview transcripts (i.e. 50%) found 'substantial' agreement between the two reviewers with a kappa value of 0.61 (Landis & Koch, 1977). Given this substantial level of agreement the remaining 13 transcripts were coded by the first author alone. Although the interviews provided a highly rich dataset, due to space constraints we focus here only on key misconceptions (as verified by recourse to literature searches and further expert consultation), knowledge gaps and uncertainties due to their role in developing the survey for Study 2.

2.3 Results

Misconceptions, knowledge gaps and uncertainties about the types of shellfish regularly harvested in UK waters were diverse and existed among both the public and stakeholder groups. A summary of 10 misconceptions and 2 potential knowledge gaps is presented in Table 1 (with explanation of the misconceptions and knowledge gaps noted in Supplementary table 2). Most misconceptions fell into the broad categories of health and the environment, with provenance and quality issues also mentioned. Knowledge gaps were defined as topics not mentioned by participants, even though they are potentially important. As we did not explicitly assess knowledge in Study 1, the gaps referred to thus represented *potential* knowledge gaps (until Study 2 when the gaps were directly assessed).

Misconception (M) or knowledge gap (K)	**Stakeholder (n)**	**Public (n)**	**Assessed in Study 2 survey?**
Health			
'Dead man's fingers,* are poisonous (M)	✓ (1)	✓ (2)	Yes
Shellfish are high in fat (M)	✓ (1)	–	Yes
Cholesterol in shellfish is detrimental to health (M)	✓ (1)	✓ (3)	Yes
Shellfish should be avoided when pregnant (M)	✓ (1)	–	No
Allergy affected by shellfish freshness (M)	✓ (1)	–	Yes
Norovirus awareness (K)	✓ (6)	–	No
Gout associated with shellfish consumption (K)	–	✓ (1)	No
Environment			
Landing size not protective (M)	✓ (1)	✓ (1)	Yes

Shellfish are generally overfished (M)	–	✓ (2)	Yes
Farmed shellfish are unsustainable (M)	✓ (2)	✓ (3)	Yes
Provenance			
Don't eat shellfish in a month without an 'r' (M)	✓ (4)	✓ (1)	No
Quality			
Minimal / no processing prior to sale (M)	–	✓ (1)	Yes

Table 1. Summary of misconceptions and knowledge gaps amongst stakeholders (n=12) and the public (n=14). ✓=misconception or knowledge present in that group. *crustaceans' gills.

Regarding health, some stakeholders and members of the public believed certain parts of a crab were poisonous ('*dead man's fingers I suppose suggests that you wouldn't be very well, I did think they could kill you but that's probably a bit of a myth*' PB22; '*there are bits in there, what we call the devil's fingers, will definitely make you sick*', EP08), despite this not being true. Similarly, it seems individuals in both groups over-generalised information about the cholesterol levels of shrimps and prawns (and fat, in the stakeholder group) to other shellfish harvested in UK waters. A potentially very important misconception among one stakeholder concerned the belief that allergic reactions were related to freshness ('*as long as stuff is really fresh no-one is going to get an allergic reaction. A lot of these allergies, you develop an allergy because they've probably had it when it wasn't quite so good*' EP04). This is incorrect because the allergy is caused by an individual's response to protein in shellfish, not freshness (see Supplementary table 2). By contrast, because shellfish is a highly-perishable food, a lack of freshness may increase the risk of microbial pathogens (Sagoo, Little, & Greenwood, 2007). Even 'fresh' shellfish can pose health risks, for example where bivalve molluscs have been exposed to toxins from harmful algal blooms, or pathogens such as norovirus (Lowther, Gustar, Powell, Hartnell, & Lees, 2012; Hinder et al., 2011). The two health-related knowledge gaps related to 'norovirus' amongst the public participants, who instead tended to refer to 'food poisoning' more generally, and a failure by any member of the stakeholder group to raise the risk of gout caused by consuming shellfish, despite a public participant being aware of this issue.

In terms of environmental issues, these mainly concerned stakeholder and consumer uncertainties about stock management. With shellfish encompassing a variety of species, production and harvesting methods, these perceptions are difficult to wholly support or refute. However, evidence indicates that for some factors, such as carbon footprint, shellfish (e.g. mussels) has a lower environmental impact than alternative animal protein sources

such as beef (see Supplementary table 2). There was also evidence of transference of sustainability concerns in finfish (e.g. salmon) and prawn and shrimp aquaculture, to domestic shellfish aquaculture: e.g. '*I don't think it's sustainable environmentally, because they're using more and more drugs to stop them getting diseases*' PB13 (Kutty, 2005; Naylor et al., 2000; Primavera, 2006). With respect to provenance, we also saw evidence of a common misperception regarding whether shellfish can be eaten in a month containing an 'r' i.e. May to August ('*you always hear the adage 'don't eat oysters in a month with an 'r' because that's out of season, but is that true?*' EP01). Finally, members of the public, but not stakeholders, were often unaware that pre-processing (e.g. depuration) occurs before the shellfish are sold to the public: '*my understanding is that you get the shellfish out the sea, pop it open and eat it straightaway, so there is no processing in it*' (PB15). Providing more information about processing could support consumers in making more informed decisions.

As well as helping identify some key misconceptions and knowledge gaps, the interviews also highlighted areas of uncertainty. A number of the public interviewees, for instance, expressed concerns about their own abilities to safely prepare and cook shellfish ('*I really haven't much idea about mussels, so if I bought a pack of mussels I wouldn't really know [what] I ought to do with them*' PB11), a topic that again could be addressed in a communication. Finally, the interviews revealed a range of interesting themes that, while not directly related to a lack of knowledge or uncertainties, were nonetheless of interest to better understanding shellfish consumption among the UK population. Specifically, three themes commonly emerged. First, many participants discussed organoleptic concepts such as taste, which were often polarised: '*a lot of people…get turned off by the thought of eating shellfish, and there's others who just can't get enough*' (EP07). Second, several people mentioned shellfish was something to be consumed on special occasions or as a treat ('*it always tends to be something that's a special occasion, shellfish, never, not part of the staple diet*' PB22). That was in part due to an inaccurate belief (often, but not exclusively, amongst public participants) that shellfish was, generically, expensive: '*what puts me off, it's more the cost*' (PB03). In fact, some shellfish (e.g. mussels) are commonly priced lower than (or comparable to) more popular beef, poultry and pork. Thirdly, identity was an important factor with shellfish consumption linked to social class by participants in both groups. This related in particular to lobsters and oysters, which were described as 'posh' and perceived as an upper class food.

2.4 Discussion

Misunderstandings and knowledge gaps about shellfish were present amongst stakeholders and the public. Current findings partly aligned with Verbeke et al. (2005), where seafood misconceptions amongst Belgian consumers were explored. One implication of these findings is consumers are relying, in part, on erroneous information about shellfish when deciding whether to consume this food. How this knowledge might affect shellfish consumption amongst UK consumers (and associated health benefits or risks) is uncertain. Previous research indicates a positive relationship between consumer knowledge and seafood consumption (Pieniak, Verbeke, Olso, Hansen & Brunso, 2010; Pieniak, Verbeke & Scholderer, 2010), however consumer behaviour does not always align with scientific advice (Anacleto et al., 2014). Interestingly, some misconceptions and knowledge gaps were present in the stakeholder group, who are generally expected to have a better factual understanding of a given topic than the public (Hagemann & Scholderer, 2007, 2009; Morgan et al., 2002).

Health, environmental and economic aspects were important components of mental models in both groups. Whilst participants noted risks associated with consuming shellfish, there was broad agreement that shellfish is a healthy food. These findings support existing research where seafood was viewed as healthy (Ueland et al., 2012; Vanhonacker, Pieniak, & Verbeke, 2013), and health issues were an important component of perceptions (Olsen, 2004; Pieniak, Verbeke, Scholderer, Brunsø, & Olsen, 2008). The generally negative perceptions of aquaculture amongst the public participants also aligned with existing research, the latter study of which included UK consumers (Mazur & Curtis, 2006; Schlag & Ystgaard, 2013). Participants' connection between shellfish aquaculture and finfish farming appeared to be an example of image transfer, whereby participants' negative views of a similar topic (i.e. finfish production) were used to furnish their shellfish mental model (Verbeke, Sioen, Brunso, Henauw, & Camp, 2007). The implication of this perception is some participants held a disproportionately negative view of shellfish aquaculture, due to their association with finfish farming.

Lastly, other factors were connected to participants' perceptions, including behavioural and cultural issues. Behavioural factors including attitudinal concepts (e.g. taste) were particularly important for participants, in agreement with Birch, Lawley, & Hamblin (2012). Cultural factors, such as the notion that shellfish is a treat food (rather than something consumed everyday) were also present amongst consumers in both groups. The implication of this idea is people may consume less shellfish because of a cultural association with special occasions. Similarly, Jacobs et al. (2015) identified seafood consumption in several European countries was driven more by cultural factors rather than risk and benefit

perceptions. Establishing the relative importance of such factors in Study 2 should help further elucidate the factors that affect shellfish consumption in the UK. Additionally, some participants' perception of shellfish (in particular lobsters and oysters) as upper class may be linked to cost, specifically higher socioeconomic classes having a greater disposable income. This finding supports the link between diet and social class noted by Darmon & Drewnowski (2008), and the existence of a class system in Britain described by Savage et al. (2013). Interestingly, class perception appeared to influence people's shellfish choice beyond economic affordability, suggesting food identity is an important factor for consumers. The implication here is consumer choices are in part dependent on the foods they typically associate with their self-perceived class. These findings related to taste, occasion and class illustrate the broad and complex set of factors appearing to influence shellfish consumption. Whilst Study 2 applied variables from the Theory of Planned Behaviour, investigating the full set of factors that Study 1 suggests influence UK shellfish consumption was outside the scope of the Study 2. Consequently, future studies looking at shellfish consumption may wish to further explore the roles of factors such as occasion and class.

3. Study 2

3.1 Introduction

Study 2 aimed to quantify the prevalence of the misconceptions and knowledge gaps identified in Study 1 amongst a larger sample of UK consumers. Study 2 also aimed to investigate: a) how values and food consumption behaviours affect shellfish consumption; and b) the pathways through which any misconceptions and knowledge gaps might be influencing behavioural intentions to eat or avoid shellfish. To do this we also included seafood specific operationalisations of the key variables of the Theory of Planned Behaviour, namely attitudes, perceived social norms, perceived efficacy and intentions. Specifically, Study 2 aimed to address the following questions:

- What is the prevalence of specific misconceptions and knowledge gaps amongst the UK public?
- What is the influence of misconceptions and knowledge gaps on the UK public's intentions to consume shellfish?
- What is the influence of values, perceptions and other behavioural antecedents on the UK public's intentions to consume shellfish?

- Through what psychological pathway(s) do misconceptions and knowledge gaps affect participants' current shellfish consumption and intentions to consume shellfish?

3.2 Materials and methods

3.2.1 Survey development and sample

An online survey was developed and refined following pilot-testing with shellfish industry and academic experts, members of the public and a marketing organisation. Survey readability for our target population was checked using an online readability calculator ("Readability Score," 2011; "The Readability Test Tool," 2011), and was hosted online by an international market research company (CINT) who recruit quasi-representative citizen panels. Based on past studies and our planned statistical approaches we aimed to recruit approximately 1,500 participants, stratified on age, gender and socioeconomic status.

In the event, 1,568 participants completed the survey during December 2013. Because it is hard to know how seriously people take online surveys we decided *a priori* to exclude participants that took <5 minutes or >60 minutes, prior to analysis (Lugtig & Toepoel, 2016; Zhang & Conrad, 2013). This resulted in a final sample of n = 1,433, and as intended they were broadly representative of the UK population (see Supplementary table 3).

3.2.2 Procedure and measures

The following definition of shellfish was provided at the start of the survey: '*For the purposes of this survey, the word shellfish refers to both crustaceans (such as crabs, lobsters and langoustines/wholetail scampi), and molluscs (such as mussels, scallops, oysters, clams and winkles). In this survey, we are NOT including prawns as a type of shellfish.*' Prawns were excluded because our focus was on UK produced species. The survey had several sections, of which five (relating to consumption barriers, food values, shellfish consumption, knowledge, and TPB variables; described below) are most pertinent here (see Table 2 for items and response scales).

Construct	Item wording, and origin	Response scale
Demographics and prohibitors		
Age	*Provided by market research company*	Years
Gender	*Provided by market research company*	Female or male

Income	Which of the following best represents your total household income per year (before tax)? *Approximate mid-points from income quintiles were formed from UK Office for National Statistics data (2013).*	GBP <15,000; 15,000-24,999; 25,000-34,999; 35,000-49,999; >50,000
Religion	My religion forbids consumption of shellfish	Yes; no
Diet	Please select the response that best describes your diet *From Allen, Wilson, Ng, & Dunne (2000).*	Omnivore; pescetarian; vegetarian; vegan
Allergy	I'm allergic to shellfish	Yes; no
Values. *All questions mirrored Hauser et al. (2013). Item wording for the value questions began with 'It is important to me…'*		
Sustainability	• …to look for environmentally and animal friendly production and processing when shopping for food • …to know how the products were produced and where they came from	Seven-point scale (from 'not at all' (0) ...to 'very' (6))
Quality	• …that foods are fresh and untreated • …to get reliable quality through buying controlled and certified products	As above
Health	• …to have a balanced diet and make healthy choices • …to have light and wholesome meals	As above
Price	• …that I know exactly where I can buy what foods at the lowest price • …that I am well informed about the prices of foods at different shops	As above
Convenience	• …to have ready-to-eat meals, because they are easy, convenient, and available anytime	As above
Past experience		
Personally ill	I've been ill after eating shellfish	Yes; no
Friend / relative ill	A friend or relative has been ill after eating shellfish	Yes; no

Consumption	How often, on average, do you consume [shellfish; pork, soft cheese; fish; poultry; salad]? *Derived from Markhus et al. (2013).*	Five items (3 or more times a week; 1 to 2 times a week; 1 to 3 times a month; less than once a month; never)
Knowledge		
Misconceptions	Ten questions assessed participant knowledge, presented in Figure 1. *The response scale was adapted from Morgan et al. (2002).*	Five-item scale (-2 to +2, false, maybe false, don't know, maybe true, true)
Theory of Planned Behaviour (TPB)		
Attitude	• bad – good • unpleasant – pleasant • unsatisfying – satisfying • not tasty – tasty • unappetising – appetising *The first three items mirrored Honkanen et al. (2005); the remaining two items were derived from the interviews to measure taste, in line with the notion that taste is an attitudinal component (Olsen, 2004).*	Seven-point semantic differential scale (0-6)
Perceived social norm	• In general, my friends and family think eating shellfish is ok. *Adapted from Åstrøsm & Rise, (2001); Dowd & Burke, (2013); Tarkiainen & Sundqvist, (2005).*	Likert scale (-2 to +2, strongly disagree, disagree, neither agree or disagree, agree, strongly agree)
Perceived efficacy	• I know where I could buy shellfish easily • I know how to prepare shellfish *These questions related to product availability and consumer effectiveness, which were*	As above

	aspects of consumer efficacy described as important by Vermeir & Verbeke (2008).	
Intentions	Within the next six months… • I'm planning to eat shellfish • I'm expecting to eat shellfish • I will try to eat shellfish *Derived from Olsen et al. (2008); Verbeke & Vackier (2005).*	Seven-point scale (from disagree (0) to agree (6)

Table 2. Survey construct wording and response scales.

The first section identified factors that would inhibit the consumption of shellfish, irrespective of psychological factors such as misconceptions, attitudes etc. These factors included religious and dietary reasons (e.g. being vegan), as well as health issues (e.g. being allergic to shellfish). For current purposes the important thing was to identify those individuals who would have no intention to eat shellfish irrespective of their misconceptions of the issues, because other factors take precedence.

The second section included statements concerning five food-related values: sustainability, quality, health, price and convenience identified in previous literature and in Study 1.

The third section included shellfish consumption and whether the respondent, or a friend or relative, had been ill after eating shellfish. These items were included because the literature indicates a positive relationship between past shellfish consumption and consumer intentions (Honkanen et al., 2005). Risk of illness from eating shellfish was a concern voiced by Study 1 participants, and the literature identifies risk as being negatively related to consumer intentions (Birch et al., 2012; Pieniak et al., 2008).

The fourth section included ten statements drawn from the stakeholder interviews that reflected possible misconceptions and knowledge gaps (see Figure 1 for precise wording). Response options ranging from 'True' to 'False' with a 'don't know' option, were adapted from Morgan et al. (2002) and presented in a similar fashion to Bearth, Cousin, & Siegrist (2013). If a respondent said True when it was True, or False when it was False, their response was rated as 'Correct'. If they said it was True when it was False, or False when it was True, there response was rated as 'Incorrect'. The sum of 'Incorrects' constituted their 'misconceptions' score. The sum of 'don't knows' constituted their 'Uncertainty' score. In

other words there were two knowledge gap scores, one for ‘misconceptions’ (incorrect responses) and one for ‘uncertainties’ (‘don’t know’ responses).

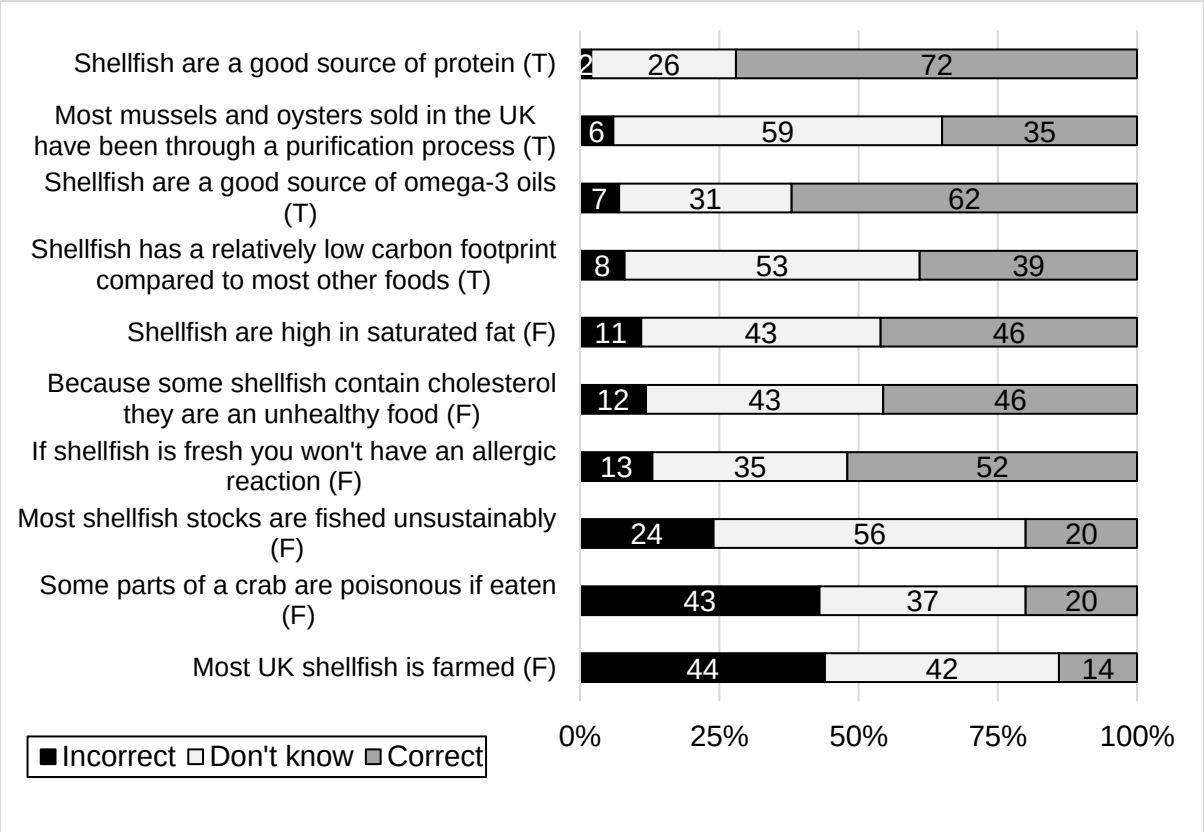

Figure 1. Participant responses to objective knowledge (all survey respondents). Scores represent the proportion of participants that answered incorrectly, don’t know, or correctly. (T) indicates the statement is true; (F) indicates the statement is false.

The final section included items pertaining to the TPB, including attitudes, perceived social norms, perceived efficacy and intentions. All items were adapted from previous scales (see Table 2), and for current purposes, perceived social norms and perceived efficacy results were recoded so -2=1, -1=2, 0=3, 1=4 and 2=5. Data for participants’ intentions and attitude were highly polarised. Therefore prior to analysis the 7-point scale (recoded so that 0=1, 1=2, 2=3 etc.) was collapsed into 3 items (combining 1.00-2.99, 3.00-5.99, 6.00-7.00 into the new variables). This ensured more normal distributions and thus suitability for subsequent correlations and regression analyses. Following completion, participants were automatically debriefed and thanked, and their participation automatically registered with the CINT panel for payment.

3.2.3 Analysis Plan

Data were analysed using SPSS version 24. We constructed a series of OLS hierarchical linear regressions with shellfish consumption intentions as the dependent variable. Linear regression was selected as the appropriate method for our analyses (rather than ordinal regression). This was justified by considerable evidence that indicates the assumptions for linearity are robust to multiple methods (Ferrer-i-Carbonell & Frijters, 2004). The implication of this is ordinal and linear models would produce very similar results, with the latter selected for current analysis to support comparison of our findings with the literature, where similar methods have been used (Åstrøsm & Rise, 2001; Verbeke & Vackier, 2005; Vermeir & Verbeke, 2008). Our first aim was to examine whether knowledge gaps (misconceptions and uncertainties separately) could increase the explanatory power of the models after controlling for demographics, values and past experiences. Our second aim was to examine whether any associations between knowledge gap variables and intentions reduced once the three TPB items were included in the models. If this happened, it would suggest the effects of knowledge gaps on intentions were mediated by TPB variable(s). Participants who indicated they were either allergic to shellfish, did not eat shellfish for religious reasons, or were vegetarian or vegan, were excluded from this analysis. This was because these factors fundamentally preclude their shellfish consumption and such participants were not of interest to this analysis.

The first three models systematically added demographics, values, and then past experiences (including recent consumption). Step 4 models added either 'misconception' or 'uncertainty' scores as operationalisations of any knowledge gaps. Step 5 then added attitudes, perceived social norm and perceived efficacy scores to each of the step 4 models respectively. Model fit was assessed using Akaike's Information Criterion (AIC), with AIC values decreasing between models suggesting an improving model fit (Field, 2013).

If the hierarchical regressions indicated potential mediation, we planned to conduct associated path analysis to explore the mediation pathways further, using AMOS (Arbuckle, 2012). These models would use maximum likelihood estimation, and the following four indices to assess model fit: chi-square, RMSEA (Root Mean Square Error of Approximation), CFI (Comparative Fit Index) and NFI (Normed Fit Index). A good model fit would be indicated by a non-significant X^2 (although sometimes a significant value will be returned due a large sample size rather than poor model fit), RMSEA<0.1, and values >0.9 for CFI and NFI (Kline, 2011; Snelgar, 2006).

3.3 Results

Descriptive data for four potential consumption prohibitors indicated 2.5% of participants (n=36) avoided shellfish for religious reasons; 3.1% (n=44) reported being allergic to shellfish; 4.6% (n=66) were vegetarian; and 0.8% (n=11) were vegan: these participants were excluded from the regression models and path analysis.

20.9% participants (n=300) reported a friend or relative had been ill due to consuming shellfish; and 11.6% (n=166) had personally been ill after consuming shellfish.

Food consumption data (Supplementary table 4) indicated that, consistent with earlier findings, shellfish was consumed less frequently than the other five foods, with nearly a third of participants (31.7%) reporting they never ate shellfish, and nearly a third (31.3%) eating shellfish less than once per month. Only 11.2% respondents ate shellfish at least once per week. In contrast, just 6.4% participants reported never eating poultry, with over two thirds eating poultry at least once per week.

Figure 1 presents the percentage of people responding correctly, incorrectly or don't know to the ten knowledge questions. Knowledge of health benefits was strongest, with most participants correctly indicating shellfish is a source of protein and omega-3 oils. On the other hand, the highest number of misconceptions related to whether parts of a crab were poisonous, and whether most UK shellfish is farmed (>40% of participants answered each of these questions incorrectly). A large number of participants also responded 'don't know', indicating a lack of knowledge rather than a misconception. For some questions the 'don't know' response was selected by over half the respondents, for example whether most mussels and oysters have undergone purification, and two questions relating to environmental risks and benefits (i.e. the carbon footprint of shellfish, and whether stocks are fished sustainably).

3.3.1 Antecedents of intentions to consume shellfish

The means and standard deviations for the values and TPB items are presented in Supplementary table 5. Quality was perceived as the most important value, followed by health, price, sustainability and convenience. Bonferroni-adjusted pairwise comparisons indicated significant differences between each of the values, apart from quality and health, and health and price. Attitudes to and intentions to consume shellfish were relatively low with means of 4.71 and 4.45 (on recoded 1-7 scales). This is consistent with the evidence of low shellfish consumption in the UK. Perceived social norm and efficacy means of 3.52 and 3.10, respectively, indicated (on recoded scales of 1-5) moderate results for these variables.

These scores agree with Study 1 interviews, for example where participants' reported ability to source and prepare shellfish varied.

Bivariate analyses using Pearson's correlations indicated all key variables were highly significantly correlated (Supplementary table 6). The direction of the relationships differed for each of the two knowledge variables. Firstly, misconceptions was positively associated with all variables (apart from uncertainty), for example, attitude (r =.22). In contrast, uncertainty was negatively, and more strongly, related to all variables (apart from misconceptions), for example attitude (r = -.38). Importantly, prior consumption was strongly correlated with intentions (r = .68), a finding that supports the TPB (Ajzen & Fishbein, 1980; Mahon, Cowan, & McCarthy, 2006).

Regression model outcomes are shown in Table 3. In Model 1 only demographics were included and suggested that older, wealthier respondents had significantly higher shellfish consumption intentions. Gender was not significantly related to intentions. In Model 2, the significant values were quality and health, with those valuing quality and health more highly having greater intentions to consume shellfish in the next six months. In Model 3, the frequency of consumption emerged, not surprisingly, as a strong positive predictor of future intentions, although personal or others' experience of illness did not reduce intentions. Intriguingly, controlling for experiences, convenience now emerged as a significant predictor, and income was no longer significant. In other words, once past consumption behaviour had been accounted for, a greater weight placed on convenience was associated with lower intentions to consume shellfish, and income *per se* was no longer important. At this stage, nearly half of the variance (47%) in intentions was already accounted for.

Predictors	Model 1	Model 2	Model 3	Model 4a	Model 4b	Model 5a	Model 5b
	D only	D + V	D + V + P	D + V + P + M	D + V + P + U	D + V + P + M + TPB	D + V + P + U + TPB
Demographics and inhibitors (D)							
Age	.087**	.023	.057*	.048*	.035	.010	.008
Female	-.022	-.061*	-.021	-.019	-.018	-.011	-.011
Income	.102***	.069*	.016	.017	.009	.010	.008
Values (V)							
Sustainability	–	.068	.001	-.006	-.008	.002	.001
Quality	–	.158***	.079*	.076*	.065*	.018	.017
Health	–	.079*	.021	.015	.021	.003	.005
Price	–	-.039	-.008	-.010	-.022	-.008	-.011
Convenience	–	-.055	-.077***	-.079***	-.061**	-.019	-.016
Past experience (P)							
Personally ill	–	–	.005	-.004	-.012	-.021	-.022
Friend / relative ill	–	–	-.023	-.028	-.032	-.006	-.008
Consumption	–	–	.645***	.630***	.593***	.278***	.279***
Knowledge							
Misconceptions (M)	–	–	–	.091***	–	.030	–
Uncertainty (U)	–	–	–	–	-.198***	–	-.057**
Theory of Planned Behaviour (TPB)							
Attitude	–	–	–	–	–	.453***	.448***
Social norm	–	–	–	–	–	.089***	.083**

Perceived efficacy	–	–	–	–	–	.142***	.133***
Summary							
Constant (B)	1.804	1.260	1.144	1.150	1.570	0.104	0.255
n	1228	1228	1228	1228	1228	1228	1228
R^2	.018	.088	.472	.480	.506	.683	.685
ΔR^2	.018	.070	.384	.007	.033	.204	.179
Model selection (AIC)	-527.0	-607.9	-1273.7	-1289.1	-1352.2	-1892.6	-1898.8

Table 3. Regression model with intentions to consume shellfish as the dependent variable, with misconceptions (M) and uncertainty (U) as separate knowledge variables as indicated. Beta coefficients and signficance displayed (*p<.05; **p<.01; ***p<.001). This table is based on the analysis sample only, i.e. participants who identified as vegetarian, vegan, allergic to shellfish, or did not eat shellfish for religious reasons were excluded.

Models 4a and 4b explored our key issue of whether knowledge gaps, or more specifically misconceptions and uncertainties respectively, predict intentions, once other factors such as demographics, values and past experiences have been taken into account. Model 4a shows a significantly positive coefficient for misconceptions, and Model 4b a significantly negative coefficient for uncertainties. The more incorrect answers the greater the intention to consume shellfish, but the more uncertainties the lower the intention. Despite the variables' significance, the explanatory power of the models including these variables was only slightly better than those without them (ΔR^2 = 1% and 3% respectively).

Models 5a and 5b added the TPB variables and increased the amount of variance in intentions explained to nearly 70%, with attitudes, social norms and efficacy, all significant. For knowledge, in Model 5a the coefficient for misconceptions dropped to β = .030 (from β =.091) and in model 5b the coefficient for uncertainties dropped to β = -.057 (from β = -.198). Misconception was no longer significant, however the uncertainty coefficient remained significant (p<.01), with the drops suggesting full and partial mediation respectively. That is, the relationship between misconceptions and intentions was fully explained by the three TPB variables, whereas the relationship between uncertainty and intentions was only partly explained by the three TPB variables. That other variables that were predictive in earlier models were no longer significant in these final models (e.g. age, quality, health, convenience) suggested their impact on intentions was fully mediated through attitudes, norms and efficacy beliefs.

3.3.2 Path analysis

The two path analysis subsequently conducted to examine the relationships between misconceptions and uncertainties on intentions, via the TPB variables are presented in Figure 2 and Figure 3. To keep the models parsimonious we excluded the demographic, values and negative past experience variables, which were non-significant. The models also included error covariances between the mediating variables but these are not shown here for clarity. The two models exhibited a very strong fit: specifically, for the misconceptions model $X^2(1)=3.753$ (p=.053), RMSEA=.046, CFI=.999 and NFI=.999. For the uncertainty model, $X^2(1)=0.121$ (p=.728), RMSEA=.000, CFI=1.000 and NFI=1.000.

The total, direct and indirect effects of misconceptions and uncertainty, and beliefs, on current consumption and intentions are displayed in Supplementary table 7. This revealed that misconceptions and uncertainty have small direct effects on intentions to consume shellfish, albeit significant for uncertainty only (.03, p=.08; -.06, p<.01 respectively).

However, both misconceptions and uncertainty exhibited much larger indirect effects on both consumption (.17 and -.29 respectively) and intentions (.20 and -.34 respectively).

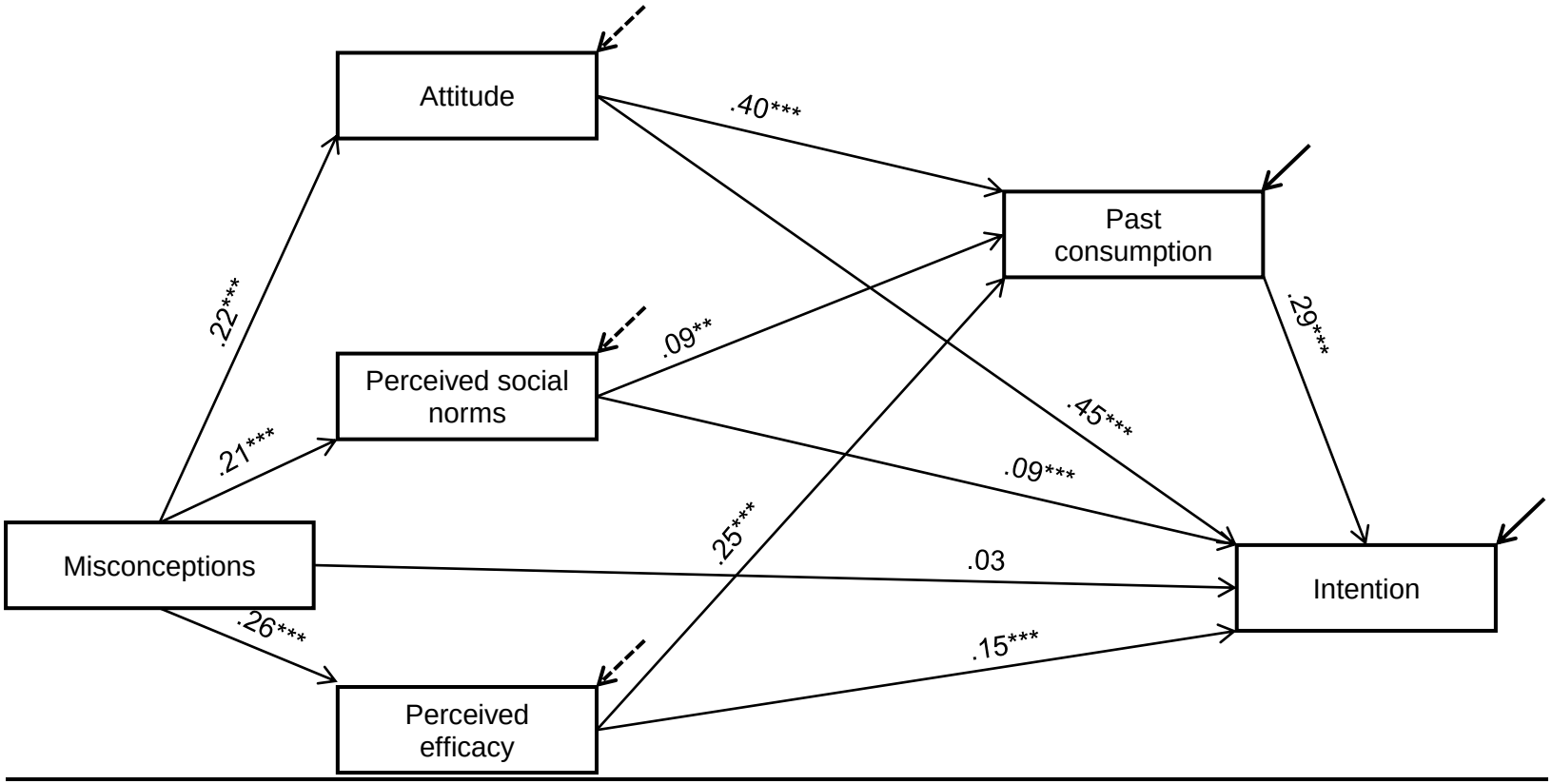

Figure 2. Misconceptions model path analysis. Standardised coefficients and significance are displayed. **p<0.01; ***p<0.001. Short arrows at top right-hand corner of endogenous variables represent error variables, and dashed arrows indicate correlated errors. This figure is based on the analysis sample only (i.e. excluding participants who identified as vegetarian, vegan, allergic to shellfish, or did not eat shellfish for religious reasons).

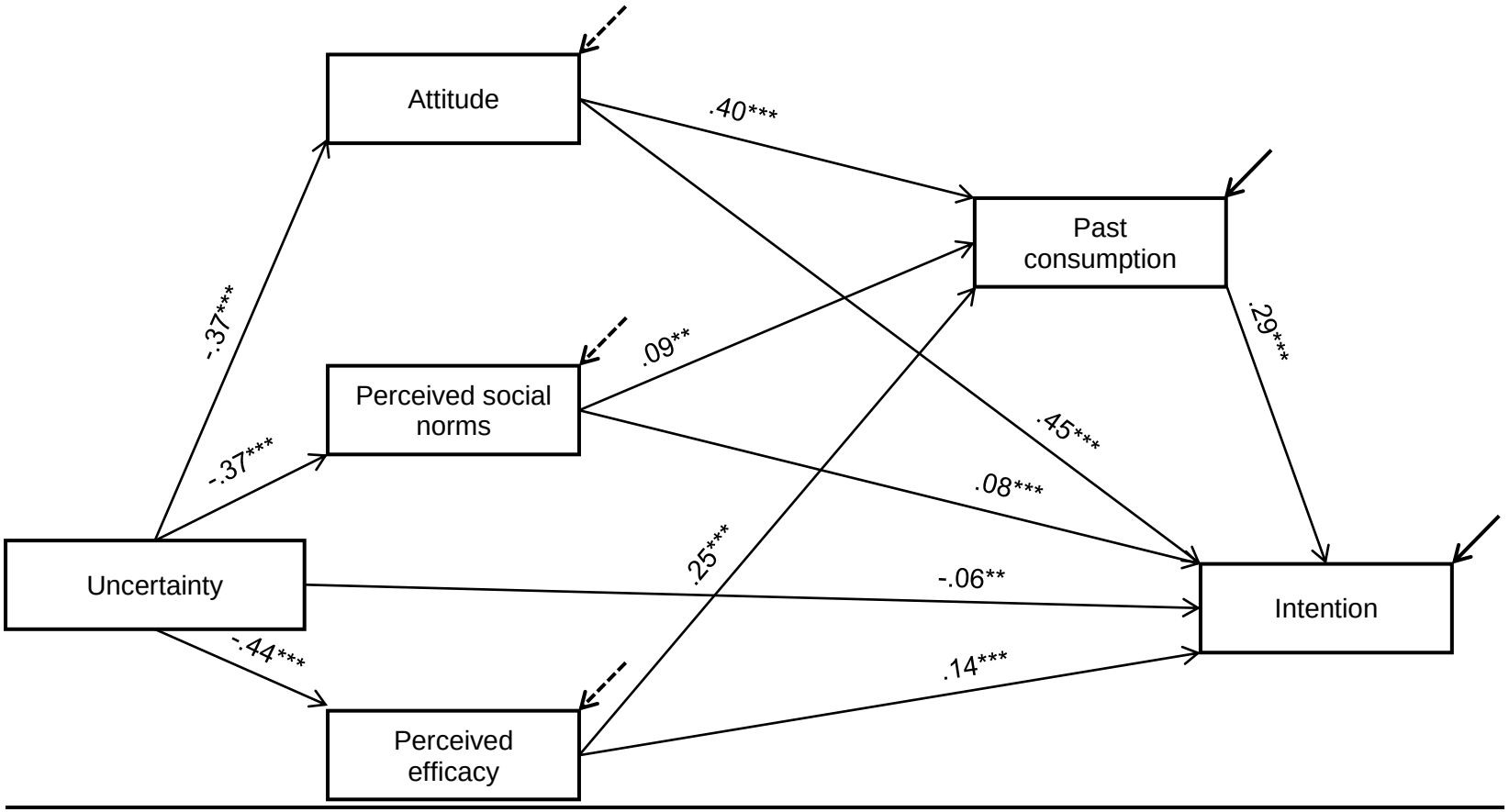

Figure 3. Uncertainty model path analysis. Standardised coefficients and significance are displayed. **p<0.01; ***p<0.001. Short arrows at top right-hand corner of endogenous variables represent error variables, and dashed arrows indicate correlated errors. This figure is based on the analysis sample only (i.e. excluding participants who identified as vegetarian, vegan, allergic to shellfish, or did not eat shellfish for religious reasons).

3.4 Discussion

An online survey of the UK public (n=1,433) revealed their thoughts and preferences towards shellfish. The primary aim was to quantify the prevalence of specific misconceptions and uncertainties and see whether these influenced intentions, even after controlling for a range of other relevant variables. Results suggested the public's knowledge of some aspects (e.g. nutrition) appeared strong, with misconceptions in other areas e.g. sustainability and environmental issues. Uncertainties (i.e. where respondents selected 'don't know') were high for some items, representing over half the responses for some questions (e.g. whether most mussels and oysters are purified before sale). Multiple regressions (n=1,228) indicated whilst variables such as attitude and past consumption were stronger predictors of intentions to consume shellfish than knowledge variables, knowledge nonetheless played a distinct, significant role. Implications are discussed below.

3.4.1 The prevalence of specific misconceptions and knowledge gaps amongst the UK public

Two particular misconceptions were present in nearly half the sample: that some parts of a crab are poisonous (43% answered incorrectly), and most UK shellfish is farmed (44% answered incorrectly). Perceiving parts of crab as poisonous may deter people from consuming this food due to perceived negative health consequences. The finding that many people incorrectly believe most UK shellfish is farmed may also deter consumers, given the interviews (Study 1) and literature indicated aquaculture is perceived with mixed views by the UK public (Schlag, 2010; Schlag & Ystgaard, 2013). These topics represent areas a communication could seek to address, to ensure people draw on accurate information when deciding whether to consume or avoid shellfish. Several misconceptions, such as whether shellfish contains cholesterol and saturated fat, were also present in the sample, but less widespread at 12% and 11% respectively. These erroneous beliefs are also likely to deter consumers from eating shellfish, due to an inaccurate perception that shellfish (for the factors identified) is less healthy than in reality.

Although correct knowledge varied between participants (Figure 1), the sample was generally well informed that shellfish provide a source of both protein (72% correct), and omega-3 oils (62% correct). A survey of Belgian consumers (n=429) in 2003 investigated knowledge of fish, where only 32% correctly identified this food as a source of omega-3 oils (Verbeke et al., 2005). Present findings suggest UK consumers may be better informed for

this particular aspect of nutrition. Some caution should be used in comparing results due to different study focus (i.e. shellfish vs. fish, and Belgium rather than UK), and time, with nearly a decade having elapsed since Verbeke et al. (2005). Promotional efforts by industry and other stakeholders may have resulted in more informed consumers during that time. The implication of this finding is the UK public are broadly aware of important nutritional components of shellfish associated with positive health e.g. tissue maintenance and growth, and reduction in cardiovascular disease risk (Larsen et al., 2011; Weichselbaum et al., 2013). One uncertainty of the current study is it did not ascertain whether respondents understood protein and omega-3 oils were healthy, rather, it focussed on whether shellfish provided these nutrients. However, it might reasonably be expected this is the case, as a recent survey of UK consumers (n=921) concluded most were aware that dietary protein and omega-3 fatty acids are important for health (Grunert, Wills, & Fernández-Celemín, 2010).

The majority of respondents were generally uncertain rather than incorrect for most of the ten knowledge questions (i.e. a greater proportion of respondents answered 'don't know', than gave an incorrect answer). This was most pronounced for the two environmental questions of shellfish stock sustainability (56%) and their carbon footprint (53%), but also whether mussels and oysters have undergone a purification process prior to sale (59%). The lack of knowledge about these areas suggests when people are deciding whether to consume shellfish, information about these aspects is absent from their mental models. Given shellfish production often has a low carbon footprint (and domestic species can be from sustainably managed sources), providing this information may encourage consumption amongst consumers who were unaware of these environmental benefits ("Good Fish Guide: your guide to choosing sustainable seafood," n.d.; Nijdam et al., 2012).

3.4.2 The influence of misconceptions and knowledge gaps on the UK public's intentions to consume shellfish

Whilst both misconceptions and uncertainty had a significant effect on intentions, the direction of each was different, with the former positively, and the latter negatively, associated with intentions. These opposite effects may be a product of whether consumers felt informed about shellfish (i.e. their subjective knowledge, which is not necessarily correct). Although subjective knowledge was not measured separately in the current survey, it is logical to assume that when a participant incorrectly answered a question (i.e. held a misconception), they possessed some level of confidence in their knowledge (although it was inaccurate) because they selected true or false, rather than 'don't know'. On the other hand, the 'don't know' response indicated uncertainty in participants' mental models, i.e.

awareness of their lack of knowledge. Additionally, not only was the direction of the effect different, so was the size, with uncertainty representing a stronger relationship with intentions, compared to misconceptions. This suggests what people know may be less important than whether people know something, when it comes to assessing the magnitude of the relationship between knowledge and intentions.

Uncertainties and misconceptions may lead to suboptimal decision-making. For instance, being unaware of the health and environmental benefits may reduce people's likelihood of eating shellfish. By contrast, greater knowledge appears to be associated with increased levels of consumption of this potentially nutritious, sustainable food. Implications of misconceptions are less straightforward, being dependent on the precise topics that are misunderstood. For example, a consumer incorrectly perceiving a major health risk as minor may result in insufficient risk avoidance, and *vice versa*. With misconceptions positively associated with intentions, the results suggest reducing misconceptions may also reduce shellfish consumption. However, if the argument that the misconceptions and intentions relationship actually reflects the extent to which people perceived themselves as knowledgeable, a reduction in shellfish consumption would not be expected. Either way, the upshot of these misconceptions and uncertainty findings is the same: communications could, in theory, be developed to reduce them, with potential impacts on intentions and behaviour.

Much risk communication research on uncertainty considers the communication of scientific uncertainty, i.e. where the evidence is incomplete or contradictory (Frewer et al., 2002; Kasperson, 2014). This represents top-down uncertainty, in that risk communicators are unsure of the effect of providing uncertain information to the public. In the current study, uncertainty represented where consumers were unsure of the correct answer (i.e. a cognitive uncertainty rather than a scientific uncertainty). It is recommended that any communication aimed at encouraging consumers to eat more local shellfish considers this cognitive aspect of uncertainty when assessing the communication's effectiveness.

3.4.3 The influence of values, perceptions and behavioural antecedents on the UK public's intentions to consume shellfish

The effect of knowledge gaps on intentions appeared, at least partially (fully for misconceptions), to be mediated through two of the main factors associated with the TPB, i.e. attitudes and efficacy. The inclusion of these variables was an extension of the standard confirmatory survey step of the MMARC, which traditionally focuses on knowledge prevalence only (Morgan et al., 2002). Given that none of our ten knowledge items (Table 1)

related to social norms (rather, they focussed on more objective topics such as health), perhaps the lack of mediation through the perceived social norms pathway is unsurprising. Overall, the items included in the model explained a substantial amount (nearly 70%) of the variance in stated intentions. This is broadly similar to earlier studies, for example Verbeke & Vackier (2005) concluded the TPB explained 42-44% of variation in intentions to consume fish; Åstrøsm & Rise's (2001) healthy food consumption model explained 52% of variation in intentions; Vermeir & Verbeke (2008) explained 50% of variation in a model predicting intentions to consume hypothetical sustainable dairy products; and Carlucci et al. (2015)'s systematic review of seafood consumption identified the TPB as a strong model. Current results also mirror Armitage & Conner (2001)'s meta-analysis of TPB studies, where TPB variables explained 39% variance in intentions. The additional explanatory power of the current model (i.e. nearly 70% variance) appears largely due to the inclusion of past behaviour and knowledge gaps.

In general, demographic variables (i.e. age, gender, income) were significant predictors of intentions to consume shellfish until Model 4. Supporting previous findings, the demographic variables indicated older, wealthier males were associated with increased intentions to consume shellfish (Olsen, 2003; Verbeke & Vackier, 2005). The current income findings also aligned with Verbeke & Vackier (2005)'s application of the TPB to understanding seafood consumption in Belgium. The effect of gender has varied in previous seafood consumption studies, but the current results supported Anacleto et al. (2014), where intentions were greater for men than women, but contrasted with Verbeke & Vackier (2005) where the opposite was observed. These partial agreements with other studies, conducted across countries other than the UK, suggest some seafood behavioural antecedents may be country-specific, reinforcing Jacobs et al. (2015)'s conclusion that cultural factors strongly influence seafood perceptions. The consequence for understanding and informing UK consumers about shellfish is that a tailored approach, focussing specifically on a target population segment, would be appropriate.

Values exerted weaker explanatory power than other variables (e.g. knowledge and TPB factors) but provided some insights into understanding consumer intentions with respect to shellfish, with quality (and health in model 2 only), positively associated and convenience negatively associated with intentions. The significance of quality being an important value (which included the concept of freshness; Table 2) in the earlier models reinforces the importance of freshness as a prerequisite for consuming shellfish in the public (and stakeholder) mental models observed in Study 1. The importance of quality for participants in the current study supports the findings of Garza-Gil et al. (2016), where the same factor

was of high importance for Spanish consumers. Price and sustainability did not provide significant explanation of participants' intentions to consume shellfish in any models. The findings for convenience perhaps reflect the belief that shellfish is a complicated food to cook. Although the results of these earlier models support broader literature demonstrating a link between values and food choice (Aertsens et al., 2009; Hauser et al., 2013; Vermeir & Verbeke, 2008), unlike Hauser et al. (2013), our analysis indicated values did not provide any additional explanatory power once attitudes were included in the model.

That all three TPB variables were significant predictors of consumption intentions is in line with earlier work, which also noted the particular importance of attitude (Carlucci et al., 2015; Verbeke et al., 2015; Verbeke & Vackier, 2005; Vermeir & Verbeke, 2008). The findings also supported the interview results of Study 1, where participants' perceptions of shellfish were attitudinal and often polarised. The overall results of these models demonstrate the importance of other factors, alongside knowledge, in influencing the UK's shellfish consumption. This serves firstly to provide policymakers, and people promoting shellfish consumption (or developing advisories), with a clearer idea of what factors affect consumer behaviour. Secondly, the findings suggest consideration of factors, such as where to buy and how to prepare shellfish (i.e. efficacy), may also be worthwhile including, alongside information about shellfish benefits and risks, in communication intended to promote informed decision-making and safe consumption.

3.4.4 Path analysis

The fourth research question assessed pathways through which misconceptions and uncertainty might affect participants' consumption of, and intentions to consume shellfish. Whilst misconceptions and uncertainty were both strongly associated with intentions to consume shellfish, this relationship was predominantly indirect. For example, uncertainty exhibited a total effect of -.40 on intentions, most of which was indirect. In both cases attitudes, followed by perceived efficacy, appeared to be the main paths, while perceived social norms played less of a role. In practice, this would mean where consumers are uncertain in their knowledge of shellfish, they display less positive attitudes towards shellfish, and weaker efficacy beliefs and subsequently lower intentions to consume this food.

The mediating role of attitudes is consistent with existing research (Ajzen, Joyce, Sheikh, & Cote, 2011). The current findings also extend our understanding of the relationships between shellfish consumption antecedents beyond other studies that focussed specifically on, for example, how attitude mediated the effect of consumer age on consumption (Olsen,

2003), and how consumers' interest in healthy eating mediated the effect of health involvement on fish consumption (Pieniak et al., 2008). For the present study, one implication is that providing consumers with information about shellfish would be expected to have some effect on their intentions to consume shellfish. With knowledge related to intentions (indirectly, and including potentially via attitudes), it is recommended consumer attitudes are assessed alongside knowledge (inclusive of both misconceptions and uncertainty), as part of communication efforts.

4. General discussion of Study 1 and Study 2

This paper reports semi-structured interviews which elicited stakeholder and public participants' perceptions of shellfish (Study 1), and a national survey which established the prevalence of these perceptions and their role in influencing intentions to consume shellfish (Study 2). Whilst detailed discussion of each study is provided above, this section outlines two key points relevant to the dual approach applied. Firstly, the current paper's engagement of participants by both interviews and survey adds weight to the value of the findings for informing any subsequent communications to support the public's informed consumption of shellfish. This is because it respects the principle that the public's ideas are essential components of any communication process, involving first participation (interviews), and secondly confirmation with the target audience (Bruni et al., 2008; Wooden, 2006, Barnett et al., 2012; Rowe & Frewer, 2000).

Secondly, the current approach investigated the relative impact of consumer knowledge and behavioural factors on future intentions to consume shellfish, rather than concentrating solely on knowledge (the traditional focus of the MMARC). Specifically, Study 1 revealed some of the behavioural factors important to understanding UK consumers (e.g. attitudes, perceived efficacy), and provided the rationale to quantify the importance of these in the Study 2 regression models (Table 3). This revealed the relative importance of knowledge compared to behavioural factors, for example consumer uncertainty remaining a significant predictor of intentions to consume shellfish, even after including TPB variables in the models. Findings supports the inclusion of behavioural factors in future MMARC applications, supporting Bruine de Bruin & Bostrom's (2013) suggestion that people's attitudes should be measured and compared to knowledge using regression analysis during the confirmatory survey.

5. Limitations and conclusion

Despite the encouraging findings, we also acknowledge several limitations in the current research. First, in Study 1 all interviews were conducted by the same interviewer (the first author). Although this ensured standardisation of delivery, it also may have induced systematic bias. Although every step was taken to avoid this in terms of extensive interview training, a series of pilot interviews, and the development of a clear interview schedule, it is possible another interviewer would have elicited slightly different mental models, and in particular different misconceptions and uncertainties. We remain open to alternative mental models on this topic being elicited in future, especially among stakeholders in other parts of the UK, rather than just Cornwall, e.g. West Scotland where there is a considerable aquaculture (finfish and shellfish) industry.

Second, the ten knowledge questions used to represent misconceptions and uncertainty in the Study 2 survey did not provide a complete measure of participant knowledge. In line with the MMARC, they reflected specific knowledge gaps and uncertainties identified during the Study 1 interviews. However, future studies could consider a more comprehensive knowledge assessment with additional items. Third, the sampling method in Study 2 (i.e. online consumer panels) could be affected by bias, specifically self-selection because participants were recruited from a group of people who had already indicated they were willing to participate in surveys. Although some element of bias is often associated with sampling, this should be borne in mind for the current study as the sample may not be reflective of the broader UK population.

These limitations notwithstanding, the current studies provide novel insights into the mental models of shellfish industry stakeholders and consumers in the UK, and the degree to which misconceptions and uncertainties may be affecting people's stated future intentions to consume shellfish. These findings are of relevance to the shellfish industry, retailers, policy and public health officials and others wishing to understand, and potentially influence, how people perceive shellfish as a food source in the UK. Understanding these factors represents the first step towards tackling potential misconceptions and uncertainty amongst consumers. The findings detailed here could therefore help inform future efforts aimed at encouraging a diet inclusive of safe, sustainable shellfish, through targeted communications aimed at improving knowledge and informed decision-making.

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Declaration of interests

None.

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Supplementary tables

Introduction (standard)
Thanks for time
Consent to participate and data protection / record audio
Project: interested in what people think about shellfish, in particular consuming shellfish
Several interviews to understand this further
Interview scope: I've some questions which start broad, so I don't bias your answers, then maybe some questions which become more specific
Not formal; area of shellfish new to me
Interested to hear your views; less so whether they're right or wrong
I'm interested in both professional and personal views
Any questions? Ask as we're going through if you're not sure…

Basic questions
- What are the first three words that come to mind when you hear the word 'shellfish'?
- What is your personal/professional interest in the area of shellfish?
- What animals do you think of when I say shellfish? (I'm looking at crustaceans, e.g. crabs; and molluscs, e.g. mussels)
- Tell me about shellfish

Personal experience
- Do you eat shellfish?
- Why / why not?
- If so, where from? (e.g. restaurant, shops, self-harvest)
- What influences whether you buy or eat shellfish?
- What's important to you when deciding whether to eat shellfish?
- If you eat shellfish, where do you normally eat it? Why?

Prompts – optional depending on participant responses to the above questions
- When you say 'shellfish and health' / 'shellfish and the environment / 'shellfish and sustainability' / 'shellfish and culture', what do you think of?
- How does x affect y? (e.g. shellfish affect health?)
- Some people think x is a risk from shellfish, what do you think?
- Whose responsibility is it / should it be to manage x risk?
- Anything else/more?
- Can you explain why…?
- Can you tell me any more about…?

Comparison
- Are the risks from shellfish significant, or not really something to worry about?
- Can you give me some idea of how the risks/benefits from shellfish compare to other foods?

Information (at the end)
- Have you ever searched for information about eating shellfish?
- Are there any rules you follow when eating shellfish?
- If so, which information sources did you find/use?
- What are the misconceptions, and what information would you most like to communicate/to whom? What information do you think consumers are aware of at the moment? What information should be available to consumers to help them better understand the risks and benefits of consuming shellfish?

Close
- Anything else?

Thanks for time

Supplementary table 1. Interview schedule for stakeholder and public interviews (underlined text relevant to stakeholder participants only).

Misconception or knowledge gap	Explanation
Health	
Dead man's fingers are poisonous (M)	'Dead man's fingers' (crustaceans' gills) are not thought to be poisonous, although due to their unpleasant texture should not be eaten (Barrento et al., 2009).
Shellfish are high in fat (M)	The UK's National Health Service defines a high fat food as one with a fat content greater than 17.5g per 100g (NHS, 2017). Shellfish, with a fat content ranging from 0.5% to 5.5% for crustaceans, and below 2% for molluscs, is therefore not high fat (Woolmer, 2010). Additionally, shellfish fats are predominantly polyunsaturated fatty acids, which are associated with beneficial health (Larsen et al., 2011).
Cholesterol in shellfish is detrimental to health (M)	Dietary cholesterol is present in crustaceans, but because shellfish is low in fat it does not normally need to be avoided by people concerned about their cholesterol levels (Seafish, 2008). Historically it was thought dietary cholesterol was the most important factor influencing circulating cholesterol levels. High levels of circulating cholesterol are associated with an increased risk of serious health conditions such as coronary heart disease (Gray & Griffin, 2009). It is now known dietary saturated fat is instead the main risk factor for high circulating cholesterol levels (EFSA Panel on Dietetic Products Nutrition and Allergies (NDA), 2010), and UK National Health Service advice reflects our better understanding of this topic (NHS, 2015b). N.B. There is a rare exception: where an inherited condition called familial hypercholesterolaemia is present, which affects about 1 in 500 people in the UK, then it *is* important to control dietary cholesterol (Gray & Griffin, 2009).
Shellfish should be avoided when pregnant (M)	Shellfish can be consumed by pregnant women in line with the UK's National Health Service guidance (NHS, 2015a). However, the guidance does state pregnant women can lower their risk of food poisoning by avoiding consuming raw shellfish. Other parts of the guidance are open to interpretation, for example 'regular fish-eaters should avoid eating brown crab meat too often' where 'too often' is ambiguous.
Allergy affected by shellfish freshness (M)	Shellfish allergy is an IgE antibody-mediated response to a protein (most commonly tropomyosin) being ingested or inhaled (Sicherer, Munoz-Furlong, & Sampson, 2004). It is not linked to shellfish freshness. This misconception in one stakeholder mental model could be due to allergy being confused with food poisoning (where the likelihood of suffering food poisoning *is* dependent on shellfish freshness), a misunderstanding that has been observed elsewhere (Woo & Bahna, 2011).

Norovirus awareness (K)	Norovirus was correctly mentioned by many stakeholders as a potential health risk, particularly associated with consumption of raw bivalve molluscs, but was not mentioned by any public participants. However, food poisoning was the most frequently mentioned health risk in the public's mental model, of which 'sickness and diarrhoea' were the most commonly described symptoms, which are the two main symptoms of norovirus (Glass, Parashar, & Estes, 2009). This suggests whilst public participants were unaware of norovirus by name (in connection with shellfish), there was awareness of a similar risk as judged by the symptoms described.
Gout associated with shellfish consumption (K)	Despite an expectation that stakeholders would have more (factually) complete mental models than the public, a link between gout and shellfish consumption was correctly mentioned by a member of the public but *not* by any stakeholders. This link is in line with research identifying purines within seafood as one of the (dietary) factors positively correlated with gout risk (alongside factors such as diabetes, obesity, alcohol consumption and genetic predisposition; Choi, Atkinson, Karlson, Willett, & Curhan, 2004; Kim, Schumacher, Hunsche, Wertheimer, & Kong, 2003; Singh, Reddy, & Kundukulam, 2011).
Environment	
Landing size not protective (M)	There was concern amongst both stakeholders and the public over whether current landing sizes are protective of shellfish stocks. This appeared to be a heuristic judgement based on the shellfish appearing small. UK fisheries are subject to regulations including a species dependent minimum landing size (MLS; UK Government, 2017). The MLS for fish caught in English inshore waters (up to six nautical miles offshore) varies regionally (depending on the local Inshore Fisheries and Conservation Authority), and beyond six miles from shore a different limit may apply. Perhaps due to this regulatory complexity (combined with the public's general lack of trust in the industry), there was uncertainty about what landing size is acceptable and as a result participants judged that small shellfish are unsustainable.
Shellfish are generally overfished (M)	This broad statement is difficult to wholly support or refute because of the variety of shellfish species caught in the UK, plus those imported from other countries, which are each caught using a variety of techniques, and from many populations. Such a blanket statement may also be an example of where the public's shellfish mental models were linked to finfish, where overfishing and its consequences have been well-documented (e.g. Molfese, Beare, & Hall-Spencer, 2014).
Farmed shellfish are unsustainable (M)	Several species of shellfish are farmed around the UK, including mussels and oysters. The carbon footprint associated with mussels is up to 100 times smaller than alternative protein sources such as beef (Nijdam et al., 2012). Aquaculture can reduce wild stock pressure, thus increasing its sustainability. However, UK aquaculture knowledge was scarce in the public's mental models, and their views appeared to be influenced by an association with prawn and shrimp farming (e.g. in south east Asia), where sustainability challenges have been described (Kutty, 2005; Naylor et al., 2000; Primavera, 2006).

Provenance	
Don't eat in a month without an 'r' (M)	There were differing opinions amongst stakeholders about whether shellfish can be eaten in a month without an 'r' (i.e. May, June, July, August), the reasons behind this traditional saying, and to which species this applies. This origin of this phrase may be based on some truth: specifically, some shellfish (e.g. native oysters *Ostrea edulis*) reproduce in warmer summer waters and are less palatable during this time (due to spawning) and, from a safety perspective, some risks (e.g. toxins from harmful algal blooms) are associated with warmer summer waters (Hinder et al., 2011). However, commercially produced shellfish are tested to reduce consumer risks, and avoiding shellfish in months without an 'r' does not guarantee safety (Davies, Davies, & Efird, 2013).
Quality	
Minimal / no processing prior to sale (M)	There was a lack of knowledge amongst the public about whether shellfish are processed prior to sale. This related primarily to bivalve molluscs, where there was also the perception that shellfish should be immersed in cold/fresh water prior to cooking. In the UK (and throughout the EU) bivalve molluscs are often depurated after harvesting but prior to sale, in line with relevant legislation (European Commission, 2004), and should not be kept in water prior to cooking (NHS, 2015a).

Supplementary table 2. Explanation of the misconceptions and knowledge gaps identified amongst participants in Study 1.

Category	All respondents (n=1433)		Analysis sample* (n=1288)		National values
	n	%	n	%	%
Age (years)					
18 to 30	304	21.2	260	20.2	23.1 [a]
31 to 40	205	14.3	174	13.5	17.2
41 to 50	275	19.2	247	19.2	19.1
51 to 60	284	19.8	264	20.5	16.8
61 to 70	263	18.4	247	19.2	14.5
71 to 80	102	7.1	96	7.5	9.4
Unanswered	0	0.0	0	0.0	-
Gender					
Female	737	51.4	652	50.6	50.8 [a]
Male	696	48.6	636	49.4	49.2
Unanswered	0	0.0	0	0.0	-
Income (gross household)					
<£15000	319	22.3	281	21.8	- [b]
£15000 to 24999	295	20.6	271	21.0	-
£25000 to 34999	270	18.8	241	18.7	-
£35000 to 49999	213	14.9	189	14.7	-
£50000+	200	14.0	181	14.1	-
Don't know	132	9.2	121	9.4	-
Unanswered	4	0.3	4	0.3	-
Live with a partner?					
Yes	844	58.9	758	58.9	- [c]
No	581	40.5	523	40.6	-
Unanswered	8	0.6	7	0.5	-
Number additional people in household					
0	248	17.3	222	17.2	-
1	591	41.2	533	41.4	-
2	367	25.6	328	25.5	-
3+	222	15.5	200	15.5	-
Unanswered	5	0.3	5	0.4	-
Number children (<16 years) in household					
0	1102	76.9	1011	78.5	-
1	164	11.4	138	10.7	-
2	126	8.8	102	7.9	-
3+	29	2.0	27	2.1	-
Unanswered	12	0.8	10	0.8	-
Diet					
Omnivore	1295	90.4	1231	95.6	- [d]
Vegetarian	66	4.6	-	-	2
Vegan	11	0.8	-	-	<1
Pescetarian	47	3.3	45	3.5	-
Unanswered	14	1.0	12	0.9	-

Supplementary table 3. Sample description: survey. *The analysis sample excludes respondents who identified as vegetarian, vegan, allergic to shellfish, or did not eat shellfish for religious reasons.

a – National age and gender data downloaded from: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland (accessed 15 October 2017)

b – The income categories used in the current study do not map onto those used by the UK Government's Office for National Statistics (ONS) so we are unable to draw simple conclusions; see for example: https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/incomeandwealth/datasets/theeffectsoftaxesandbenefitsonhouseholdincomefinancialyearending2014

c – The Household composition used in the current work does not map onto those used by the ONS so we are unable to draw simple conclusions; see for example: https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/bulletins/familiesandhouseholds/2015-01-28#cohabiting-couples and https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/articles/householdsandhouseholdcompositioninenglandandwales/2014-05-29#household-composition

d – We were unable to find national statistics for omnivores and pescatarians, although the following includes data for vegetarian (2%) and vegans (<1%) only, under section 3.5 (page 57): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/594361/NDNS_Y1_to_4_UK_report_full_text_revised_February_2017.pdf. Ipsos Mori (UK-based market research company) reported a study commissioned by the Vegan Society, which identified 1.05% UK adults are dietary vegans https://www.ipsos.com/ipsos-mori/en-uk/vegan-society-poll.

Food	Consumption frequency (%)				
	Never	<once a month	1-3 times a month	1-2 times a week	3+ times a week
Shellfish	31.7	31.3	25.7	10.0	1.2
Pork	12.4	16.7	34.5	32.2	3.8
Soft cheese	11.2	23.4	27.9	27.0	10.1
Fish	7.1	9.4	26.9	49.8	6.8
Poultry	6.4	3.5	20.0	53.8	15.9
Salad	3.2	12.8	21.7	37.0	25.0

Supplementary table 4. Shellfish consumption frequency compared to five common foods (all survey respondents).

Construct (number of items)	Mean	Standard deviation
Values		
Quality (2)	5.36[a]	1.18
Health (2)	5.28[a,b]	1.16
Price (2)	5.18[b,c]	1.28
Sustainability (2)	4.64[d]	1.43
Convenience (1)	3.52[e]	1.87
Behavioural		
Attitude (5)	4.71	1.92
Perceived social norms (1)	3.52	1.11
Perceived efficacy (2)	3.10	1.14
Intentions (3)	4.45	2.29

Supplementary table 5. Survey construct descriptive statistics (analysis sample only, i.e. this table excludes participants who identified as vegetarian, vegan, allergic to shellfish, or did not eat shellfish for religious reasons). For values, a higher mean indicates greater importance, and differing superscript letters against means indicate a significant difference in their importance to participants (differences were significant at $p<0.001$). For behavioural items, a higher mean indicates more positive construct.

		Miscon.	Uncertainty	Attitude	P.S. norms	P. efficacy	Cons.	Intentions
Miscon.	Correlation coefficient	1	–	–	–	–	–	–
	Sig. (2-tailed)	–	–	–	–	–	–	–
	N	1251	–	–	–	–	–	–
Uncertainty	Correlation coefficient	-.610**	1	–	–	–	–	–
	Sig. (2-tailed)	.000	–	–	–	–	–	–
	N	1251	1251	–	–	–	–	–
Attitude	Correlation coefficient	.218**	-.376**	1	–	–	–	–
	Sig. (2-tailed)	.000	.000	–	–	–	–	–
	N	1249	1249	1286	–	–	–	–
P.S. norms	Correlation coefficient	.209**	-.372**	.493**	1	–	–	–
	Sig. (2-tailed)	.000	.000	.000	–	–	–	–
	N	1249	1249	1282	1284	–	–	–
P. efficacy	Correlation coefficient	.260**	-.439**	.616**	.549**	1	–	–
	Sig. (2-tailed)	.000	.000	.000	.000	–	–	–
	N	1251	1251	1286	1284	1288	–	–
Cons.	Correlation coefficient	.208**	-.294**	.593**	.417**	.543**	1	–
	Sig. (2-tailed)	.000	.000	.000	.000	.000	–	–
	N	1250	1250	1285	1283	1287	1287	–
Intentions	Correlation coefficient	.244**	-.399**	.761**	.516**	.635**	.676**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	–
	N	1250	1250	1285	1283	1287	1286	1287

Supplementary table 6. Pearson's Correlations between misconceptions (Miscon.), uncertainty, attitude, perceived social norms (P.S. norms), perceived efficacy (P. efficacy), current shellfish consumption (Cons.) and intentions. ***p*<0.01 (differing Ns reflects missing data for some variables). This is based on the analysis sample only, i.e. participants who identified as vegetarian, vegan, allergic to shellfish, or did not eat shellfish for religious reasons were excluded.

	Standardised coefficients and significance			
	Misconceptions model		Uncertainty model	
Variables	**Consumption**	**Intentions**	**Consumption**	**Intentions**
Total effects				
Misconceptions	.169	.231	–	–
Uncertainty	–	–	-.290	-.396
Attitude	.396	.565	.396	.560
Perceived social norms	.085	.112	.085	.105
Perceived efficacy	.252	.219	.253	.208
Consumption	–	.231	–	.287
Direct effects				
Misconceptions	–	.029	–	–
Uncertainty	–	–	–	-.057**
Attitude	.396***	.452***	.396***	.446***
Perceived social norms	.085**	.087***	.085**	.080***
Perceived efficacy	.252***	.146***	.253***	.136***
Consumption	–	.286***	–	.287***
Indirect effects				
Misconceptions	.169	.202	–	–
Uncertainty	–	–	-.290	-.339
Attitude	–	.113	–	.114
Perceived social norms	–	.024	–	.024
Perceived efficacy	–	.072	–	.072
Consumption	–	–	–	–

Supplementary table 7. Standardised total, direct and indirect effects of knowledge and beliefs on consumption and intentions, for the misconceptions and uncertainty path models. Significance values apply only to direct effects: ** $p<.01$; *** $p<.001$. This is based on the analysis sample only (i.e. participants who identified as vegetarian, vegan, allergic to shellfish, or did not eat shellfish for religious reasons were excluded).