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Multisensory contextual cues and information affect plant-based food choices and taste perception

E.H. Zandstra [a,b,*], D.E. Van Os [b,c], E. Van der Burg [d,e], I.V. Stuldreher [d], A. Toet [d], S. Velut [d], H. Hiraguchi [f], M.A. Hogervorst [d], A.-M. Brouwer [d,g], J.B.F. Van Erp [d,h]

[a] Consumer Science Insight, Unilever Foods Innovation Centre Wageningen, Wageningen, the Netherlands
[b] Division of Human Nutrition and Health, Wageningen University and Research, Wageningen, the Netherlands
[c] Department of Primary Care and Community Care, Radboud University Medical Centre, Nijmegen, the Netherlands
[d] Human Performance, Netherlands Organization for Applied Scientific Research (TNO), Soesterberg, the Netherlands
[e] Clinical Developmental Psychology, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands
[f] Kikkoman Europe R&D Laboratory B.V., Wageningen, the Netherlands
[g] Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, the Netherlands
[h] Human Media Interaction, University of Twente, Enschede, the Netherlands

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ABSTRACT

The context in which food is selected and consumed is an important factor in its choice, consumption, and acceptability. This study assessed the effect of information and multisensory contexts on meat-related food choices and taste perception. In total, 224 participants first watched one of two pitches, either discussing the implications of consuming animal meat (sustainable pitch) or promoting body movement (control pitch). Participants were then exposed to one of three multisensory contexts: a 'sustainable' context with natural green colours, nature sounds and a flower fragrance, a 'meat' context with red colours, the sounds of country music and a smokey BBQ smell, and a monotone off-white 'neutral' context with neutral background music and no additional smell. Participants were instructed to choose one of two presented hotdogs (animal meat hotdog or plant-based meat hotdog) and to taste and rate the chosen one on liking and taste attributes. Results showed that multisensory sustainable contextual cues combined with information on sustainability beforehand increased the likelihood of choosing plant-based meat hotdogs over animal meat hotdogs. In addition, while tasting the plant-based meat hotdog, multisensory contextual cues that are inspired by a meat context appeared to enhance taste perception, even for vegans and vegetarians. These findings provide further evidence for the importance of context in food choice and acceptance: the context where people choose plant-based meat should preferably be separated and different from the context of consumption. The findings also imply that information can change behaviour, not just attitudes as previous research indicated, but only if combined with multisensory cues in the context.

1. Introduction

The production of animal meat is a significant contributor to greenhouse gas emissions (Parlasca & Qaim, 2022; Pörtner et al., 2022; Willett et al., 2019). A shift to diets with less animal-source foods and more plant-based foods can reduce emissions and mitigate climate change (Godfray et al., 2018; Springmann et al., 2018; Willett et al., 2019). One way to support this shift is to replace animal meat by plant-based meat substitutes, which are designed to mimic the appearance, taste, and texture of animal meat (Boukid, 2021). Plant-based meat may be particularly suited to aid current animal meat consumers (rather than vegetarians) to reduce their animal meat consumption as they easily fit in people's habitual animal meat-centered meals without further adjustment of their eating pattern (Van Bergen et al., 2024; Zandstra et al., 2023). However, while the global market of plant-based meat is growing, plant-based meat is not widely accepted by consumers yet (Jahn et al., 2021; Michel et al., 2021; Onwezen et al., 2021). Consumer acceptance and full adoption of plant-based meat is essential to enable the transition (Spendrup & Hovmalm, 2022; Strässner & Hartmann, 2023; Zandstra, 2018). A feasible strategy to encourage people to switch

* Corresponding author at: Unilever Foods Innovation Centre Wageningen/Wageningen University and Research, Wageningen, the Netherlands.
E-mail addresses: liesbeth.zandstra@unilever.com, liesbeth.zandstra@wur.nl (E.H. Zandstra).

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to plant-based meat is to change the context in which the food is selected and consumed (Cardello & Meiselman, 2018; Spence, 2020; Spence & Piqueras-Fiszman, 2014).

Research has consistently shown that products are perceived differently in different contexts: depending on where you eat, when you eat and with whom you eat (Cardello & Meiselman, 2018; Edwards et al., 2003; Jaeger & Porcherot, 2017). For example, the experience of eating ice cream at a beach on a sunny day is much better than tasting ice cream at your couch at home on a rainy day (Zandstra, 2018; Zandstra & Lion, 2019). Indeed, several studies found that consumers' liking ratings elicited in contexts where they normally eat were higher than from those elicited under controlled laboratory settings where everything is as standardized as possible (i.e., temperature, light conditions, sound etc.) and non-product contextual information is intentionally minimized (Boutrolle et al., 2007; Holthuysen et al., 2017; Petit & Sieffermann, 2007; Willems et al., 2014). In addition, the degree to which food products are perceived to 'fit' or be congruent with a specific context (i.e., time, place) has been shown to affect food evaluations as well, with higher liking scores for congruent product-context combinations than incongruent product-context combinations (Schutz, 1994; Van Bergen et al., 2021).

The impact of sensory contextual cues on food choice and taste perception has been widely explored (Krishna, 2012). To date, researchers have primarily investigated the influence of changing a single sensory cue within a given context, with a focus on visual cues (Schifferstein et al., 2017; Vermeir & Roose, 2020), auditory cues (Swahn & Nilsen, 2023; Wang et al., 2015), and olfactory cues (Mors et al., 2018; Smeets & Dijksterhuis, 2014; Yang et al., 2023; Zhang & Spence, 2023). For example, for auditory cues, a classical study by North et al. (1997) showed that people's wine choices were influenced by the background music of the store. More specifically, French wine outsold German wine when French music was played, whereas German wine outsold French wine when German music was played, albeit based on a limited number of data points (North et al., 1997). When using olfactory cues, it has been shown that people's healthy food choices can be primed by subconscious exposure to food odours in the environment, i.e., when people were exposed to a fruit odour, they were more likely to choose desserts with fruit (Gaillet et al., 2013).

While research has shown the positive impact of single sensory cues on choice behaviour in different contexts, little is known on how multisensory contextual cues can impact choice behaviour and taste perception (Spence & Piqueras-Fiszman, 2014). Neuroscience research showed that the impact of combining different sensory cues on perception and behaviour can be different than the sum of the effects seen when each of these sensory cues are studied in isolation (Stein & Meredith, 1993; Van der Burg et al., 2011). Indeed, retailing research shows that combining congruent multisensory cues (e.g., auditory with olfactory) in a retail shopping context had a greater impact on time spent and purchase behaviour than single sensory cues (Helmefalk & Berndt, 2018; Krishna, 2012). The impact of multisensory contextual cues on taste perception has been widely explored. Many studies have shown that multisensory contextual cues significantly influence taste perception (e.g., Spence, 2020). For example, Velasco et al. (2013) created three different multisensory contexts, each combining congruent odours, sounds and visuals to enhance the grassy, sweet, and woody notes of whisky. Results showed that participants' ratings of the smell, taste, and flavour of the whisky changed by about 10 % to 20 % as a function of the multisensory context in which participants tasted the whisky (Velasco et al., 2013). For food choice behaviour, a recent study provides initial evidence for the positive impact of multisensory contexts on healthy food choices by combining visual cues with auditory cues (Vanhatalo et al., 2022). In their research, people chose more often vegetarian dishes in a 'nature' context than in a customary 'fast food' context that combined visual cues with auditory cues in a congruent way (respectively nature images & birdsongs vs. abstract red-yellow-orange images & fast-paced instrumental music) (Vanhatalo et al., 2022). To date, it remains unclear to what extent a combination of visual, auditory and olfactory contextual cues can impact sustainable food choice behaviour and taste perception.

Taste perception is a multisensory experience, integrating taste, smell, vision, touch and hearing (Dijksterhuis, 2024). When we perceive foods, many of these sensory systems are activated at the same time: our perception of the food we eat comes not only from what it looks, smells, and tastes like, but also from what it feels and sounds like in the mouth (Zandstra, 2018). Next to these so-called bottom-up effects, top-down effects also play an important role in taste perception and liking of foods (Cardello, 2007; Deliza & Macfie, 1996). Some of these stem from cognitive information, which we get from communication messages, labelling on products or otherwise. Together these create expectations that drive our perception and liking of a product (Piqueras-Fiszman & Spence, 2015; Schifferstein, 1996). For example, nutrition information on fat (Kähkönen et al., 1996) and sugar (Kuenzel et al., 2011) led to an increase in liking for the products, whereas labelling on ingredients such as soy (Wansink & Park, 2002) and salt (Liem, Miremadi, et al., 2012; Liem, Toraman Aydin, & Zandstra, 2012) decreased liking for the products. Communication can therefore have positive and negative effects on perceived taste intensity and liking, and the precise formulation of the message is very important (Zandstra et al., 2016; Zandstra et al., 2017). In this study, we used the labels 'meat' for animal meat and '100 % plant-based' for plant-based meat, as research indicated that plant-based is more appealing when labelled as 'plant-based' than when labelled as 'vegan' or 'vegetarian' (Faber et al., 2020; Ruby et al., 2024).

In relation to animal meat consumption, several studies report an ambivalence towards animal meat that negatively influences willingness to reduce animal meat consumption (Graça, Calheiros, & Oliveira, 2015; Graça, Oliveira, & Calheiros, 2015). Meat consumption elicits a cognitive dissonance between liking animals as living creatures and liking them as food (Bastian & Loughnan, 2017). This is often referred to as the 'meat-paradox' (Buttlar & Walther, 2018). Recent research on sustainability perception of foods showed that increasing consumer knowledge about the environmental impact of foods may lead to more sustainable food consumption and a willingness to decrease animal meat consumption (Siegrist & Hartmann, 2019), either via providing environment-focused text messages (Lim et al., 2021) or using videos (Bschaden et al., 2020). This study is the first study that investigated the combined effects of top-down information (knowledge, labelling) and bottom-up contextual sensory cues on sustainable food choices and taste perception.

The aim of this study was to assess the effect of top-down information and bottom-up contextual sensory cues on meat-related food choices (i.e., animal meat vs. plant-based meat) and taste perception. We hypothesized that people are more likely to choose plant-based meat when 1) they are informed about the negative consequences of the production of animal meat (i.e., sustainable pitch) rather than how body movement affects health (i.e., control pitch), and 2) when they are in a multisensory context that is perceived as congruent with plant-based meat (i.e., sustainable context) compared to an incongruent one (i.e., meat context). In addition, we hypothesized that plant-based meat will taste better in a sustainable context than in a meat context, since the sustainable context is perceived as more congruent with the product than a meat context.

2. Materials and methods

The experiment was conducted during Lowlands (https://lowlands.nl), a three-day music festival in the Netherlands (19–21 August 2022, Biddinghuizen, The Netherlands). The experiment used a 2 (pitch) x 3 (label) x 3 (context) between-subjects design, in which participants were exposed to one of two pitches (sustainable, body movement (control)) and were asked to choose between different labelled hotdogs (plant-based meat hotdog labelled as '100 % plant-based' vs. animal meat hotdog labelled as 'meat' or plant-based meat hotdog mislabelled as 'meat') in one of three contexts (sustainable, meat, neutral). Next to food

choice, we measured liking and sensory evaluations of the hotdogs, and attitudes towards the pitch and novel foods. We also collected data on skin conductance; these results have been reported elsewhere (Stuldreher et al., 2024).

2.1. Participants

In total, 240 participants (102 men, 138 women; mean age 31.6 ± 10.6 years) participated in the experiment. Exclusion criteria were an allergy to gluten, soybeans, nuts, or peanuts, and not understanding Dutch. Participants were naïve as to the purpose of the experiment and signed an informed consent prior to the experiment. Ethical approval was granted by the TNO Institutional Review Board (Approval Ref: 2021–071).

Out of the 240 participants, 224 participants (96 men, 128 women; mean age 31.3 ± 10.3 years) were included in the analysis. Data of participants were excluded when participants: 1) consumed from two plates instead of one (three times the case), 2) did not consume any food (one), 3) had trouble understanding Dutch (two), 4) were in a session with a television celebrity (eight), 5) knew the purpose of this research beforehand (two). In addition, eight participants reported a loss of smell and/or taste, their data were excluded from statistical analysis regarding taste perception and liking of the food. One participant answered the questions in the questionnaire on the pitch too quickly without proper reading (as observed by the experiment leader), these data were excluded from analysis as well.

2.2. Products

The test foods used were an animal meat hotdog (brand: Unox), a plant-based meat hotdog (brand: The Vegetarian Butcher), and tofu (brand: Albert Heijn). The hotdogs were served warm at 60–70 °C on two small plates (Ø 120 mm each) together with 6 ml of hotdog sauce (brand: Calvé) that was placed next to the hotdog. Each serving consisted of half a hotdog (animal meat hotdog 40 g; plant-based meat hotdog 37.5 g). The hotdogs were cut into four equal pieces each so that they looked similar in appearance. The tofu was served cold in 1 × 1 × 1 cm cubes at 4–8 °C on a small plate (Ø 120 mm) together with 5 ml of soy sauce in a 30 cc cup (brand: Kikkoman). Participants were served a tray with three plates with one test food on each plate. The plates with hotdogs were placed in the bottom-left and bottom-middle of the tray, the plate with tofu was placed in the top-right of the tray. Each test food was covered with a lid when served, to be revealed from left to right (Fig. 1). The findings regarding the tofu evaluations are reported elsewhere (Hiraguchi et al., 2023).

2.3. Top-down conditions: pitches and labels

For the pitches, all participants were presented a five-minute video pitch on a large TV screen in the 'pitch tent' (Fig. 1). The pitches were provided by Professor Erik Scherder (VU Amsterdam, The Netherlands), a Dutch neuropsychologist and television celebrity. The pitch was either a 'sustainable pitch' about the consumption of sustainable food and discussing (negative) implications of consuming animal meat on the environment and health, or a 'movement pitch' (control) promoting body exercise and the effects of movement on brain health. The content of both video pitches is available on request. Participants wore a headphone while watching the pitch.

For labelling, all test foods were offered together with a toothpick mini flag (white-coloured with black text; 40 × 25 mm) to label them as 'meat' (i.e., 'vlees' in Dutch) or '100 % plant-based' (i.e., '100 % plantaardig' in Dutch). Per tasting, half of the group received the animal meat hotdog labelled as 'meat' and the plant-based meat hotdog labelled as '100 % plant-based'. The other half of the group received only plant-based meat hotdogs using the same two labels 'meat' and '100 % plant-based' (i.e., the hotdog labelled as 'animal meat' was covertly a plant-based meat hotdog). The order of the hotdogs labelled as 'meat' and '100 % plant-based' were counterbalanced across participants.

2.4. Bottom-up condition: multisensory context

The tasting took part in the 'tasting tent' in one of three multisensory contexts: 1) sustainable context, 2) meat context, or 3) neutral context. Each context was designed with congruent visual (images), auditory (sounds) and olfactory (smells) contextual cues based on literature and personal observations (Bschaden et al., 2020; Langlois & Chandon, 2024; Van Bergen et al., 2021; Wang et al., 2015; Yang et al., 2023). Initially, these contextual concepts were tested with a small group (n = 8) and adjusted as needed. For example, country music was chosen for the meat context, and plates were adjusted accordingly: white sugar cane plates for both the neutral and meat contexts, and brownish palm leaf plates for the sustainable context, as music and background colour have been shown to influence perception (Spence, 2018; Wang et al., 2015). However, certain logistical constraints at the festival location, such as the inability to fit a bicycle inside the tent for the sustainability context, led to some modifications. Fig. 2 shows the three different multisensory contexts applied.

Sustainable context - The sustainable context was predominantly green in colour. Posters of flowers, trees, and a lamb grazing in a field were shown on the walls. Furthermore, we used a green tablecloth, a green light on the table, trays with an inlay with a picture of green leaves, palm leaf plates, and green napkins. Nature music with the sounds of birds was played during the session, and a flower odour (air

Fig. 1. (colour online) Impression of the setting of the 'pitch' tent wherein the pitches were shown (left) and example of how the foods were presented in the 'tasting' tent (right), each on a separate plate covered by a lid on a single tray placed in front of the participants. Upon instruction the participants lifted the lid of the plates one by one.

Fig. 2. Multisensory contexts (from left to right): sustainable, meat, neutral.

freshener 'Lavender', brand: Plus) was sprayed in the room before the session started in such a way that it was just noticeably perceived by the research team. As extra decoration, a plant and a crate filled with vegetables and fruit were placed on a small table with a green tablecloth.

Meat context - The meat context was predominantly red in colour. Posters of a BBQ, fire and trees were shown on the walls. We used a brown tablecloth with a wooden pattern, a red light on the table, trays with an inlay with a picture of a grill, white sugar cane plates, and napkins with a BBQ print. Country music was played, and a smoky BBQ odour (liquid smoke aroma, brand: Van Beekum Specerijen) was dispersed in the room before the session at a just noticeable level for the research team. As extra decoration, a red BBQ, and a few wooden logs on a small table with a brown tablecloth were placed in the room.

Neutral context – The neutral context was predominantly off-white coloured and had no potentially distracting cues. The walls were a monotone off-white colour, and we used a white tablecloth, white light on the table, trays with a white inlay, white sugar cane plates, and white napkins. Neutral background music (elevator music) was played, and no odour was distributed in the room. As extra decoration, a white ventilator and two bottles of water were placed on a small table in the room. The number of contextual cues was kept low to mimic a controlled laboratory setting as much as possible.

2.5. Procedure

The testing took place between 12:00 and 20:00 on three consecutive days at the Lowlands festival. Every hour, a group of eight visitors from Lowlands festival participated in a 20-min session. Fig. 3 shows the timeline of research activities during each session.

At the beginning of the session, participants were given verbal and written instructions. The experimental leader attached sensors for measuring skin conductance (EdaMove4, Movisens GmbH, Karlsruhe, Germany) to the nondominant hand, gave participants a smartphone to complete the questionnaires, and instructed them to take a seat in the 'pitch' tent. Once seated, participants completed the 'Baseline' questionnaire regarding sleep, alcohol consumption and use of drugs using the smartphone. Since the experiment took place at a 3-day music festival, monitoring these variables is important as they might affect participants' taste perception and food choices. Participants were then presented with one of two pitches (movement or sustainable). The pitches were shown in the form of a five-minute video on a large TV screen, and participants wore a headphone while watching. The control pitch and sustainable pitch were shown in alternating order, starting with the control pitch in both the morning and afternoon. Directly after the pitch, participants completed the 'Pitch' questionnaire concerning the pitch using the smartphone.

Participants were then guided to the 'tasting' tent, where a multisensory context was simulated. On day one the meat context (12:00–16:00) and sustainable context (16:00–20:00) were simulated, on day two the neutral context (12:00–16:00) and meat context (16:00–20:00), and on day three the sustainable context (12:00–16:00) and neutral context (16:00–20:00). Participants were seated at one of the two tables with four seats each. Participants received a tray with the food samples that was prepared shortly before the participants arrived. The experiment leader informed participants that they were to be presented with two foods consecutively and instructed the participants to lift the lid of the leftmost plate on their tray after a five second countdown, and subsequently to observe the contents of the plate for 20 s. Subsequently, participants were instructed to lift the second, middle plate on their tray after another five second count down, and to observe the contents for another 20 s. After each countdown, the experiment leader tapped their own EdaMove 4 device around their wrist to send a trigger that could be used to link participants' electrodermal response to the food reveal (more details and results on this part of the study are in Stuldreher et al. (2024) and not further discussed here). After presentation of both hotdogs, participants were asked which of the two hotdogs they wanted to taste ('meat' or '100 % plant-based'), how hungry they were, how much they were looking forward to eat the chosen hotdog and how tasty they thought that the chosen hotdog would be (questionnaire 'Before tasting'). Participants could then taste as many pieces

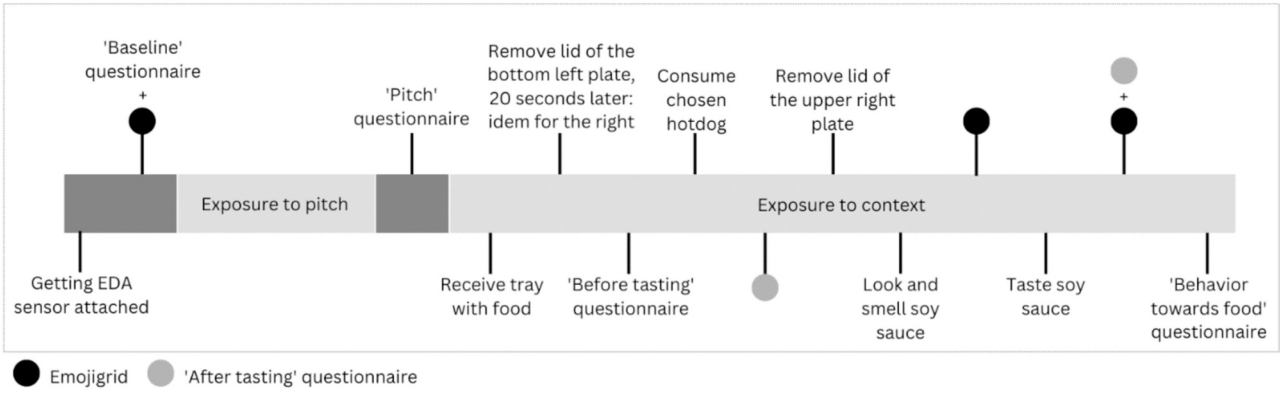

Fig. 3. Timeline of research activities during the 20 min procedure.

of their chosen hotdog as they wanted, up to a maximum of four pieces. Directly after consumption, participants answered several questions on liking and taste perception of the chosen hotdog (questionnaire 'After tasting'). The same approach was taken for the tofu served with soy sauce. As with the hotdogs, after a five-second countdown the experiment leader tapped their EdaMove 4, and participants could lift the lid of their plate. After answering some questions presented on the smartphone, participants were instructed to first smell the soy sauce, and then taste and rate the tofu in combination with the soy sauce using the EmojiGrid to measure valence and arousal (Kaneko et al., 2019) (results on this part of the study are reported in Hiraguchi et al. (2023)). Participants could then remove their EdaMove 4 device and finished the experiment with the questionnaire 'Behaviour towards food'. Qualtrics XM Platform (2022) was used for the questionnaires.

2.6. Measurements

'Baseline' Questionnaire: Sleep, alcohol consumption and drugs.

Sleep and alcohol consumption were measured using a single open item, respectively '*How many hours have you slept last night*?' and '*How many glasses of alcohol have you drunk since waking up today*?'. For use of drugs, a closed question was used '*Did you use drugs today*?' (yes, no, do not want to share).

Questionnaire 'Pitch': Attitudes towards the pitch.

Participants rated the pitch on a scale from 1 (very poor) to 10 (excellent). This aligns with the traditional grading scale used in the Dutch education system, where 1 represents the lowest and 10 the highest grade. In addition, they rated the pitch regarding how much they liked it, the importance of the topic of the pitch and how much attention they paid to it on a scale from 1 (not at all) to 10 (very).

Questionnaire 'Before tasting' and 'After tasting': Food choice, liking, taste perception and amount consumed.

For the hotdogs, participants' choice was measured by asking '*You can taste one of these two hotdogs. Which one are you going to taste?*' with two answer options 'meat' or '100 % plant-based'. After that, participants were asked how hungry they were, how much they were looking forward to eating the chosen hotdog, and how tasty they thought that the chosen hotdog would be on a scale from 1 (not at all) to 10 (very). Participants were then asked to taste their chosen hotdog; they were free to eat as many pieces of the hotdog as they wanted to, and to consume the hotdog with the sauce or not. Directly after consumption, participants had to indicate how many pieces they had consumed (0, 1, 2, 3, or 4). If they had consumed at least one piece, participants rated liking and perceived tastiness, saltiness, sourness, sweetness, bitterness, savouriness, juiciness, and firmness of the hotdog, using a scale from 1 (not at all) to 10 (very). Finally, they scored whether they would be interested to consume more of the hotdog on a scale from 1 (totally disagree) to 10 (totally agree), whether they consumed the hotdog with sauce (yes, no), and how many pieces they eventually had consumed (1, 2, 3, or 4).

Questionnaire 'Behaviour towards food': Attitudes and behaviour towards foods.

To assess animal meat consumption frequency, participants were asked to indicate on how many days per week they consume animal meat: 0 days, 1–3 days (infrequent meat eaters), 4–5 days (moderate meat eaters), 6–7 days (frequent meat eaters). In addition, participants' level of food neophobia was measured using the 10-item food neophobia scale by Pliner and Hobden (1992) that measures a reluctance to eat and/or avoid novel foods. Responses were given on a 7-point Likert scale ranging from 'strongly disagree' to 'strongly agree'.

2.7. Statistical analysis

Data are presented as means and standard errors unless stated otherwise. Statistical analyses were performed with SPSS version 28.0.1.1 (IBM Corp, 2021). We considered differences significant at $p < 0.05$.

For food choice, we conducted a binary logistic regression analysis to examine the influence of pitch and context on the likelihood that a meat eater chooses a plant-based meat hotdog over an animal meat hotdog. First, we performed a model analysis including Pitch and Context (crude analysis), followed by an adjusted model analysis by adding the covariates Gender, Meat consumption, Food neophobia, and Time slot. For both models, we assessed whether interaction effects of Pitch x Context were significant.

For liking, we performed a one-way ANOVA to assess differences in liking between the hotdogs. In addition, we performed a general linear model univariate for the meat eaters to determine the effect of pitch and context, and their respective interactions on expected liking of the plant-based meat hotdog labelled as '100 % plant-based', the animal meat hotdog labelled as 'meat', and the plant-based meat hotdog labelled as 'meat'. For the group vegetarians and vegans, we assessed the effect of pitch and context, and their respective interactions on expected liking of the plant-based meat hotdog labelled as '100 % plant-based'. First, we performed a model analysis including Pitch and Context (crude analysis). In addition, the impact of the variables Gender, Meat consumption, Food neophobia, and Time slot was assessed by including them as covariates in the crude analysis model (model adjusted for covariates). Food neophobia was included as a categorical variable. Hereafter the same model analysis was performed for actual liking, desire to eat more, taste perceptions, and number of pieces consumed, whereby the consumption of sauce was included as covariate as well.

Finally, we used a binary logistic regression analysis to determine the effect of the pitch, i.e., liking, attention, and importance of the topic, on the likelihood that a meat eater chooses a plant-based meat hotdog over an animal meat hotdog. Again, after performing the crude model, we performed a full adjusted model using the covariates Gender, Meat consumption, Time slot, and Food neophobia.

3. Results

3.1. Participants

Table 1 shows the main characteristics of the 224 participants who completed the study classified per pitch and context. Of these 224 participants, 166 participants reported to be a meat eater (i.e., consuming animal meat at least once a week) and 58 participants to eat vegetarian or vegan. Table 2 shows the main characteristics of these two groups. Overall, participants scored relatively low on food neophobia (2.2 ± 0.7 on a 7-point scale). Most participants of the meat eater group reported to have an infrequent (1–3 days a week) animal meat consumption.

3.2. Food choice

Overall, meat eaters chose most frequently the hotdog labelled as '100 % plant-based' over the hotdog labelled as 'meat', regardless of the pitch ($p > 0.05$) or context ($p > 0.05$) (Table 3). The choice for the plant-based meat hotdog labelled as '100 % plant-based' was 72.3 % vs. 62.4 % after the sustainable and control pitches, respectively. Interestingly, the combination of the sustainable pitch with the sustainable context increased the choice of the hotdog labelled as '100 % plant-based', i.e., 100 % (17 out of 17 participants) chose the hotdog labelled as '100 % plant-based' ($p < 0.05$). Fig. 4 shows the choices of the hotdogs for the different combinations of pitches and contexts.

3.3. Liking, desire to eat more and amount consumed

Meat eaters liked the animal meat hotdog labelled as 'meat' significantly better than the plant-based meat hotdog labelled as '100 % plant-based' and the plant-based meat hotdog labelled as 'meat' ($p < 0.01$; Table 4). Meat eaters gave similar liking scores to the plant-based meat hotdog labelled as 'meat' and the plant-based meat hotdog labelled as '100 % plant-based' ($p > 0.05$). For the meat eaters, the (expected)

Table 1
Characteristics of the participants classified per pitch and context (means ± SD). (n = 224; meat eaters, flexitarians, vegetarians, and vegans).

	Pitch		Context		
	Movement	Sustainable	Neutral	Sustainable	Meat
Participants (n)	130	94	78	69	77
Sex (m/w)	54/76	42/52	39/39	24/45	33/44
Age (years)	30 ± 9.5	33 ± 11.2	29 ± 9.1	34 ± 10.6	31 ± 10.9
BMI (kg/m^2)	23.4 ± 3.1	23.7 ± 3.2	23.6 ± 2.9	23.7 ± 3.3	23.2 ± 3.2
Animal meat consumption (%)					
0 days a week	22.3	30.9	24.4	23.2	29.9
1–3 days a week	37.7	38.3	28.2	47.8	39.0
4–5 days a week	28.5	25.5	35.9	24.6	20.8
6–7 days a week	11.5	5.3	11.5	4.3	10.4
Food neophobia*	2.2 ± 0.7	2.3 ± 0.7	2.2 ± 0.8	2.2 ± 0.8	2.2 ± 0.8
Sleep (hours)	5.9 ± 1.5	5.8 ± 1.4	5.8 ± 1.5	5.7 ± 1.5	6.1 ± 1.4
Alcohol consumption since waking up (n)					
0–2 Glasses	90	63	59	45	49
3–5 Glasses	29	24	15	18	20
≥ 6 Glasses	11	7	4	6	8
Use of drugs (n)					
No	120	85	71	65	69
Yes	10	7	7	3	7
Do not want to share	0	2	0	1	1

* Level of food neophobia was assessed using the Food Neophobia Scale (Pliner & Hobden, 1992), measuring a reluctance to eat novel foods using 10 items on a scale from 1 = 'Strongly disagree' to 7 = 'Strongly agree'.

Table 2
Characteristics of the participants per group (means ± SD): meat eaters (n = 166) and vegetarians and vegans (n = 58).

	Meat eaters	Vegetarians & vegans
Participants (n)	166	58
Sex (m/w)	79/87	17/41
Age (years)	32.5 ± 11.0	28.0 ± 7.1
BMI (kg/m^2)	23.7 ± 3.1	22.8 ± 3.3
Animal meat consumption (%)		
0 days a week	0	100
1–3 days a week	51.2	0
4–5 days a week	36.7	0
6–7 days a week	12.0	0
Food neophobia*	2.2 ± 0.8	2.3 ± 0.6
Sleep (hours)	5.9 ± 1.5	5.8 ± 1.3
Alcohol consumption since waking up (n)		
0–2 Glasses	115	38
3–5 Glasses	40	13
≥ 6 Glasses	11	7
Use of drugs (n)		
No	152	53
Yes	12	5
Do not want to share	2	0

* Level of food neophobia was assessed using the Food Neophobia Scale (Pliner & Hobden, 1992), measuring a reluctance to eat novel foods using 10 items on a scale from 1 = 'Strongly disagree' to 7 = 'Strongly agree'.

Table 3
Output of binary logistic regression model (crude and adjusted analysis). The effect of pitch (movement, sustainable), context (neutral, sustainable, meat) and interaction of pitchcontext on the likelihood that a meat eater chooses the hotdog labelled as '100 % plant-based' over the hotdog labelled as 'meat'.

		Crude Analysis		Adjusted Analysis*	
	N	p-value	OR (95 % CI)	p-value	OR (95 % CI)
Pitch	166				
Movement (control)	101		ref		ref
Sustainable	65	0.18	1.60 (0.81, 3.16)	0.15	1.72 (0.83, 3.56)
Context	166				
Neutral	59		ref		ref
Sustainable	53	0.30	1.53 (0.69, 3.38)	0.61	1.25 (0.53, 2.95)
Meat	54	0.45	1.35 (0.62, 2.95)	0.67	1.20 (0.52, 2.81)
Pitch*Context					
Movement* Neutral	36	ref		ref	
Movement* Sustainable	36	0.34	1.60 (0.62, 4.16)	0.08	2.56 (0.89, 7.39)
Movement*Meat	29	0.92	1.05 (0.38, 2.96)	0.52	1.44 (0.47, 4.42)
Sustainable* Neutral	23	0.27	1.83 (0.63, 5.36)	0.12	2.58 (0.79, 8.40)
Sustainable* Sustainable	17	0.06	0.13 (0.02, 1.06)	0.05	0.11 (0.01, 1.01)
Sustainable*Meat	25	0.66	0.78 (0.26, 2.37)	0.82	0.87 (0.26, 2.97)

Abbreviations: reference (ref).
* Model adjusted for gender, meat consumption, food neophobia, time slot.

liking, desire to eat more, and taste perception of the hotdogs did not differ across the pitches and contexts (all $p > 0.05$). Here, the Pitch x Context interaction was also not significant (all $p > 0.05$). In relation to the amount consumed, the pitch did not add significantly to the number of pieces consumed ($p < 0.05$), whereas context did ($p = 0.02$). That is, meat eaters ate more of the plant-based meat hotdog labelled as '100 % plant-based' when it was presented in the meat context than in the neutral context (resp. 3.4 ± 0.9 pieces vs. 2.9 ± 1.1 pieces). No difference was found in the amount of animal meat hotdog consumed whether it was eaten in the meat context or neutral context (resp. 3.4 ± 0.4 pieces vs. 3.6 ± 0.3 pieces). There was no significant interaction between Pitch x Context in the number of pieces consumed ($p > 0.05$). Further details on the general linear model univariate analysis are provided in Supplementary Table 1.

Vegetarians and vegans liked the plant-based meat hotdog labelled as '100 % plant-based' better than the meat eaters ($p = 0.03$; Table 4). For the vegetarians and vegans, there was no significant main effect for Pitch on (expected) liking, desire to eat more, and the number of pieces consumed of the plant-based meat hotdog labelled as '100 % plant-based' (all $p > 0.05$). However, there was a significant main effect for Context on perceived liking, desire to eat more, and number of pieces consumed, but not on expected liking. That is, vegetarians and vegans scored the plant-based meat hotdog in the meat context higher on perceived liking (resp. 7.9 ± 1.7 vs. 7.1 ± 1.8; $p = 0.03$) and desire to eat more (resp. 7.3 ± 2.4 vs. 5.3 ± 2.5; $p = 0.02$) than in the neutral context, and they also ate a higher number of pieces of the plant-based meat hotdog in the meat context compared to the neutral context (resp. 3.6 ± 0.9 vs. 3.2 ± 0.9; $p = 0.04$). Fig. 5 shows the mean scores of the vegetarian and vegan group on expected liking, perceived liking, and desire to eat more of the plant-based meat hotdog, classified for the three contexts. Supplementary Table 2 shows detailed results of the general linear model univariate analysis.

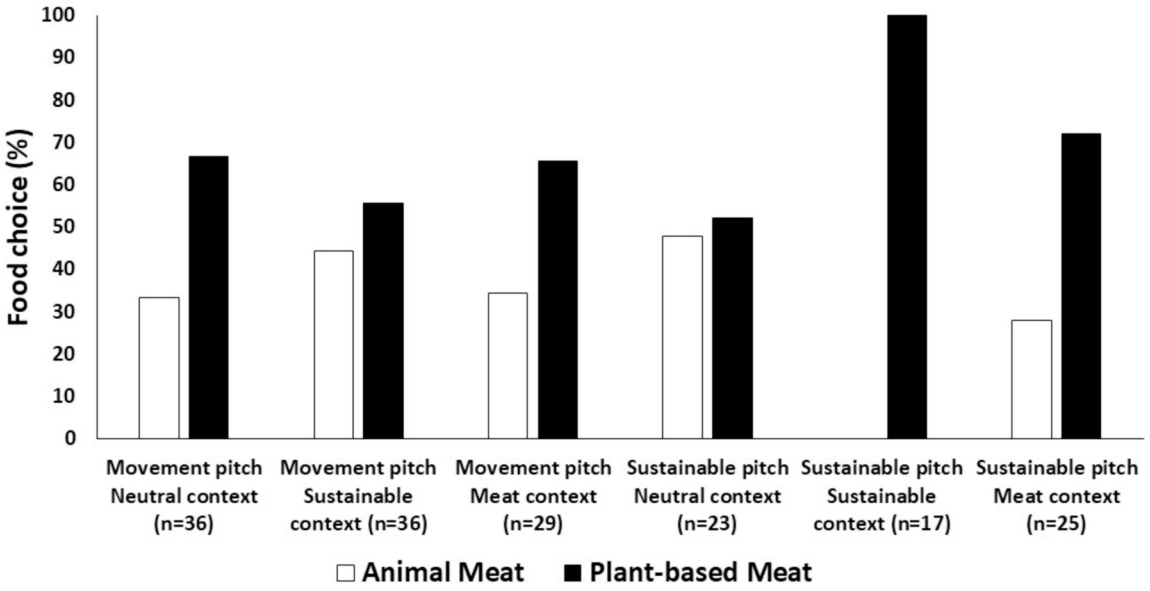

Fig. 4. The choice (%) between the hotdog labelled as 'meat' and hotdog labelled as '100 % plant-based' by meat-eaters after being exposed to one of the two pitches (movement, sustainable) and one of the three contexts (neutral, sustainable, meat).

Table 4
Mean (expected) liking and desire-to-eat-more scores and number of pieces consumed (± SE) for the animal meat hotdog and plant-based meat hotdog per label and group: meat eaters (n = 158) and vegetarians and vegans (n = 54).

	Expected Liking	Liking	Desire to eat more	Number of pieces consumed
Meat eaters				
Animal meat hotdog 'meat'	7.0 ± 0.3 ^{A}	7.9 ± 0.3 ^{A}	7.4 ± 0.4 ^{A}	3.5 ± 0.3 ^{A}
Plant-based meat hotdog '100 % plant-based'	6.5 ± 0.2 ^{A}	6.5 ± 0.2^{B}	5.3 ± 0.3 ^{B}	3.0 ± 0.2 ^{B}
Plant-based meat hotdog 'meat'	6.7 ± 0.3 ^{A}	6.1 ± 0.4^{B}	5.0 ± 0.6 ^{B}	3.3 ± 0.2 ^{AB}
Vegetarians and vegans				
Plant-based meat hotdog '100 % plant-based'	6.5 ± 0.3 ^{A}	7.3 ± 0.3 ^{A}	6.3 ± 0.4 ^{A}	3.3 ± 0.1 ^{AB}

A,B *Scores within a column with unlike superscript upper-case letters were significantly different ($p < 0.05$).*

3.4. Taste and texture perception

The group of meat eaters perceived the taste and texture of the hotdogs differently depending on the pitches and contexts. For the animal meat hotdog labelled as 'meat', there was a main effect of Pitch ($p < 0.05$) and Context ($p < 0.05$) on taste perception, but no significant interaction effects Pitch x Context (all $p > 0.05$). The meat eaters perceived the animal meat hotdog labelled as 'meat' to be firmer when exposed to the sustainable pitch compared to the control pitch (resp. 8.0 ± 1.2 vs. 7.4 ± 1.1; $p = 0.04$). Also, the same animal meat hotdog labelled as 'meat' was perceived as sourer by the meat eaters when eaten in the sustainable context compared to the neutral context (resp. 5.6 ± 1.8 vs. 3.9 ± 2.0; $p < 0.01$), and less firm when eaten in the meat context compared to the neutral context (resp. 6.9 ± 0.9 vs. 8.0 ± 1.1; $p = 0.01$).

For taste perception of the plant-based meat hotdog labelled as '100 % plant-based', there were no significant main effects for Pitch and Context, and no significant interaction effects Pitch x Context (all $p > 0.05$): meat eaters perceived the plant-based meat hotdog labelled as '100 % plant-based' with the different pitches and contexts to be similar on saltiness, sourness, sweetness, bitterness, savouriness, juiciness, and firmness. Interestingly, there were significant main effects for Pitch and Context on taste perception of the plant-based meat hotdogs labelled as 'meat': meat eaters rated this hotdog significantly lower on sourness after exposure to the sustainable pitch compared to the control pitch (resp. 4.4 ± 1.6 vs. 4.7 ± 2.1; $p = 0.02$), while they rated it higher on sourness in the sustainable context and meat context compared to the neutral context (resp. 5.3 ± 1.6 and 4.7 ± 2.3 vs. 4.0 ± 1.8; all $p < 0.01$). There were no significant interaction effects between Pitch x Context (all $p > 0.05$).

For vegetarians and vegans, there was a significant main effect of Context on taste perception of the plant-based meat hotdog labelled as '100 % plant-based'. Vegetarians and vegans perceived the plant-based meat hotdog as less sour (resp. 3.7 ± 1.5 vs. 5.2 ± 2.0; $p = 0.05$), less bitter (resp. 2.4 ± 1.6 vs. 3.5 ± 1.9; $p = 0.04$), more juicy (resp. 7.0 ± 1.6 vs. 5.8 ± 1.6; $p = 0.05$) and more firm (resp. 7.5 ± 1.3 vs. 6.6 ± 1.2; $p = 0.02$) in the meat context compared to the neutral context. The plant-based meat hotdog was also perceived as firmer in the sustainable context compared to the neutral context (resp. 7.6 ± 1.2 vs. 6.6 ± 1.2; $p = 0.02$). The main effect of Pitch was not significant (all $p > 0.05$).

Effect of grading, liking, importance and attention towards the pitch on food choice.

Table 5 shows the mean scores of grading, liking, importance of the subject and attention towards the two pitches. Overall, participants gave high scores for the pitches: both the sustainable pitch and movement (control) pitch received an overall grade of 7.7 (out of 10).

When exposed to the movement (control) pitch, the group of meat eaters were more likely to choose the plant-based meat hotdog when they liked the pitch more (OR = 1.56) ($p = 0.02$). In addition, when exposed to the sustainable pitch, the likelihood that meat eaters chose the plant-based meat hotdog increased when they gave the pitch a higher grade (OR = 1.73) ($p = 0.04$). Supplementary Table 3 provides on overview of the binary logistic regression model results.

4. Discussion

This study investigated whether bottom-up multisensory contextual cues and top-down information (knowledge, labelling) can affect food choice and taste perception of plant-based meat. For food choice, we demonstrated that multisensory contextual cues combined with sustainability information beforehand can increase people's choice of

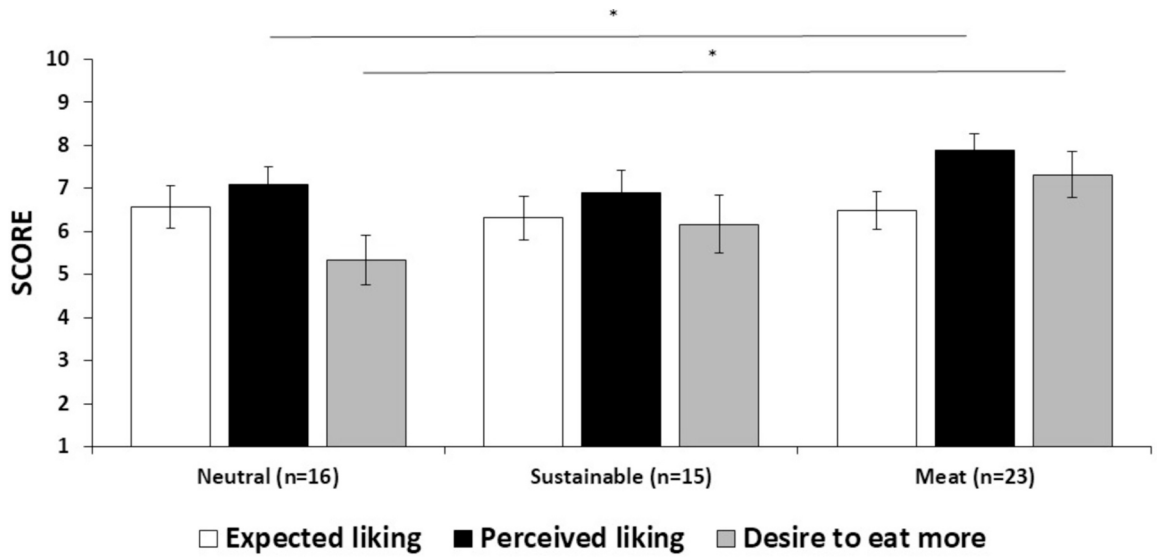

Fig. 5. Mean scores of expected liking, perceived liking, and desire to eat more of the plant-based meat hotdog labelled as '100 % plant-based' (± SE) for the vegetarians and vegans after being exposed to one of the three contexts (neutral, sustainable, meat). * *p*-value <0.05 within the model adjusted for covariates.

Table 5
Mean scores of grading, liking, importance of the subject, and attention towards the pitch from 1 (not at all) to 10 (very) *(± SE), classified per pitch and group: meat eaters (n = 166) and vegetarians and vegans (n = 58).*

	Pitch	
	Movement	Sustainable
Meat eaters		
Participants (n)	101	65
Grading	7.8 ± 0.1	7.8 ± 0.2
Liking	7.9 ± 0.1	7.7 ± 0.2
Importance of the subject	8.0 ± 0.1	8.1 ± 0.2
Attention	8.0 ± 0.2	8.2 ± 0.2
Vegetarians and vegans		
Participants (n)	29	29
Grading	7.5 ± 0.2	7.6 ± 0.2
Liking	7.5 ± 0.3	7.2 ± 0.3
Importance of the subject	7.8 ± 0.3	8.8 ± 0.4
Attention	8.0 ± 0.3	8.6 ± 0.2

plant-based meat over animal meat. In addition, for taste perception, multisensory contextual cues that are inspired by a meat context rather than a neutral context improved the taste experience of plant-based meat, even for vegans and vegetarians. Further research with plant-based food stimuli in natural everyday contexts (retail, restaurants) is needed to confirm these conclusions.

Achieving behaviour change towards eating less animal meat and more plant-based foods is hard. This transition is hampered by a notable gap between consumers' sustainable intentions and their actual consumption behaviour (Boukid, 2021; Jahn et al., 2021; Onwezen et al., 2021; Vermeir et al., 2020). Many Western consumers have positive attitudes towards plant-based food, i.e., for health, environmental, and/or animal welfare reasons (Graça, Calheiros, et al., 2015; Graça, Oliveira, et al., 2015; Michel et al., 2021), in practice, however, it appears to be difficult to act accordingly (Bastian & Loughnan, 2017; Onwezen, 2022; Sijtsema et al., 2021; Vermeir et al., 2020). The present study showed that the use of multisensory contextual cues at the location of decision making may be a promising strategy to bridge this intention-behaviour gap and support the required change. People most frequently chose the plant-based meat hotdog over the animal meat hotdog, especially in a sustainable context in combination with a sustainable pitch. Providing explicit top-down information on sustainability on its own did not increase plant-based food choices. This is in line with previous research that showed that subtle, more 'nudging' oriented approaches are more successful than many explicit information and awareness-raising campaigns (Bschaden et al., 2024; Kahneman, 2012; Thaler & Sunstein, 2008). Specifically, research on increasing knowledge about the environmental impact of foods via text messages and videos showed that it increased awareness and willingness to decrease animal meat consumption, but not (self-reported) animal meat consumption as such (Bschaden et al., 2020; Lim et al., 2021). From these recent results, one might conclude that information has no effect on animal meat consumption and therefore has little value in changing choice behaviour. However, our results show that information can have value as a catalyst for other interventions. The results of our study add to a growing literature that highlight the importance of multisensory contextual cues for food choice and consumption behaviour (Cardello & Meiselman, 2018; Edwards et al., 2003; Zandstra, 2018; Zandstra & Lion, 2019). Future research should replicate and validate these results in real-life contexts, e.g., retailer and restaurant contexts.

So far, only few real-life retail studies have investigated how changes in the physical context influences plant-based meat sales by placing plant-based meat directly next to animal meat in the conventional meat section (Institute for Grocery Distribution (IGD), 2022;Van der Meer et al., 2024; Vandenbroele et al., 2021). The results of these studies are mixed. One study in the UK showed a decrease in plant-based meat sales, where animal meat was much cheaper than plant-based meat. This price discrepancy became obvious to shoppers when products were placed side by side (Institute for Grocery Distribution (IGD), 2022). Two other studies in Belgian (Vandenbroele et al., 2021) and Dutch stores (Van der Meer et al., 2024) showed an increase in plant-based meat sales when their prices were similar to those of animal meat. However, these studies did not observe a decrease in the sales of animal meat (Van der Meer et al., 2024; Vandenbroele et al., 2021). Visibility, taste and volume had a significant impact on these results, although their effects were relatively small. We recommend future research to investigate multisensory contextual cues that are inspired by a sustainable context at the shopping floor on top of pairwise presentations in the meat shelf to amplify the effects and prompt a greater shift towards plant-based meat.

For liking and taste perception, we hypothesized that plant-based meat would be rated higher in terms of liking when presented in a sustainable context compared to a meat context, as the sustainable context is perceived as more congruent with the product. Interestingly, results of our study showed the opposite. For meat eaters, liking, desire to eat more and taste perception of the plant-based meat hotdogs did not

differ across pitches and contexts, however, they did eat most of the plant-based meat hotdog in the meat context compared to the neutral context. Also, meat eaters found the animal meat hotdog to taste more sour when eaten in the sustainable context compared to the neutral context. At this time, we do not have a clear explanation for this effect. For vegans and vegetarians, the meat context appeared to be most optimal for liking and taste perception of the plant-based meat hotdog: they perceived the plant-based meat hotdog as less sour, less bitter, juicier and firmer in the meat context compared to the neutral context. A possible explanation could be related to the colour cues used in the meat context. Colour plays a key role in how people see and perceive products (Spence, 2015; Tijssen et al., 2017). The meat context in our study was predominantly red coloured. Recent research shows that people associate the colour red with superior taste when it comes to plant-based meat, whereas people associate the colour green with health and sustainability, but not necessarily with taste (ProVeg International, 2024). People are also more willing to try plant-based meat if they are clad in red packaging, even though most commercially available plant-based meat actually have green packaging. Not only meat eaters, but also vegetarians and vegans perceived red as a signal of bold flavours and satisfying taste in plant-based products (ProVeg International, 2024). Another explanation could be that the visual cues used in the meat context were more contextually relevant as they were food-related (i.e., posters of animal meat on a BBQ, fire), whereas the ones used in the sustainable context were not (i.e., posters of flowers, a lamb grazing in a field). The degree to which foods are considered congruent with, or appropriate for, a specific time or place has been shown to affect food evaluations (Schutz, 1994). For example, viewing an image of a food presented in a background of a congruent eating situation increased the desire to eat the food and even increased salivation, a physiological indicator of preparing to eat (Papies et al., 2022). The more congruent product-context combination in the meat context may therefore have resulted in a more satisfying experience overall. In addition, congruency in pitch-context combinations may have impacted the results in a similar vein, as the combination of the sustainable pitch with the sustainable context may have been perceived as more congruent compared to the combination of the control pitch and the meat context.

This study combined visual, auditory and olfactory cues to create the contexts that produced differences in more than one sensory modality between the contexts (Schreuder et al., 2016). To specify exactly which aspect(s) of the context were responsible for the attested effects, we recommend future research to explore the role of visual, auditory and olfactory cues independently on sensory perception and liking in real-life settings as well. Finally, meat eaters liked the animal meat hotdog labelled as 'meat' better than the plant-based meat hotdog labelled as '100 % plant-based', which is in line with earlier research (Giezenaar et al., 2024; Michel et al., 2021; Onwezen et al., 2021). For product developers it is important to continuously develop plant-based meat that is similar or even better than animal meat in taste, texture and satisfaction (Pater et al., 2022; Van Bergen et al., 2024; Zandstra et al., 2023; Zandstra et al., 2024), but also in nutritional quality to fit into a healthy, balanced plant-forward diet (Lindberg et al., 2024; Neufingerl & Eilander, 2022).

A strength of the study is that it involved participants making real choices under realistic choice conditions, thereby measuring actual behaviour rather than relying on self-reported intentions via questionnaires. However, there are a few limitations that should be mentioned. The participants were attendees of the three-day Lowlands Science 2022 festival, a group that is relatively young, outgoing, and potentially more aware and open to the necessary protein transition compared to the general population. Also, they may hold stronger 'sustainable = healthy' intuitions (Erhard et al., 2024), which could affect the generalizability of the results. To enhance the generalizability of these findings, future research should aim to include a larger and more representative sample, as this study's sample was relatively small. In addition, the results are based on a plant-based meat hotdog made with soy in a snack-size format. It is recommended to replicate the study for other plant-based alternatives to animal meat (e.g., based on pulses, mycoprotein or algae) and for a broader range of plant-based meat products (e.g., burger patties, chicken/beef pieces) and formats (e.g., bread spreads, meals) to substantiate the findings. Finally, people chose and ate the hotdogs while they were sitting together at a table, and they were allowed to socialize with each other as long as they did not discuss the food samples during the session. It was a deliberate choice to implement this social setting as our study aimed to approach natural consumption settings in terms of social context as well (by testing participants in social groups rather than alone). This by itself may have affected our results (De Castro, 1994; Higgs & Thomas, 2016). In future, these specific context effects could be explored by systematically manipulating the social context (groups with family or friends vs. alone) to separate social from physical context effects on food choices and evaluations.

5. Conclusion

Taken together, our findings add to a growing literature that highlight the relevance of multisensory contextual cues for food choice and eating behaviours. More specifically, our findings suggest it is best to 1) create a multisensory sustainable context in addition to top-down information to increase plant-based food choices, and 2) create a multisensory meat context for an optimal plant-based meat product experience, even for vegetarians and vegans. In a next step, we recommend confirming the findings in real-life contexts (retail and restaurants), using larger samples and a range of different plant-based meat products.

Ethical statement

Participants were naïve as to the purpose of the experiment and signed an informed consent prior to the experiment. Ethical approval was granted by the TNO Institutional Review Board (Approval Ref: 2021–071).

CRediT authorship contribution statement

E.H. Zandstra: Writing – original draft, Resources, Methodology, Investigation, Funding acquisition, Conceptualization. **D.E. Van Os:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis. **E. Van der Burg:** Writing – review & editing, Validation, Software, Methodology, Investigation, Funding acquisition, Conceptualization. **I.V. Stuldreher:** Writing – review & editing, Validation, Software, Methodology. **A. Toet:** Writing – review & editing, Validation, Methodology. **S. Velut:** Writing – review & editing, Validation, Software, Methodology, Investigation. **H. Hiraguchi:** Writing – review & editing, Methodology, Investigation, Funding acquisition, Formal analysis. **M.A. Hogervorst:** Writing – review & editing, Methodology, Investigation. **A.-M. Brouwer:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **J.B.F. Van Erp:** Writing – review & editing, Resources, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: E. H.Z. is employee of Unilever Foods Innovation Centre Wageningen, a global FMCG company that markets among others plant-based food products, and H.H. is employee of Kikkoman Europe R&D Laboratory B. V., a company that markets soy sauce, soy-sauce-based seasonings and wholesale of oriental foods. E.H.Z. had a role in the study methodology, data collection, interpretation of the data and preparation of the manuscript, but no role in the data analyses. H.H. had a role in the data

collection and preparation of the manuscript, but no role in the study methodology, data analyses or interpretation of the data. The authors D. E.v.O., E.v.d.B., I.V.S., A.T., S.V., H.H., M.A.H., A.-M.B. and J.B.F.v.E. declare no conflict of interest in relation to this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2024.105385.

Data availability

Data will be made available on request.

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