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Consumer attitudes and willingness to pay for novel bio-based products using hypothetical bottle choice

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ABSTRACT

Fossil-based plastic contributes to environmental pollution through carbon dioxide emissions during production and lifecycle. Bio-based plastic from renewable biomass retains functionality and can have a lower carbon footprint. Any large-scale investment in bio-based plastic by the industry requires knowing that consumers are willing to purchase these products and learning how best to market them. This online study ($N = 529$) investigated psychological factors influencing preferences for three types of plastic bottles: a conventional fossil-based bottle (PET plastic), a visually identical bio-based bottle (PEF plastic), and a visually distinct bio-based bottle with a paper outer layer (paper PEF). The key outcomes were attitudes and willingness to pay. We also tested whether consumers' choices being visible to valued others affected these judgments. Participants reported positive attitudes towards bio-based plastic, were willing to pay more for it, and, irrespective of being observed, overwhelmingly preferred the bio-based bottles (96.8 %). We discuss how these findings may be applied by the industry to increase the uptake of bio-based plastic and other sustainable consumer alternatives.

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1. Introduction

Fossil fuels (i.e., oil, coal, and natural gas) have been powering economies for over 150 years. Burning fossil fuels accounts for around three-quarters of global greenhouse gas emissions (Ritchie et al., 2020). While there is increasing pressure to move away from fossil fuels, they still accounted for 84 % of the world's primary energy consumption in 2019 (Rapier, 2020). The plastic industry is mainly based on fossil feedstocks and has an increasingly large contribution to CO₂ emissions. Plastic emits greenhouse gases both during its production (1.4 Gt or 3 % of total global annual CO₂ emissions; Hertwich, 2019) and at the end of its lifecycle (e.g., during incineration; World Economic Forum, 2016). By 2050, plastic production alone is expected to use 15 % of the carbon budget (Paris Agreement) required to keep global warming under 2 °C (World Economic Forum, 2016). We have fewer than 30 years to reduce the carbon footprint of plastic before overwhelming the 2050 CO₂ emissions budget, but it seems unrealistic to stop using plastic.

Currently, biomass is the only known alternative carbon feedstock for making virgin, non-recycled plastic (Murcia Valderrama et al., 2019).

1.1. Bio-based plastic

Bio-based plastic may help reduce the carbon footprint of the plastic industry and mitigate climate change (Ruf et al., 2022; Scherer et al., 2018). Bio-based plastic is made from biomass such as starch, vegetable oils, wood, animal waste, or crops and their byproducts (Mehta et al., 2021; Mohanty et al., 2002; Scherer et al., 2018; van den Oever et al., 2017), which can be cultivated in many parts of the world (Scherer et al., 2018). Like the fossil-based material, bio-based plastic has a great variety of properties and applications. Some types of bio-based plastic are biodegradable (i.e., under specific conditions they biodegrade into mainly CO₂, water, and compost), while others biodegrade slowly like traditional plastic (Mohanty et al., 2002; Orset et al., 2017; van den Oever et al., 2017). Bio-based plastic does not add any additional CO₂ to the atmosphere, even if not recycled, because it is produced from carbon (biomass) that was already above the ground. Therefore, the natural carbon cycle already includes most of the CO₂ released during the lifecycle of bio-based products.

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Bio-based plastic currently makes up <1 % of the plastic market share (European Bioplastics, 2021a). However, the share of bio-based and biodegradable plastic production is expected to more than triple within the next five years (European Bioplastics, 2021b). The current paper focusses on Polyethylene Furanoate (PEF) (Avantium, 2022b), which is made from renewable resources, 100 % recyclable, but poorly biodegradable (Orset et al., 2017). PEF will reach consumers in 2024 (Avantium, 2022a) and has half the carbon footprint of fossil-based plastic (Erhart et al., 2012).

1.2. The importance of consumer attitudes

The successful transition away from fossil-based plastic will require a profound transformation of production and consumption patterns and involve actors across different sectors (Gaffey et al., 2021). The development of sustainable alternatives is only part of the solution. For bio-based plastic products to become widely adopted, they need to be accepted and purchased by the consumer (Steenis et al., 2018). Through their consumption choices, consumers can create crucial market pull, demanding more sustainable products and practices (De Marchi et al., 2020; Gaffey et al., 2021). The environmental benefit of sustainable alternatives is not only dependent on the physical characteristics of the products but also on consumer willingness to purchase these alternatives (Steenis et al., 2018). A positive attitude towards sustainable products is the starting point to stimulate sustainable consumption (Park and Lin, 2020), with attitudes towards a product having the highest impact on the purchase intention of that product (Rausch and Kopplin, 2021). The limited literature on attitudes towards bio-based products suggests that while many consumers feel positively towards bio-based plastic products and are willing to pay more for them, people also report mixed or negative feelings towards bio-based products in part due to a lack of knowledge (e.g., see Gaffey et al., 2021).

1.3. The present research

This research aimed to determine how interested people are in bio-based bottles. We also compared bio-based options to the fossil-based industry standard and determined consumer reactions to both. We measured consumer demand for bio-based plastic bottles as an alternative to a conventional (fossil-based) plastic bottle and investigated what conditions underlie this preference (e.g., bottle appearance). Previous research compared visually identical products to determine whether consumers preferred the more sustainable option and would be willing to pay more for it (Zwicker et al., 2021; Zwicker et al., 2020a). Here, we extended this work by investigating when participants are willing to pay more for a real product that is more sustainable and visually different from the conventional alternative. Moreover, we investigated whether the social context of a choice (e.g., being observed by members of an important social group) influenced the more sustainable choice. This research aimed to provide insights into some of the psychological factors related to the choice of a sustainable alternative (i.e., a bio-based plastic bottle).

2. Literature review

2.1. Consumer demand: attitudes and willingness to pay

One drawback of more sustainable or “green” products such as bio-based plastic is their initially higher price caused by small production volume that results in production costs that are 2–3 times higher (Filho et al., 2022). Consumer demand can facilitate more efficient large-scale production systems that in turn lower prices (European Bioplastics, 2020; Wensing et al., 2020). Therefore, consumer attitudes and willingness to pay constitute a first step of whether consumers would purchase different bio-based products.

A growing body of literature suggests that consumers prefer, think positively about, and are willing to pay more for bio-based products (De Marchi et al., 2020; Gaffey et al., 2021; Ruf et al., 2022; Scherer et al., 2018; Zwicker et al., 2021; Zwicker et al., 2020a). Consumers report being willing to pay a price premium for sustainable plastic alternatives including recycled or bio-based plastic bottles (Orset et al., 2017; Zwicker et al., 2021), plant-based takeout food containers (Barnes et al., 2011), products made of recycled ocean plastic (Magnier et al., 2019), wood-polymer packaging (Friedrich, 2020), and bowls made of wheat straw fibre (Gill et al., 2020). However, consumers can also have mixed or negative feelings towards bio-based products for example due to a lack of knowledge (e.g., see Gaffey et al., 2021). Mehta et al. (2021) found that while most environmental professionals and plastic processors found it acceptable to pay higher prices for bio-based plastic, cynicism towards the industry resulted in lower willingness to pay among most consumers. So, while there is some evidence pointing towards consumers holding mixed or negative attitudes towards bio-based products, most studies suggested that consumers hold positive attitudes and are willing to pay a price premium.

We expected to replicate the findings of general positivity towards bio-based plastic and therefore hypothesised that participants would have more positive attitudes towards products made from bio-based, compared to those made from fossil-based plastic (H1a¹). We also expected that participants would indicate that they would be willing to pay more for bio-based products, compared to fossil-based products (H2a). Given that attitudes tend to be one of the main predictors of behaviour, we also expected that participants' attitudes towards the different types of materials would relate to their choice of bottle. In particular, we hypothesised that attitudes will relate to bottle choice, i.e., positive attitudes towards bio-based plastic, and/or negative attitudes about fossil-based plastic will relate to choosing a bio-based bottle (H3). We did not have specific predictions of whether positive or negative attitudes about a certain material would relate most to bottle choice.

The findings about consumers' apparent demand for sustainable alternatives parallel increases in the availability of more sustainable products. In November 2021, the Coca-Cola Company announced its first-ever beverage bottle made from 100 % plant-based plastic, following the launch of their PlantBottle™ in 2009 (The Coca-Cola Company, 2021). The Kraft Heinz Company is shifting to reduce their packaging and to use more sustainable materials, including plant-based materials (The Kraft Heinz Company, 2022). Additionally, a long list of other big brands announced that they are working towards using 100 % reusable, recyclable, or compostable packaging by 2025 (Tuckerman, 2018).

In this research, we focused on beverage bottles. Globally, more than 76 billion cases of bottled water and 36 billion cases of carbonated soft drinks are sold per year (Ridder, 2022), the majority of which bottled in plastic. A large and increasing amount of fossil fuel consumption and CO₂ emissions occur at various stages of the supply chain from the manufacturing of the plastic bottles to their transportation, and the pollution caused by (improper) disposal (Etale et al., 2018). It is therefore important to determine what factors might influence consumers to switch to more sustainable materials, especially given that most consumers will come across bottled beverages and have the means to purchase them. Given their importance in creating consumer demand, we assessed the attitudes and willingness to pay towards the different materials (one fossil-based and two bio-based plastic bottles), and under which conditions (i.e., observability of behaviour and social context) consumers might make different product choices.

¹ The hypothesis numbering does not correspond with the pre-registration numbering, but the content is consistent.

2.2. Signalling benefit

The studies above provide initial evidence for positive attitudes and willingness to pay but not about what factors influence them. Such positive attitudes towards sustainable alternatives are often not translated into behaviour. This intention-behaviour gap has been observed in many sustainability-related domains (Fielding et al., 2008; Ketelsen et al., 2020). One reason is that the environmental rewards of the sustainable consumer decision are psychologically distant (e.g., longer term), whereas the costs such as price or inconvenience are psychologically proximate (e.g., immediate). In this research, we tested whether we could change that temporal imbalance by generating more immediate benefits for the sustainable decision. One way of boosting benefits is to make the sustainable choice a signal for something socially desirable. This is based on the notion of “going green to be seen” (Brick et al., 2017), in which reputation concerns and social signalling help explain the purchase, possession, or consumption of sustainable products. To create a visual signal, we manipulated the appearance of one of the bio-based bottles to make the sustainable behaviour more visible to others.

Following signalling theory, green products can serve as a signal of social status by signalling wealth and prosocial traits, both of which can increase people's attractiveness as allies and exchange partners (Berger, 2017). More expensive sustainable products can signal a person's ability to spend and are thus perceived as higher in status and wealthier (Berger, 2017). Additionally, pro-environmental behaviour can signal prosocial traits (Berger, 2019; Braun Kohlová and Urban, 2020). Consumers of sustainable goods are perceived as more cooperative and trustworthy because they buy products benefiting the environment (and thus, the public; Vesely et al., 2020). Green consumption has also been linked to valued personality traits such as morality and competence (see Braun Kohlová and Urban, 2020), innovativeness, knowledge, and intelligence (Noppers et al., 2014). Thus, consumers might be willing to pay more for sustainable products because of the positive attributes they signal (Berger, 2017, 2019).

For this signalling to pay off, the pro-environmental behaviour needs to be observable by others, for example during purchase or consumption. Accordingly, consumers are willing to pay more for sustainable products when their choice is made in public rather than in private (Berger, 2019). Also, participants whose decisions were observable to others donated 23 % more towards a renewable energy development than those in a control condition (Vesely et al., 2022). Relatedly, consumers paid more for clearly identifiable hybrid cars (e.g., the Toyota Prius™) compared to hybrid models that looked similar to conventional cars (Sexton and Sexton, 2012).

We therefore hypothesised that, not only will participants have more favourable attitudes towards bio-based plastic compared to fossil-based plastic (H1a), but that their attitude will be most favourable towards the bio-based option that is visually recognisable as being the sustainable choice (H1b). We expected the signalling benefit of the visually distinct bio-based bottle to also relate to how much participants indicate being willing to pay for it. We therefore hypothesised that participants will report higher willingness to pay for bio-based than conventional plastic bottles (H2a) and that they will be willing to pay the most for the visually distinct bio-based bottle (H2b).

2.3. Social influence

Above we argued that social factors can play an important role in the present context, and one such factor is identifying as a member of a group. The social identity approach (Reicher et al., 2010) suggests that social identities reflect where people feel they belong, who they are, and shape their behaviour (Fritzsche et al., 2018). Social identities are “an individual's self-concept, which derives from his [or her] knowledge of his [or her] membership of a social group (or groups) together with

the value and emotional significance attached to that membership” (Tajfel, 1978, p. 63).

Individuals often act in accordance with the groups they belong to, especially groups they strongly identify with and that are relevant and salient in a given situation (Bouman et al., 2020). That is, individuals are more likely to engage in behaviours they believe are common or accepted within a valued group (see Bouman et al., 2020). Individuals may therefore increase or reduce their pro-environmental behaviour to either bolster a valued identity or to avoid signalling unwanted associations, depending on the context and company (Berger and Heath, 2007; Brick and Sherman, 2021). As group norms and identification are focal predictors of environmentally friendly behaviour, the pro-environmental social identities of an individual's valued social group are crucial when trying to understand pro-environmental behaviour (Fritzsche et al., 2018; Jans, 2021). We therefore hypothesised that being observed will affect bottle choice. In particular, when observed by others important to them, participants will choose the visibly distinct bio-based bottle more (H4). This main effect is likely also qualified by whether the observers think positively about the sustainable choice, but the current design did not allow for testing this interaction.

Similar to H4 we thought that social identity will affect collective self-esteem: an individual's level of social identity based on their social group membership (Luhtanen and Crocker, 1992). Therefore, we hypothesised that participants' collective self-esteem will be higher when participants imagine being with members of a social group that is important to them, compared to when they are with members of a social group that is not very important to them (H5). This served as a manipulation check for group importance.

There are inconsistencies in the literature about whether being watched affects pro-environmental behaviour which might be explained by who is doing the watching. People may not care about being observed by strangers in one-shot social interactions (Brick and Sherman, 2021; Lange et al., 2020). Brick and Sherman (2021) therefore suggested measuring and manipulating which audience is observing the behaviours, as well as varying the visibility of the behaviour. The present research addresses both these points. By manipulating the presence and importance of the audience observing the behavioural choice, we investigated two potential moderators: one, does being observed influence the bottle choice? And second, does the importance of observers to one's social identity influence the choice of bottle? Both factors were investigated using random assignment to experimental conditions. How much individuals see themselves as (or want to be seen as) environmentalists has been shown to be a strong predictor of self-reported pro-environmental behaviour (Brick and Lai, 2018; Brick et al., 2017). Environmentalist identity might therefore also affect bottle choice and how much participants indicate they would be willing to pay for the bio-based bottles.

While self-reported willingness to pay can give a good first indication of consumer acceptance and signal a demand for sustainable alternatives, it does not reflect actual purchasing behaviour. We therefore also included the WEPT (Work for Environmental Protection Task; Lange and Dewitte, 2021) as a measure of actual behaviour. We hypothesised that higher environmentalist identity will positively relate to a) choosing a bio-based bottle, b) being more willing to pay for bio-based bottles, and c) showing more pro-environmental behaviour in the WEPT (H6).

We also tested how attitudes relate to willingness to pay (WTP). We wanted to determine whether more negative attitudes towards a material type led to lower WTP for that type of plastic and whether more negative attitudes towards fossil-based plastic could lead to a higher WTP for bio-based bottles. We also assessed political orientation, because it might relate to belief in climate change as a whole (McCright et al., 2016) and visible pro-environmental behaviour in particular (Brick et al., 2017). For additional secondary hypotheses and their results, refer to the Supplement. All hypotheses and analyses were pre-registered unless stated otherwise.

3. Methods

3.1. General overview

In this research, participants chose between beverages in three different kinds of bottles in a scenario situation: a see-through plastic bottle made from fossil-based plastic (PET, or polyethylene terephthalate), a visually identical bio-based bottle, and another bio-based bottle with a thin bio-based plastic inner lining and a paper exterior (see Table 1). Depending on condition, participants imagined being in the company of members from a social group that was very important to them (most valued condition), or not very important to them (least valued condition), or the control condition where no social group was mentioned.

Participants for both the pilot and the main study were recruited via the crowdsourcing platform Prolific, an online subject recruitment platform that caters to researchers (Palan and Schitter, 2018). Prolific is widely used in psychological research because the quality of its samples compares positively to similar alternatives (Peer et al., 2017). Samples were chosen based on nationality, language fluency, and approval rate. All measures, data, and analysis code are available at the Open Science Framework <https://osf.io/62xvj/>. The full questionnaire is in the Supplement.

3.2. Pilot study

A qualitative pilot study determined common social groups people are typically part of (Table 2). Fifty-two Dutch participants took part in the pilot study, 28 males and 24 females, age $M(SD) = 28.6(10.8)$. Participants came from varied educational backgrounds with 52 % having a university degree as their highest education.

Table 2
Social groups reported in the pilot study (29).

(Former) colleagues, close friends, (old) school friends, sports group, sports team, gaming group, neighbours, roommates, study group, student association, classmates, pop culture fan group, going out group, online community members, book club, fellow movie lovers, fellow animal lovers, fellow nature lovers, music group, arts group, religious community members, cooking club, fellow British people, expat community members, LGBT community members, fellow house owners, fellow people living in your town/city, fellow people from your country.

After consenting, participants received information about what makes up a social group. They then listed five social groups they were a member of (forced response). Participants were prompted to list additional social groups they might be part of, while being reminded of the ones they previously mentioned (no forced response). They were then asked whether there were any other social groups they would like to mention. For all these social groups they indicated how much they valued the groups with two 7-point Likert questions, e.g., “How important is it to you that the members of this group think positively about you?” (1 = not important at all to 7 = extremely important). To inquire about the influence of the social groups on participants' behaviour we asked: “How often do you adapt or change your usual behaviour to make a positive impression on the members of this social group?” (1 = never to 7 = most of the time). Finally, they provided demographics and were debriefed and paid.

The qualitative social group responses were distilled into 29 social groups (Table 2) (see Supplement for coding process). They included both groups frequently mentioned as being important and several higher-level groups that several participants mentioned being part of but rarely made it into the first five groups they mentioned (e.g., people from your country, fellow house owners). The group

Table 1
Participants read these bottle type descriptions.

Bottle Type	Description
 <p>PET plastic</p>	<p>You know the plastic that water bottles are made of? That is PET. PET's uses range from packaging, polyester clothing, fabrics, films, car parts, electronics, to many other products. PET can be recycled; however, a lot of single-use plastic still finds its way into the environment and only a small percentage of the recycled plastic can be made into the same product again.</p> <p><i>Downsides:</i> PET is made from fossil feedstock such as oil and natural gas. Plastic production alone makes up 6% of global oil consumption, about the same as the entire global aviation sector. During its life cycle, PET releases large amounts of CO₂ into the atmosphere and thereby substantially contributes to global warming. PET bottles are not biodegradable and take about 450 years to decompose. Other products made from PET can take up to 1000 years to decompose.</p>
 <p>PEF plastic</p>	<p>PEF is very similar to PET both chemically and visually, but is derived from 100% renewable raw materials such as wood, straw, sugar, maize, algae, or bio-waste. PEF bottles require less material and can be lighter than PET as they are stronger. PEF can also easily hold carbonated drinks like soda or beer for long periods of time because of better barrier properties than other plastics. The carbon footprint of PEF is also 50-70% smaller than that of PET. PEF typically biodegrades within 5 years (PET: 450 years), so PEF will not endlessly accumulate in nature. It can also be recycled just like the current PET plastic bottles. Additionally, PEF can be incinerated in an environmentally friendly manner (generating electricity), as no additional fossil-based CO₂ emissions are produced.</p> <p><i>Downsides:</i> PEF cannot be produced on an industrial scale yet. While there are pilot production plants, the quantities are currently too small to replace PET.</p>
 <p>Paper PEF</p>	<p>Because traditional PET does not hold liquids as well as the newer materials, bottles made from PEF could use less plastic and still hold carbonated drinks like soda and beer. However, bottles that are too thin become floppy. One solution is to provide structure and stability by adding an outer paper/cardboard structure (see image). This way, the bottle is stable and even less PEF is needed, making paper PEF bottles even more sustainable than bottles made just of PEF plastic. Because the paper and plastic layer are separable, paper PEF bottles can also be recycled. Using only a very thin layer of PEF also allows for even faster biodegradation.</p> <p><i>Downsides:</i> Paper PEF bottles have the same downsides as bottles made from only PEF. However, because much less PEF is used in the paper PEF bottle, more bottles can be produced at less cost.</p>

'family' was excluded because people's complex relationships with their families might influence the effectiveness of our manipulation. These pilot-tested groups were used in the main study below to increase psychological realism of the vignette situation.

3.3. Main study

3.3.1. Participants and design

The online survey was distributed by panel provider Prolific to 529 individuals with British nationality, English fluency, and a study approval rate at or above 99% (Table 3). We aimed to recruit 525 participants (175 per condition) based on an a priori power analysis conducted using the 'pwr' package in R (Champely et al., 2020) showing 80% power at $\alpha = .05$ to detect chi-square: $\omega = 0.15$ (H4); paired samples *t*-test: $d = 0.2$ (H1 and H2); independent samples *t*-test: $d = 0.3$ (H5), a small-to-moderate effect size in psychology.

Participants were randomly assigned to one of three conditions with varying social contexts: most valued ($N = 177$), least valued ($N = 173$), and control ($N = 179$). In the most valued condition, participants imagined being in the company of members from a social group that was very important to them; in the least valued condition they imagined the presence of members of a social group not very important to them; and in the control condition no social group was mentioned. They were paid £1.30 for the 15-minute study.

Bottle choice was the main dependent variable and participants chose one of three bottles (see Table 1). We expected choice to be predicted by condition (H4) and attitudes (H3). Consumer demand was assessed with attitudes and reported willingness to pay. These measures were compared between different bottle types (H1 and H2). We also tested the relationships between bottle choice, environmentalist identity, willingness to pay, and pro-environmental behaviour (H6).

3.3.2. Materials

3.3.2.1. Plastic information. Participants read three informational texts each describing the characteristics and downsides of the three different types of materials: PET plastic, PEF plastic, and paper PEF in that order (see Table 1 for the complete text). Throughout the study, the names of the different materials were printed in three different colours (PET plastic: blue, PEF plastic: purple, paper PEF: orange) to help distinguish the options. The labels and bottle caps also had these colours. To ensure that participants read the text thoroughly, they could only proceed to the next question after 10 seconds. The texts were each about 150 words and were displayed next to a picture of the corresponding bottle.

Each text was followed by a 1-item multiple-choice comprehension check with three response options to ensure that participants understood the differences between bottle types. Participants could try again until they selected the correct answer. A summary of the information provided in Table 1 was displayed after participants read all the information and successfully completed the comprehension checks and remained visible during the assessment of attitudes.

Table 3
Demographic Information ($N = 529$).

	<i>M</i>	<i>SD</i>	%	Value
Gender			70.5	Female
			28.7	Male
			0.6	Other
			0.2	Prefer not to say
Age	36.4	13.4		Years
Education			0.4	Primary
			25.3	Secondary
			9.5	Trade, technical, or vocational
			47.3	Undergraduate
		17.6	Postgraduate	

Note: There were no significant differences between the conditions in demographics, prior knowledge, environmentalist identity, or political orientation, all p s > 0.73 (Table S1).

3.3.2.2. Attitudes. Because consumers' positive and negative evaluations regarding the different types of materials are likely to vary independently (e.g., van Harreveld et al., 2015) we separately assessed both the positive and negative evaluations of the three different materials (i.e., PET plastic, PEF plastic, and paper PEF) (for a similar approach see Zwicker et al., 2021). For example, how much one thinks plastic is useful is not the same as how much one thinks plastic contributes to climate change (also see Sijtsema et al., 2016).

Participants saw one positive and one negative attitude item about each material. The PET plastic items read: "Think about your attitude towards PET plastic products. Considering only the *positive/negative* aspects of PET plastic products, how (un)favourable is your evaluation of PET plastic product use?". Participants responded on a 7-point Likert scale ranging from 1 = *Not at all (un)favourable* to 7 = *Extremely (un)favourable*.

3.3.2.3. Group manipulation and choice scenario. The most valued and least valued condition manipulated the social context in which participants made a behavioural choice. Participants responded to an adapted version of the self-affirmation procedure used by Voisin et al. (2018), which presented them with the 28 different social groups identified in the pilot (Table 2). In the most valued condition, participants indicated the one social group that was most important to them other than their family. In the least valued condition, participants selected one social group that they belong to but that was of little importance to them. If the specific group they were thinking of was not on the list, they picked the one that best described that specific group.

Participants then wrote down 2–3 sentences (minimum of 100 characters) describing why they made that choice. For example, in the least valued condition participants were asked to "Explain why this group is of less importance to you than other groups you belong to. Give an example of why it does not influence your everyday as much as other groups you belong to." Control condition participants were asked to write 2–3 sentences describing what they ate for breakfast the day before, whether that was their usual breakfast, and whether they enjoyed it or not.

3.3.2.4. Scenario and bottle choice. This research was conducted during the COVID-19 pandemic. It was not feasible to conduct a field or laboratory study to let participants handle the actual bottles. We therefore aimed to create a realistic and immersive purchase choice situation online, as is common in psychological research on decision-making (Connolly and Zeelenberg, 2002; Inman and Zeelenberg, 2002).

Participants read a scenario describing the atmosphere at a festival. A sketch of an outdoor festival was also displayed to help participants visualise being at the festival. Depending on condition, the participant was either alone (control), with members of a group that (s)he valued highly (most valued condition), or that were not very important to him/her (least valued condition). The participants were told they wanted something to drink, and that they and their group (if applicable) were headed to a refreshment stall with beverages offered in three types of bottles (PET plastic, PEF plastic, and paper PEF). Participants were shown pictures of the three different bottle types and asked to choose a type of bottle, while being told that all group members present were expectantly awaiting the participant's choice (in all but the control condition). The complete scenarios including the visuals are in the Supplement. At the end of this section participants were asked how clearly they imagined the situation as a manipulation check.

3.3.2.5. Willingness to pay. Participants reported their willingness to pay for each of the three bottle types: PET plastic, PEF plastic, and Paper PEF. Using a similar approach to Zwicker et al. (2021; 2020), participants indicated their willingness to pay on a slider from £0 - £2. The slider started at £0 and increased in increments of £0.20.

3.3.2.6. Environmentalist identity. Participants indicated how much they identified as an environmentalist in four items (e.g., "I see myself as

an environmentalist"; 1 = disagree strongly to 7 = agree strongly) based on Brick et al. (2017). The scale showed excellent reliability with a Cronbach's alpha = .94.

3.3.2.7. Collective self-esteem. Participants in the most valued and least valued condition completed the 16-item Collective Self-Esteem Scale (Luhtanen and Crocker, 1992). This scale assessed participants' level of social identity based on their social group membership. Participants were asked to think of their most/least important group (piped text) when responding to the four subscales (membership, private, public, and identity), 1 = strongly disagree to 7 = strongly agree. This scale had a very good reliability for both conditions with a Cronbach's alpha = .88.

3.3.2.8. Pro-environmental behaviour. To objectively measure pro-environmental behaviour, we used the Work for Environmental Protection Task (WEPT; Lange and Dewitte, 2021). The WEPT is highly reliable and correlates with self-reports and objective observations of other pro-environmental behaviours and conceptually related measures (Lange and Dewitte, 2021). The repeated trade-offs between behavioural costs and environmental benefits mean this represents an objectively observed pro-environmental behaviour. In this web-based, multi-trial task, participants could choose to exert extra effort in completing trivial operations with numbers in exchange for genuine donations to an environmental organisation. Participants were shown a series of two-digit numbers and asked to select all numbers that consisted of an even first digit and an odd second digit. After a familiarisation period, participants could decide how much time and effort to invest into the task. Completion of this task was voluntary and they could stop at any time. There were 15 pages of 50 numbers each that could be completed and participants were told that 90 % accuracy was required for completion (not enforced). For each completed page, £0.10 was donated by the researchers to the Woodland Trust, a UK based pro-environmental charity (total = £147.10). Split-half reliability sampling using 1000 iterations revealed an excellent median reliability, $\rho_{SP} = 0.96$. Of the sampled reliability coefficients, 95 % were between $\rho_{SP} = 0.90$ and $\rho_{SP} = 0.98$ (Steinke and Kopp, 2020).

3.3.2.9. Perceived environmental norms of the group. Participants in the most valued and least valued condition were asked how important the environment was to their mentioned social group. Participants responded to a 3-item pro-environmental descriptive norm measure used by Bissing-Olson et al. (2016) (1 = disagree strongly to 7 = agree strongly). For both conditions, this scale showed an excellent reliability of $\alpha = .96$. This measure was exploratory and was not included in the main analysis.

3.3.2.10. Motivation. We also assessed intrinsic and extrinsic motivation for pro-environmental behaviour. Participants indicated on a 7-point Likert scale how much they agreed with five statements assessing their explicit and five items assessing their implicit motivation (Brick and Lai, 2018). Both subscales showed very good reliability with respective Cronbach's alphas = .79, .87. This measure was exploratory and was not included in the main analysis.

3.3.2.11. Demographics. We also assessed participants' age, gender, education, political orientation, and inquired how much they knew about the different types of plastic before this study. To measure political orientation, participants indicated on a 11-point Likert scale where they placed themselves on a political left-right and progressive-conservative continuum, as well as two more left-right continua for economic and then social issues (measure adapted from Zwicker et al., 2020b). The four combined items had an excellent reliability of $\alpha = .92$.

3.3.3. Procedure

After consenting to take part, participants read informational texts about the three different types of materials, followed by the corresponding comprehension checks. We then assessed participants attitudes towards the three materials. According to their condition, participants

Table 4
Bottle choice by condition.

Condition	Bottle choice		
	PET plastic	PEF plastic	paper PEF
Control	2.8 %	29.1 %	68.2 %
Most valued	3.4 %	25.4 %	71.2 %
Least valued	3.5 %	25.4 %	71.1 %

then indicated which social group was of most or least importance to them. Then followed the scenario and the subsequent bottle choice task. Participants then indicated their willingness to pay for each of the three bottles and how much they identified as an environmentalist. Participants in the most valued and least valued condition also responded to the collective self-esteem scale. All participants completed demographic questions before getting the option to complete the WEPT, which was followed by the debriefing and payment.

4. Results

4.1. Manipulation checks

Collective self-esteem was higher in the valued condition ($M = 5.48$, $SD = 0.75$) than in the least valued condition in an independent samples t -test ($M = 3.95$, $SD = 0.88$), $t(348) = 17.60$, $p < .001$, which is supportive evidence of the intent for the social group manipulation and H5.

Generally, participants imagined the festival scenario clearly ($M = 6.2$ out of 7) and there were no differences between conditions in a one-way ANOVA, $F(2, 526) = 0.98$, $p = .38$. Imagination did relate to bottle choice, $F(1, 527) = 6.30$, $p = .012$, $R^2 = 0.11$, with less immersion leading to a less sustainable bottle choice.

4.2. Condition on bottle choice

Participants strongly preferred the paper PEF bottle over the other two bottle types (Table 4). Contrary to H4, there was no association between imagined group type and bottle choice in a chi-square test, $\chi^2(4) = 0.884$, $p = .927$, Cramer's $V = 0.029$. Bonferroni-corrected post-hoc analysis with adjusted residuals did not reveal any significant differences between the conditions.

4.3. Attitudes and willingness to pay by bottle

We deviated from the pre-registration to test the additional contrasts of H1a and H1b, and H2a and H2b as suggested by an anonymous reviewer. Paired-samples t -tests revealed that participants were more positive towards bio-based bottles ($M = 2.89$, $SD = 1.67$) than towards the fossil-based bottle ($M = -1.86$, $SD = 2.90$), $t(528) = -29.50$, $p < .001$, $d = 3.70$, 95 % CI [-5.06, -4.43]. As predicted, attitudes were most positive towards paper PEF and most negative towards PET plastic, with attitudes towards PEF plastic in between (Table 5).

The same pattern was found for willingness to pay (WTP). Participants indicated that they would be willing to pay more for a bio-based bottle ($M = £1.08$, $SD = 0.37$) than for a fossil-based bottle ($M = £0.80$, $SD = 0.36$), $t(528) = -21.78$, $p < .001$, $d = 0.29$, 95 % CI [-0.30, -0.25]. Participants were willing to pay the least for PET plastic, followed by PEF plastic, and the most for paper PEF (Table 5). Paired sampled t -tests examined whether the attitudes and WTP were lowest for the PET plastic bottle, and whether there was a difference between the PEF plastic and paper PEF.² Attitudes and WTP differed for all bottle types (all $ps < .001$; Table 6). This supports both H1 and H2.

² Even when using the Bonferroni method to correct for multiple testing (0.05 / 3 for both attitudes and WTP), the p -values were still statistically significant (all $ps < 0.001$).

Table 5
Means (SD) for attitude and WTP by bottle type.

Mean (SD)	Bottle type		
	PET plastic	PEF plastic	Paper PEF
Attitude ^a	−1.86 (2.90)	2.34 (1.87)	3.44 (2.29)
Willingness to pay	£0.80 (0.36)	£1.03 (0.38)	£1.12 (0.42)

^a Mean composite of favourable and unfavourable attitudes (range − 6 to 6).

Table 6
Paired-sample tests: attitudes and WTP by bottle comparisons.

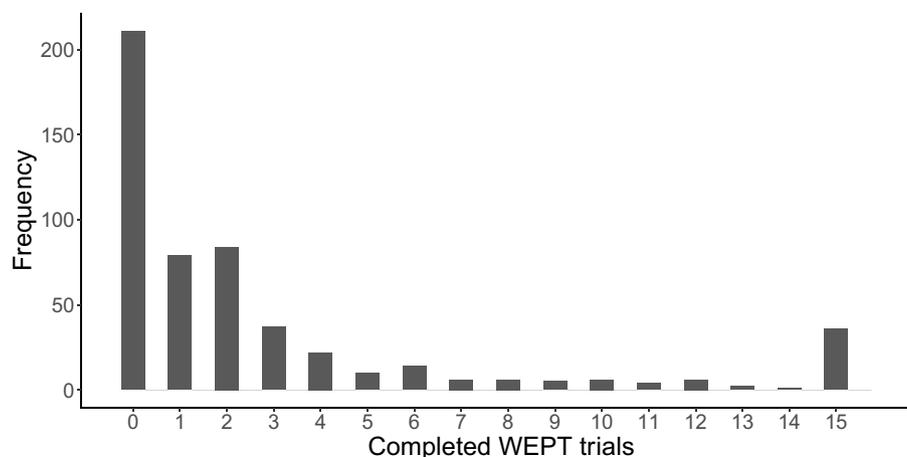
	<i>t</i>	<i>d</i>	<i>p</i>	95 % CI of the difference		
				Lower	Upper	
Attitude pair	PET – PEF	−27.7	3.5	< .001	−4.50	−3.90
	PET – Paper PEF	−28.4	4.3	< .001	−5.66	−4.93
	PEF – Paper PEF	−10.1	2.5	< .001	−1.31	−0.89
WTP Pair	PET – PEF	−20.8	0.26	< .001	−0.26	−0.21
	PET – Paper PEF	−19.5	0.38	< .001	−0.35	−0.29
	PEF – Paper PEF	−7.13	0.28	< .001	−0.11	−0.06

4.4. Attitude on bottle choice

We hypothesised that attitudes would relate to bottle choice (H3). We pre-registered a correlational analysis, but realised that would not be sufficient to test the full hypothesis. Correlations would only inform us whether bottle choice in general related to different attitudes. To determine which attitude aspects (e.g., unfavourable attitude towards PET plastic, favourable attitude towards paper PEF) drove the choice for a specific bottle, we instead conducted a logistic regression. In all cases, PET plastic was used as the reference category.

Participants were more likely to choose the PEF plastic over the PET bottle when their positive attitude towards PET was low ($b = -0.59$, Wald $\chi^2 = 9.64$, $p = .020$) and their positive attitude towards PEF plastic was high ($b = 0.55$, Wald $\chi^2 = 4.80$, $p = .029$). None of the other factors were significant (Table S2).

Participants were more likely to choose the paper PEF bottle over the PET plastic bottle when their positive attitude towards PET was low ($b = -0.78$, Wald $\chi^2 = 16.55$, $p < .001$) and their positive attitude towards paper PEF was high ($b = 1.12$, Wald $\chi^2 = 22.89$, $p < .001$). The positive attitude towards paper PEF appeared to be the largest driver of the effect. None of the other factors were significant.

**Fig. 1.** Histogram of the WEPT (Pro-Environmental Behaviour).

In sum, less positive attitudes towards PET, and positive attitudes towards the bio-based choice, both related to choosing PEF plastic and paper PEF bottles.

4.5. Environmentalist identity

We hypothesised that identifying as an environmentalist would be positively correlated with choosing a sustainable bottle (i.e., PEF plastic or paper PEF), the willingness to pay more for the bio-based bottles (compared to low-identifiers), and with completed WEPT rounds (H6). As with the effect of attitude on bottle choice, we pre-registered a correlational analysis, but realised that a multinomial logistic regression would better determine whether environmentalist identity relates to the choice of the different bottle types. PET plastic was used as the reference category.

4.5.1. Bottle choice

People identifying more vs. less as environmentalists did not differ in choosing the PEF plastic bottle, $b = 0.20$, Wald $\chi^2 = 1.16$, $p = .281$. Environmentalist identification did relate to the choice of the paper PEF bottle, $b = 0.57$, Wald $\chi^2 = 10.15$, $p < .001$. This hypothesis was partially supported: participants who identified more as environmentalists more often chose the paper PEF bottle, but not the plastic PEF bottle that was visually identical to the conventional fossil-based option.

4.5.2. Willingness to pay

Participants who identified more as environmentalists were willing to pay more for bottles made from PEF plastic, $r(527) = 0.092$, $p = .034$, 95 % CI [0.01, 0.18], and especially paper PEF bottles, $r(527) = 0.23$, $p < .001$, 95 % CI [0.15, 0.31] in a bootstrapped Pearson correlation (5000). Willingness to pay for the conventional PET plastic bottle did not correlate with environmentalist identity, $r(527) = -0.056$, $p = .199$, 95 % CI [−0.14, 0.03].

4.5.3. WEPT

Most participants (60.1 %) completed at least one WEPT trial ($M = 2.78$, $SD = 4.23$) (Fig. 1). 36 participants (6.8 %) completed all the trials. The more participants identified with being an environmentalist, the more time they invested in the WEPT task, $r(527) = 0.183$, $p < .001$, 95 % CI [0.10, 0.26] (Table 7). The WEPT also positively correlated with choice of the bio-based bottles, $r(527) = 0.11$, $p = .012$, BCa 95 % CI [0.21, 0.20].

4.6. Pre-registered exploratory analyses

4.6.1. Attitude on willingness to pay

A multiple regression (rather than the pre-registered ANOVA, because of the ordinal nature of the attitude variables) assessed the effect of

Table 7
Correlations (5000 Bootstraps).

	1	2	3	4 ^a	5	6 ^a	7	8	9
1. PET WTP									
2. PEF plastic WTP	0.76 ^z								
3. Paper PEF WTP	0.54 ^z	0.76 ^z							
4. Bio-based bottle choice ^a	-0.10 ^x	0.03	0.06						
5. Political orientation (conservatism)	-0.03	-0.15 ^z	-0.20 ^z	-0.05					
6. WEPT trials ^a	-0.05	0.02	0.04	0.11 ^x	-0.16 ^z				
7. Environmentalist ID	-0.06	0.09 ^x	0.23 ^z	0.11 ^x	-0.35 ^z	0.18 ^z			
8. PET attitude	0.04	-0.02	-0.11 ^x	-0.19 ^z	0.12 ^y	-0.04	-0.11 ^x		
9. PEF plastic attitude	0.05	0.13 ^y	0.01	-0.09	-0.08	0.09	0.06	-0.03	
10. Paper PEF attitude	-0.13 ^y	-0.03	0.09 ^x	0.14 ^y	-0.11 ^y	0.14 ^y	0.15 ^z	-0.36 ^z	0.29 ^z

^x $p < .05$.^y $p < .01$.^z $p < .001$.

^a Spearman correlation instead of Pearson correlation. 'Bio-based bottle choice' combines the choices of the PEF plastic and the paper PEF bottle because their carbon footprint is similar compared to PET plastic, and because it simplifies the analyses and communicating the results.

overall attitude towards the different kind of materials on the WTP for the different bottle types, while controlling for environmentalist identity.

The more negative participants' attitude towards paper PEF ($\beta = -0.16$, $p < .001$, 95 % CI_B [-0.04, -0.01]), and the more positive their attitude towards PEF plastic ($\beta = 0.10$, $p = .028$, 95 % CI_B [0.002, 0.04]), the more they were willing to pay for the PET plastic bottle. Attitude towards the PET plastic bottle did not relate to WTP, ($\beta = -0.02$, $p = .74$, 95 % CI_B [-0.01, 0.01]).

Both a more positive attitude towards PEF plastic, ($\beta = 0.15$, $p < .001$, 95 % CI_B [0.013, 0.049]) and a more negative attitude towards paper PEF ($\beta = -0.16$, $p < .001$, 95 % CI_B [-0.041, -0.010]) related to WTP for the PEF plastic bottle. Attitude towards the PET plastic bottle had no effect, $\beta = -0.041$, $p = .38$, 95 % CI_B [-0.02, 0.007]. Higher identification as an environmentalist also lead to higher WTP for the PEF plastic bottle, $\beta = 0.032$, $p = .032$, 95 % CI_B [0.002, 0.049].

Only environmentalist identity ($\beta = 0.22$, $p < .001$, 95 % CI_B [0.04, 0.09]) related to WTP for the paper PEF bottle. In summary, attitudes towards the bio-based bottles had the strongest relation to WTP for the PET and PEF plastic bottles. WTP for the paper PEF bottle was related to other factors, including participants' identification as an environmentalist.

5. Discussion

Plastic is an increasingly large contributor to climate change and novel alternatives to fossil-based plastic such as PEF are under development. However, just creating sustainable technologies will not slow climate change by itself, because consumers have to adopt these novel technologies (Filho et al., 2022; Ketelsen et al., 2020). We examined the psychological factors that determine consumers' attitudes and willingness to pay for different types of plastic bottles.

Participants clearly preferred and indicated being willing to pay more for the visually distinct paper PEF over PEF plastic, and for PEF plastic over PET plastic; indeed, 70 % chose the paper PEF bottle. Psychological variables such as attitudes and environmentalist identity helped explain preferences for the different bottles. For example, less positive attitudes towards PET and more positive attitudes towards the bio-based options were associated with choosing PEF plastic and paper PEF bottles. The more participants identified as an environmentalist, the more likely they were to choose the paper PEF bottle, pay more for bio-based bottles, and spend more time on a pro-environmental behaviour task. There was no difference in bottle choice between the experimental conditions that manipulated social context.

5.1. Positive attitudes towards bio-based plastic

Participants held positive attitudes towards bio-based plastic, indicated being willing to pay more for it, and, irrespective of social context,

chose a bio-based bottle (96.8 %) over a fossil-based one. This replicates previous research finding more positive attitudes and higher willingness to pay (WTP) for bio-based plastic (De Marchi et al., 2020; Gaffey et al., 2021; Zwicker et al., 2021; Zwicker et al., 2020a).

Not only were consumers positive about bio-based plastic, but they were willing to pay up to 40 % more for bio-based compared to fossil-based products. This is encouraging, given that early small production volumes are partially responsible for initially making new products and materials more expensive. These findings signal to companies that consumers are demanding more sustainable products and that there might be a commercial upside to providing more sustainable bio-based plastic products.

These results extend previous work on observability by showing that both positive attitudes and WTP were highest for the visually distinct paper PEF bottle, followed by the PEF plastic bottle, followed by the PET plastic bottle. That the visually distinct sustainable option was overwhelmingly rated more favourably and as more valuable aligns with signalling theory, which suggests that sustainable products can serve as a signal of social status by signalling wealth and prosocial traits (Berger, 2017, 2019; Braun Kohlová and Urban, 2020). For this beneficial signalling to work, the pro-environmental behaviour needs to be observable by others, for example by being visually recognisable as a sustainable choice. Participants choosing the paper PEF over the PEF plastic bottle therefore correspond with previous research findings on consumers paying more for clearly identifiable sustainable choices (e.g., Sexton and Sexton, 2012). These results suggest that using visually distinct packaging or appearances for sustainable alternatives could increase sales of sustainable products. This corresponds with the findings by De Marchi et al. (2020), who found a higher WTP for materials with easily recognisable sustainable characteristics. Given the distinct differences in attitudes and WTP towards the three bottles, communicating the differences in attributes between different products is not trivial. Previous research found a lack of knowledge and misconceptions about bio-based plastic (Kainz et al., 2013; Ruf et al., 2022; Zwicker et al., 2021; Zwicker et al., 2020a). Therefore, communicating the benefits and harms of different materials remains critical (Ketelsen et al., 2020).

This research focused on beverage bottles. While the findings about attitudes and willingness to pay were aligned with studies of other bio-based products, e.g., sand toys for children (Scherer et al., 2017) and sports equipment (Scherer et al., 2018), they might not generalise to all bio-based products (Ruf et al., 2022). Similarly, these null results for social context may be specific to these products and this study context.

5.2. Factors influencing WTP and product uptake

There is increasing attention to attitudes about bioplastic in general (e.g., Filho et al., 2022). In this study, we provided evidence for a specific

product in a more psychologically realistic scenario, moving this research along the continuum from attitudes towards intention and behaviours. We found that attitudes towards the bio-based bottles related to WTP for the PET and PEF plastic bottles. This suggests that a marketing focus on the positive characteristics of bio-based products may be more effective than emphasising the negative impact of fossil-based products. In addition to attitudes, many other factors might influence individuals to behave more sustainably. Environmentalist identity and political orientation were both linked to WTP for bio-based bottles in the present research and associated with other pro-environmental behaviours in the literature (Brick and Lai, 2018; Brick et al., 2017). This would suggest that targeting environmentally concerned and politically left-wing consumers might be most effective when first introducing sustainable technologies such as bio-based plastic.

5.3. No effects on bottle choice of being observed nor social group

The type of social group people had in mind when making the decision did not appear to affect bottle choice. This may be due to the use of scenario vignettes. Participants who imagined the scenario less clearly made less sustainable choices, but there were no differences in scenario immersion between conditions. The social group manipulation might also have been ineffective or too subtle. However, participants indicated that they felt higher collective self-esteem in the most valued condition than in the least valued condition.

The effect of observability on sustainable behaviours might also be smaller or less general than previous literature would suggest. A recent Registered Report did not find any evidence that being observed changed pro-environmental behaviour (Lange et al., 2020). Brick and Sherman (2021) conducted three experiments in which they tested for and did not find visibility effects, even though they employed a different manipulation of visibility in each study, and investigated a range of pro-environmental preferences and behaviours. Given the large body of previous literature, we suspect there are genuine effects of reputation management, demand, and signalling with pro-environmental behaviours, although they appear to be more elusive than originally thought.

5.4. Other limitations and future directions

Participants might have preferred the paper PEF bottle not solely because of its appearance and signalling properties, but because it seemed more sustainable than the plastic PEF. An alternative way of testing might be to keep the properties of the PEF and the paper PEF bottle constant and just vary the appearance. Both bottles exist and are expected to reach the market in 2024 (Avantium, 2022a, 2022b).

We cannot rule out an order effect in this design. All participants saw information about the PET plastic bottle first, followed by PEF plastic, followed by paper PEF. We consistently kept this order throughout to avoid confusion (as the names are very similar) and because knowledge of conventional PET plastic and its characteristics is crucial in understanding PEF plastic and its properties. As the paper PEF bottle is made from PEF, an understanding of PEF is required before seeing the paper PEF. Seeing the paper PEF last might have given of the impression that it was the most sustainable choice.

We investigated self-reported willingness to pay (WTP), not actual purchasing. WTP was related to actual behaviour in earlier work on plastic-related attitudes and behaviour (data Study 3, Zwicker et al., 2020a). In this study, we did not find a relationship between WPT and the objective WEPT task of donating time for environmental causes. However, the WEPT did relate to bottle choice. Given the well-known intention-behaviour gap (Sheeran, 2002), we encourage future studies to assess actual WTP.

The participants were highly educated and disproportionately female, which was not representative of the sample population. Some research suggests that education (e.g., Meyer, 2015) and gender

(e.g., Vicente-Molina et al., 2018) can increase the likelihood of acting pro-environmentally. Future research with more representative samples is needed to test whether these results generalise to other populations including in the Global South (Ruf et al., 2022).

Future research could also investigate recycling behaviour with the paper PEF bottle. Consumers often harbour misconceptions about recycling bio-based plastic (Zwicker et al., 2021) and the paper layer might lead to more confusion. Communicators will need to be careful about explaining that the two layers of the paper PEF bottle are separable and give disposal instructions, or these bottles will end up in the refuse stream.

6. Conclusion

The present study provides encouraging results about consumer attitudes and willingness to pay for bio-based plastic. The results suggest that there is consumer demand for these materials, as attitudes were positive and hypothetical willingness to pay higher for bio-based than for conventional fossil-based bottles. These outcomes related to other beliefs and factors such as environmentalist identity and suggest that more sustainable alternatives are not only in demand but that consumers might be willing to initially pay more for them. Future research could investigate actual purchasing behaviour, test the generalisability of these results to other bio-based products and different populations, and identify other individual difference and contextual factors influencing sustainable choices. Our findings also inform the potential marketing of bio-based products. We recommend that the sustainable nature of the product be made visible, and marketing focus on the positive aspects of the sustainable product, as well as clear communication about the key characteristics of the materials (e.g., biodegradability). Ultimately, such materials could help solve the problems of the current linear, extractive plastic industry based on fossil fuels.

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CRediT authorship contribution statement

Role	MZ	CB	GG	FvH
Conceptualization	•	•	•	•
Pre-registration	•	•		•
Data curation	•			
Formal analysis	•	•		•
Funding acquisition			•	•
Investigation	•	•		•
Methodology	•	•	•	•
Project administration			•	•
Supervision		•		•
Visualization	•			
Writing-original draft	•			
Writing-review and editing	•	•	•	•

Note. See <https://www.casrai.org/credit.html> for the details and definitions of each role.

Declaration of competing interest

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

Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.spc.2022.10.021>.

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