 doi:10.20944/preprints202012.0230.v1

Article

(Not) Doing the Right Things for the Wrong Reasons: An Investigation of Consumer Attitudes, Perceptions, and Willingness to Pay for Bio-Based Plastics

Maria V. Zwicker[1]*, Cameron Brick[1], Gert-Jan M. Gruter[2,3] and Frenk van Harreveld[1,4]

[1] Department of Social Psychology, University of Amsterdam, Nieuwe Achtergracht 129-B, 1018 WT, Amsterdam, The Netherlands
[2] Industrial Sustainable Chemistry, University of Amsterdam, Science Park 904 1098 XH, Amsterdam, The Netherlands
[3] Avantium NV, Zekeringstraat 29, 1014BV Amsterdam, The Netherlands
[4] National Institute for Public Health and the Environment (RIVM), Antonie van Leeuwenhoeklaan 9, 3721 MA, Bilthoven, The Netherlands
* Correspondence: m.zwicker@uva.nl Tel.: +31 6 87249100

Abstract: Fossil-based plastics are significant contributors to global warming through CO_2 emissions. For more sustainable alternatives to be successful, it is important to ensure that consumers become aware of the benefits of innovations such as bio-based plastics, in order to create demand and a willingness to initially pay more. In four studies, we investigated participants' attitudes towards fossil-based and bio-based plastic, their perceived importance of recycling both types of plastic, their willingness to pay, and their perceptions of bio-based plastic. The pre-registered fourth study experimentally manipulated information about bio-based plastic and measured willingness to pay for different types of plastic. The results suggest participants hold very favourable attitudes and are willing to pay more for bio-based products. However, they also harbour misconceptions, especially overestimating bio-based plastic's biodegradability, and they find it less important to recycle bio-based than fossil-based plastic. Study 4 provided evidence that educating consumers about the properties of bio-based plastic can dispel misconceptions, retain a favourable attitude and a high willingness to pay. We found mixed evidence for the effect of attitudes on willingness to pay. We discuss how attitudes and misconceptions affect the uptake of new sustainable technologies such as bio-based plastics and consumers' willingness to purchase them.

Keywords: plastic; bio-based plastic; willingness to pay; attitudes; recycling

1. Introduction

Plastics are an extensive family of different materials designed for specific applications. In our daily lives, we are continuously surrounded by plastic in grocery packaging, clothes, other fabrics, transportation, medical devices, household objects and tools including electronics. In 2018, global plastics production reached 360 million tonnes, 39.9% of which was used for packaging [1]. While plastics are a valuable resource that benefit society in numerous ways, they also contribute to marine litter and climate change [emitting almost 1 billion metric tons of CO2 emissions in 2019, 2].

Consumers are becoming increasingly aware that plastic can have harmful effects on the environment, which is at least partially due to the increasing media coverage on the topic over the last years [3]. However, much of consumers' concern focuses on the post-consumption or end-of-life effects of plastic on the environment, such as recyclability, biodegradability, and reusability [4, 5]. The effect of plastic on the environment however starts well before it hits store shelves: it starts with the extraction of fossil fuels. Around 99% of virgin plastics are derived from fossil fuels (i.e., oil, coal, or natural gas)[6]. This currently makes up about 6% of global oil consumption and by 2050 it is expected that 20% of the current volume of global oil will be used for the production of plastic alone

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

[7]. Consumers' focus on the end-of-life attributes of plastic is not surprising, as this is the stage in plastics' lifecycle that is both most visible to consumers and is relevant to their own behaviour, as they are faced with the decision on how to dispose of the product [5].

Transitioning away from fossil-based plastics is difficult, especially because the continued increase in plastic production and use [1, 8] suggests that proximity to plastic waste in itself is not enough to persuade consumers to change their behaviour. Technological developments alone are also not sufficient to successfully make the transition; the adoption of new technologies by consumers, as well as a change in attitude and behaviour is key. In order for new, more sustainable plastic alternatives to be adopted, a different type of awareness is needed—not just of the pollution of natural environments, but also of the production process, carbon footprint and specific characteristics of plastic products.

1. 1. Bio-based Plastic

With new technological advances such as bio-based plastics, it is possible to retain the advantages and characteristics of conventional fossil-based plastics while reducing the impact plastic has on global warming. Bio-based plastics are derived from renewable materials, or 'biomass' (sugar cane, starch, vegetable oils, etc.) [1, 9, 10]. Regardless of being fossil- or bio-based, certain plastics are biodegradable (i.e., under very specific conditions, they can biodegrade into mainly CO_2 and water or become compost), while others are not, depending on the application they were designed for [1, 9]. Thus, many plastics made from biomass are not (readily) biodegradable (the bio-based plastics studied in this research are not). What makes bio-based plastics more sustainable than conventional fossil-based plastics is that they do not add any additional CO_2 to the atmosphere because they are sourced from carbon above the ground. An example of a new type of bio-based plastic is Polyethylene Furanoate or PEF, which is expected to reach consumers in the next few years. PEF, for instance, has a carbon footprint that is less than half of that of conventional plastic [43%-56% reduction in CO2 emissions, 11, 12].

1.1.1. Lack of Knowledge

For alternatives to conventional plastics to be successful, adoption by consumers is key to generate a market pull. Without the interest or demand from consumers, there is no incentive for companies to adopt bio-based plastics, as this can be financially costly. It is therefore important to ensure that consumers become aware of the benefits of innovations such as bio-based plastics, in order to create a demand for them.

While more and more plastic alternatives such as bio-based plastics are entering the market, consumers lack the knowledge of what it means if a product is 'bio-based' or 'biodegradable' [13]. While consumers report preferring more sustainable plastics over conventional ones, there seems to be a general lack of knowledge about the characteristics of bio-based products [5, 13-16]. This might partially be due to the aforementioned tendency to focus on the end-of-life attributes of plastics, which creates a disadvantage for bio-based products, whose pro-environmental effects are based on their origin from renewable resources [5]. Another reason for this lack of knowledge about bio-based plastics is their rarity and the confusion created through the term 'bioplastics' which can refer to either the bio-based origin or the biodegradable character of a plastic [9]. Additionally, it can be difficult to differentiate between conventional and bio-based plastic products, since they are similar in appearance and attributes [10]. Whatever the cause, many consumers appear to think that bio-based products are automatically biodegradable, which is not necessarily the case. The lack of knowledge can lead consumers to form their attitudes based on incorrect associations and expectations about bio-based plastics [17]. What kind of expectations and attitudes consumers have towards bio-based plastic can influence their behaviour.

1.2. Attitudes

Attitudes are a key predictor of behaviour [for an extensive overview see 18]. In the present research we therefore investigate people's attitudes towards plastic (both bio-based and

 doi:10.20944/preprints202012.0230.v1

conventional) as a first step in understanding how to best persuade people to adopt a more sustainable plastic-behaviour. Some research suggests that attitudes towards bio-based plastics are one of the strongest influencers of purchase intentions for bio-based plastic products [10], however, research on attitudes towards plastic and especially bio-based plastic is scarce. Some studies suggest that, while people report having general reservations about fossil-based plastics, they indicate having a favourable view of products made from renewable resources [5]. Other studies indicate that the majority of people seem to have positive associations with 'bioplastics' (whether or not biodegradable) and bio-based technologies [15-17]. However, there are also studies that suggest that new environmental innovations, like bio-based plastics, can also evoke negative emotions, unfavourable attitudes, and lower purchase intentions [see 19]. Bio-based products can also produce simultaneously positive (related to environmental topics) and negative (related to technological topics) evaluations, generally causing uncertainty and mixed feelings [20].

In the current research we assess people's attitudes towards both conventional and bio-based plastic in a series of four studies, to obtain a better understanding of people's general evaluation of these different types of plastics. Having a favourable attitude and accurate knowledge of bio-based plastic is the foundation of consumer acceptance and willingness to pay (more) for bio-based plastic. This shift will support a durable transition towards a more sustainable plastic economy.

1.3. Overview of Studies

In four online studies[1], we examined consumers' attitudes and perceptions about conventional and bio-based plastics. In our first study (N = 97) we aimed to investigate whether participants' attitudes differed with regards to conventional and bio-based plastics. Study 2 (N = 52) replicated these results and examined behavioural factors such as willingness to pay and perceived importance to recycle, in order to test the attitude-behaviour relationship. The third study (N = 508) aimed to replicate the results of the previous studies with a larger sample. It also assessed participants' most common misconceptions towards bio-based plastic, as they might influence both plastic-related attitudes and behaviour. To extend the correlational previous studies, Study 4 (N = 304) was a pre-registered experimental study that manipulated knowledge about bio-based plastic and measured the effect of this manipulation on attitudes, importance to recycle, willingness to pay, and objective pro-environmental behaviour.

2. Materials and Methods

All studies were approved by the Ethics Review Board of the Faculty of Social and Behavioral Sciences, University of Amsterdam, The Netherlands, designed using Qualtrics and distributed to participants from western countries via Prolific Academic (see the Supplementary material for complete list of countries). All data, study items and analysis scripts are available at the Open Science Framework (https://osf.io/p3ftu/?view_only=73cb294dd0f44b0784d85339d14d565d). All analyses were conducted using SPSS version 24 and all power analyses were conducted using the R 'pwr' package [22].

2.1. Attitudes

In all studies, we assessed participants' attitude towards both conventional and bio-based plastic. Individuals can hold both positive and negative attitudes about a target [23] leading to ambivalence and mixed feelings [24]. Consumers' positive and negative evaluations regarding plastic are likely to vary independently. The extent to which one thinks plastic is useful might be unrelated to how much one thinks plastic contributes to climate change [also see 20]. We therefore separately assessed both the positive and negative evaluations people hold towards fossil-based and bio-based plastic, rather than in a single bipolar scale [for a similar approach see 21].

---

[1] Studies 1-3 were parts of larger studies; see 21. Zwicker, M.V., et al., *Applying an attitude network approach to consumer behaviour towards plastic.* Journal of Environmental Psychology, 2020. **69**: p. 101433. for the additional measures.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

In this research, we measured participants' attitudes towards (bio-based) plastic by asking them to consider only the positive/negative aspects of using (bio-based) plastic products and asking them how (un)favourable their evaluation of (bio-based) plastic use is on a 7-point Likert scale ranging from *1 = Not at all (un)favourable* to *7 = Extremely (un)favourable*[2].

2.2. Study 1[3]

2.2.1. Participants

See Table 1 for sample details of the 97 participants.

Table 1. Sample details for Studies 1 to 4.

	Study 1	**Study 2**	**Study 3**	**Study 4**
Number of participants	97	52	508	304
Gender				
Female (%)	61 (62.9%)	29 (55.8%)	268 (52.8%)	164 (53.9%)
Male (%)	36 (37.1%)	23 (44.2%)	232 (45.7%)	137 (45.1%)
Preferred not to say/other (%)	0 (0%)	0 (0%)	8 (1.6%)	3 (1.0%)
Mean age (SD)	33.9 (12.1)	28.5 (9.7)	32.4 (10.8)	34.7 (12.1)
Age range	18 - 64 years	18 - 68 years	18 - 72 years	18 - 74 years
Education completed (%)				
secondary education	30.9%	26.9%	24.2%	26.9%
undergraduate degree	50.5%	42.3%	47.4%	42.3%
postgraduate education	8.4%	21.2%	17.9%	21.2%
trade/technical/or vocational training	9.3%	9.6%	8.7%	9.6%
primary school	1.0%	0.0%	1.8%	0.0%
Country of residence				
United Kingdom	58%	46%	33.1%	61.5%
Europe	28%	44%	46.1%	29.6%
North America	14%	8%	17.1%	4.3%
Other	0%	2%	3.7%	4.6%

2.2.2. Results

[2] In Study 1, a 5-point version of the same scale was used.

[3] For more information about this study see [21, Study 1].

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

We conducted a series of paired samples t-tests to compare people's attitudes towards conventional plastic with their attitudes towards bio-based plastics[4]. A sensitivity analysis revealed 80% power to detect a medium effect size ($d = 0.41$) at $\alpha = 0.05$. As illustrated in Figure 1 (Study 1), evaluations of conventional plastic were less positive than those of bio-based plastic, $t(96) = -5.76$, $p < .001$, $d = -0.59$. Participants were also more unfavourable towards conventional than towards bio-based plastic, $t(96) = 7.17$, $p < .001$, $d = 0.73$. This indicates that participants had both more positive and less negative attitudes towards bio-based plastics than towards conventional plastics. While there was no difference between positive and negative attitudes towards conventional plastic $t(96) = -1.43$, $p = .16$, $d = -0.15$, participants reported being more positive than negative towards bio-based plastic, $t(96) = -10.71$, $p < .001$, $d = 1.09$.

2.2.3. Discussion

Study 1 provided a first indication that participants' attitudes differ from one type of plastic to another. The results show that bio-based plastic was evaluated more positively (and less negatively) than conventional plastic. We next aimed to replicate this finding and assess behavioural factors related to bio-based plastic, namely the perceived importance to recycle the different types of plastic and people's willingness to pay.

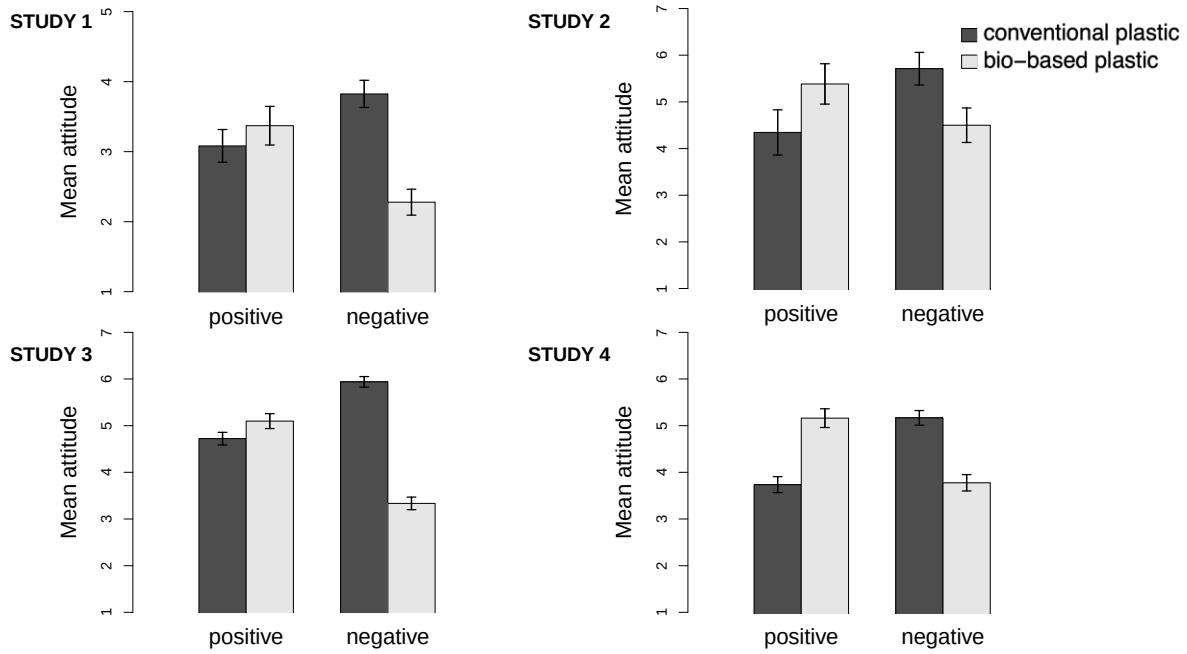

Figure 1 Mean attitudes towards regular and bio-based plastic for Studies 1 to 4. Error bars represent the Standard Error.

2.3. Study 2

The first study indicated positive attitudes towards bio-based products. As attitudes are presumed to influence behaviour, we wanted to investigate whether attitudes would relate to participants' willingness to pay more for bio-based products. Due to small production scales and an early stage of technology development, these new materials are likely to be initially more expensive. For new and more sustainable technologies to be made widely available, companies need to know consumers are willing to pay more to make the financial investment worth it. There are studies that suggest consumers would indeed be willing to pay 'a little' more for bio-based products [15], but the literature is sparse on the willingness to pay for bio-based products.

Furthermore, despite the generally positive attitudes towards bio-based plastic, uncertainty remains about how to correctly dispose of bio-based products [15, 25]. People may know how to correctly dispose of non-biodegradable recyclable plastic but not how to deal with (biodegradable) bio-

[4] Because some of the attitude distributions displayed a slight skew, we also performed a Wilcoxon rank-sum test. The results remained the same; see Supplementary Tables S1 and S2.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

based plastic [25]. This is problematic because of the common misconception that all bio-based plastics are biodegradable could lead to a continuation (or even increase) of littering, with consumers assuming that this type of plastic waste will degrade in nature. Additionally, bio-based plastic might be perceived as a technical solution to the plastic problem that does not appear to require specific actions or a change in behaviour from the individual, effectively removing any responsibility from the consumer to dispose of plastic products properly [26]. We therefore also assessed how important participants considered recycling of both conventional and bio-based plastics.

2.3.1. Willingness to pay

Studies 2, 3, and 4 included a measure of participants' willingness to pay[5]. Participants were shown an image of a 1.5-liter water bottle made from conventional plastic and told that it costs €1[6]. They were then asked how much they would be willing to pay for the same bottle if it were made from bio-based plastic instead. Participants responded on a continuous slider measure reaching from €0 - €2 with the slider's starting position being €1.

2.3.2. Importance to recycle

Importance to recycle was assessed by two items (one for each type of plastic) asking participants how important they thought it was to recycle items made from conventional and bio-based plastic on a 7-point Likert scale ranging from *1 = not at all important* to *7 = extremely important*. The items did not significantly correlate, $r(50) = 0.26$, $p = 0.63$, and were treated separately in the analysis.

2.3.3. Participants

See Table 1 for sample details of the 52 participants.

2.3.4. Results

2.3.4.1. Attitudes.

Paired-sampled t-tests[7] compared participants' attitudes towards conventional and bio-based plastic. The means and standard errors are displayed in Figure 1 (Study 2). Participants felt more positive towards bio-based than towards conventional plastic $t(51) = -5.70$, $p < .001$, $d = -0.79$. Conversely, participants reported being more negative towards regular plastic than towards bio-based plastic, $t(51) = 2.76$, $p = .008$, $d = 0.38$. This replicates the findings from Study 1 and indicates that participants again had both more positive and less negative attitudes towards bio-based plastics than towards regular plastics. Unlike in Study 1, participants felt significantly more negative than positive towards conventional plastic, $t(51) = -3.04$, $p = .004$, $d = -0.42$. As in the first study, their general attitudes were more positive than negative concerning bio-based plastics, $t(51) = 5.68$, $p < .001$, $d = 0.79$.

2.3.4.2. Importance to recycle.

Participants found it important to recycle in general. The distributions for participants' perceived importance to recycle were significantly skewed (-3.45 and -2.18 for conventional and bio-based plastic respectively, $SE = 0.33$). We therefore conducted a Wilcoxon signed-rank test, which suggested that participants found it more important to recycle items made from conventional plastic ($M = 6.8$, $SD = 0.7$) than bio-based plastic ($M = 6.4$, $SD = 1.1$), $T = 20.0$, $p = .021$, $r = -0.33$, see Figure 2 (Study 2).

2.3.4.3. Willingness to pay.

[5] The willingness to pay results for Study 2 were also reported in the supplementary material and the results of Study 3 in the main manuscript of [21]. However, the current paper focuses on the relationship between attitudes and willingness to pay which was not covered in the previous paper.

[6] In Study 4 the currency of the bottle was measured in GBP with the same scale values (0-2£).

[7] Due to a slight skew of some of the attitude distributions, we also performed Wilcoxon rank-sum tests. The skew information and the results for the non-parametric tests can be found in Table S3 and S4. The results did not differ from the parametric ones.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

A paired samples t-test showed that participants were willing to pay more for a bio-based than a conventional plastic bottle, $t(51) = -6.18$, $p < .001$, $d = 0.86$[8], with the majority of participants having this preference (70.6%). On average, participants reported that they would be willing to pay €1.30 (Median = 1.20, $SD = 0.36$) for a bio-based bottle: 30% more than for a water bottle made from conventional plastic that costs €1.00.

We also ran a bootstrapped regression (5000 bootstraps) to determine the relationship between people's attitudes and willingness to pay. The results suggest that, while attitude towards regular plastic predicted willingness to pay for a bio-based plastic product, $B = -.0412$, $t(49) = -2.04$, $p = .033$, 95%$CI_{Bootstrap}$ [-0.080, -0.007], attitude towards bio-based plastic did not, $B = .031$, $t(49) = 0.96$, $p = .40$, 95%$CI_{Bootstrap}$ [-0.043, 0.102]. Together, the attitudes towards both types of plastic did not significantly explain the variance of people's reported willingness to pay for the bio-based product ($R^2 = .088$, $F(2, 49) = 2.37$, $p = .104$).

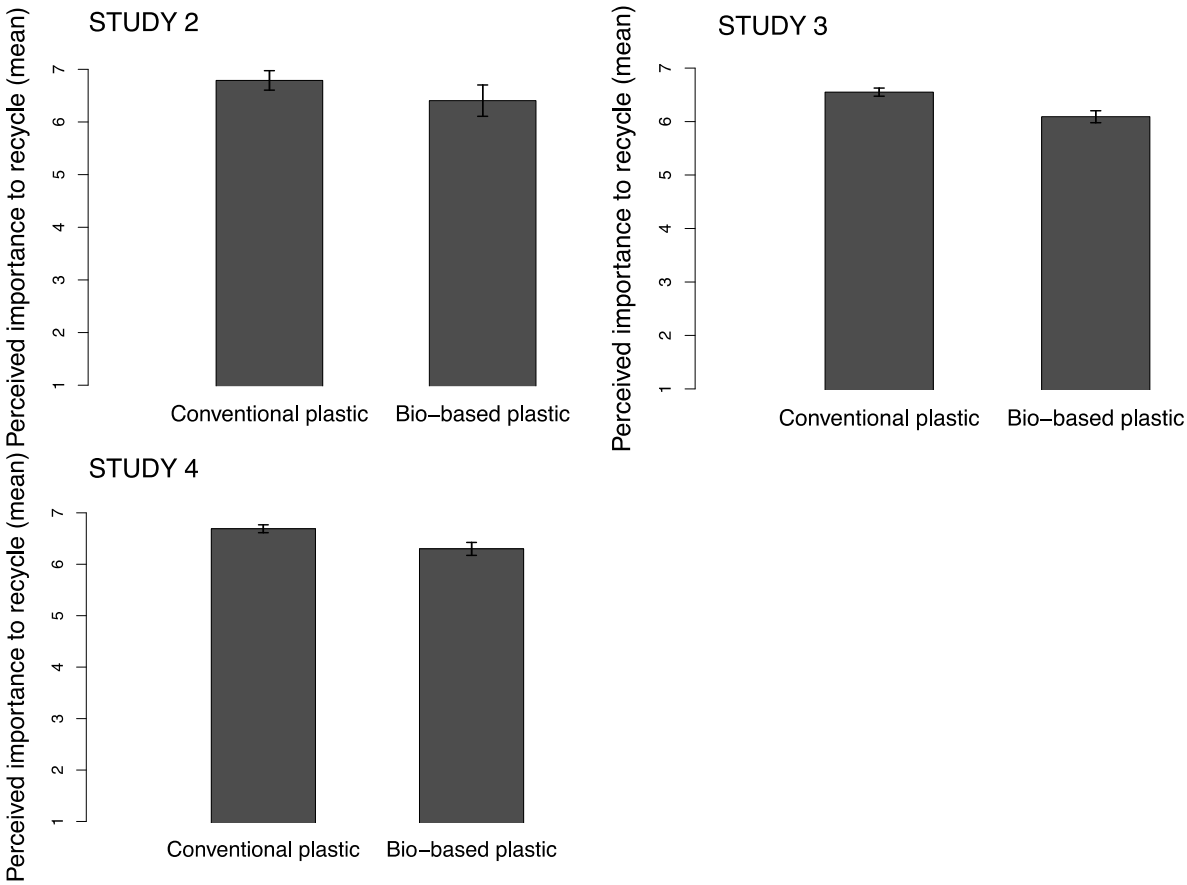

Figure 2. Mean perceived importance to recycle for regular and bio-based plastic for Study 2, 3 and 4. Error bars represent the Standard Error.

2.3.5. Discussion

Study 2 replicated that participants have more positive attitudes toward bio-based than conventional plastic and that this was driven by being more positive and less negative about the more sustainable plastic. Study 2 also demonstrated that people report being willing to pay more for a bio-based plastic water bottle. The results suggest that participants' attitudes towards conventional but not bio-based plastic might have influenced their willingness to pay more for a bio-based product. This contradicts findings by Klein, Emberger-Klein [10] and might relate to the fact that consumers are willing to pay more when feeling guilty about their use of conventional plastic [21]. This would suggest

[8] Because the willingness to pay distribution for regular plastic was slightly skewed (0.65, $SE = 0.33$), we also conducted a Wilcoxon signed-rank test. The results remain unchanged, $T = 48.50$, $p < .001$, $r = -0.71$.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

willingness to pay to be mainly driven by an aversion of conventional plastic, rather than liking of bio-based plastic. Participants also reported finding it less important to recycle bio-based plastic. This suggests that while participants have positive attitudes towards bio-based plastic, they may also have misconceptions which may drive their apparent willingness to pay, as well as their perception that it is less important to recycle bio-based plastic. In practice, it is just as important to recycle bio-based plastic as regular plastic, as both are harmful to the environment as they degrade slowly. One limitation of this study was its low statistical power due to the small sample size. A sensitivity power analysis revealed 80% power to detect a medium effect of $d = 0.57$ at $\alpha = 0.05$ (paired samples t-test). We therefore aimed to replicate and extend the findings with a larger sample size.

2.4. Study 3

Previous research suggests that consumers lack knowledge about bio-based plastics and thus fill this knowledge gap with assumptions. That all bio-based plastics are biodegradable seems to be the most common misconception [5, 13-15], however, there is also uncertainty about the disposal [15, 25] and recyclability (Study 2) of bio-based products. Other perceptions pertaining to bio-based plastic are concerns about the production of biomass (required to make bio-based plastic) leading to deforestation and competition with land for food production [15, 17, 21, supplementary material Study 1]. This is not true. Today, bio-based plastics are mostly made from carbohydrate-rich food crops, such as corn, sugar cane and plant oil (i.e., first generation feedstock). However, land use for the production of bio-based plastic only accounts for 0.01% of agricultural land use, is predicted to stay this low, and is not in competition with land use for food or animal feed growth [27, 28]. Research is also being done on large-scale use of second generation feedstock (crops and plants not suitable for human or animal consumption, such as straw, forestry residues, corn stover or bagasse, which are usually left on the field) and third generation feedstock (i.e., biomass derived from algae) [27, 29].

As these kinds of perceptions might influence consumers' (bio-based) plastic-related attitudes, behaviour, and willingness to pay, we investigated next whether participants shared these perceptions. As in the previous study, we also assessed participants' general attitudes about both conventional and bio-based plastic, their perceived importance to recycle, and willingness to pay.

2.4.1. Participants

See Table 1 for sample details. A sensitivity power analysis (paired samples t-test) revealed that with a sample of 508 participants we had 80% to detect a small effect ($d = 0.18$) at $\alpha = 0.05$.

2.4.2. Perceptions of Bio-based Plastic

We assessed four common perceptions concerning plastic made from biomass pertaining to its recyclability, biodegradability, deforestation, and competition for land used for food production. Participants indicated how much they agreed with these four items on a 7-point Likert scale ranging from *1 = strongly disagree* to *7 = strongly agree*.

2.4.3. Procedure

After reading the information letter and consenting to take part, participants read information about the difference between conventional and bio-based plastics (Supplementary material). First, participants reported their perceived importance to recycle and their attitudes about conventional, then about bio-based plastic. Next, they responded to the perception/misconception items. Finally, their demographic information was noted, and the participants were debriefed and paid.

2.4.3. Results

2.4.3.1. Attitudes[9]

A paired-sampled t-test comparing participants' attitudes towards conventional and bio-based plastic suggested that participants felt more favourable towards bio-based plastic than towards conventional plastic, $t(507) = -16.64$, $p < .001$, $d = -0.74$ (means and *SE*s displayed in Figure 1, Study 3). Participants also felt more unfavourable towards regular plastic than towards bio-based plastic, $t(507) = 17.80$, $p < .001$, $d = 0.79$. This replicates the findings from the previous two studies. As in Study 2,

[9] These results were also reported in [21].

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

participants were more negative than positive towards regular plastic ($t(507) = -3.43$, $p < .001$, $d = -0.15$) and more positive than negative towards bio-based plastic ($t(507) = 26.61$, $p < .001$, $d = 1.18$).

2.4.3.2. Importance to Recycle

Again, the general perceived importance to recycle was very high. Due to the skewed nature of the data (-2.40 and -1.52 for regular and bio-based plastic respectively, $SE = 0.11$), we conducted a Wilcoxon signed-rank test to determine whether there was a difference in how important participants found it to recycle the two different types of plastic. As in the previous study, participants found it more important to recycle items made from conventional plastic ($M = 6.55$, $SD = 0.86$) than from bio-based plastic ($M = 6.1$, $SD = 1.3$), $T = 4120$, $p < .001$, $r = -0.35$ (Figure 2, Study 3).

2.4.3.2. Perceptions of Bio-based Plastic.

As illustrated in Figure 3, most participants thought that bio-based plastic could be recycled (as is the case for the bio-based plastic studied here). However, participants also thought that bio-based plastic was biodegradable, which is not necessarily the case. Participants were not as concerned about the production of bio-based plastic resulting in deforestation, or competing with land otherwise used for food production. See Table 2 for response frequencies.

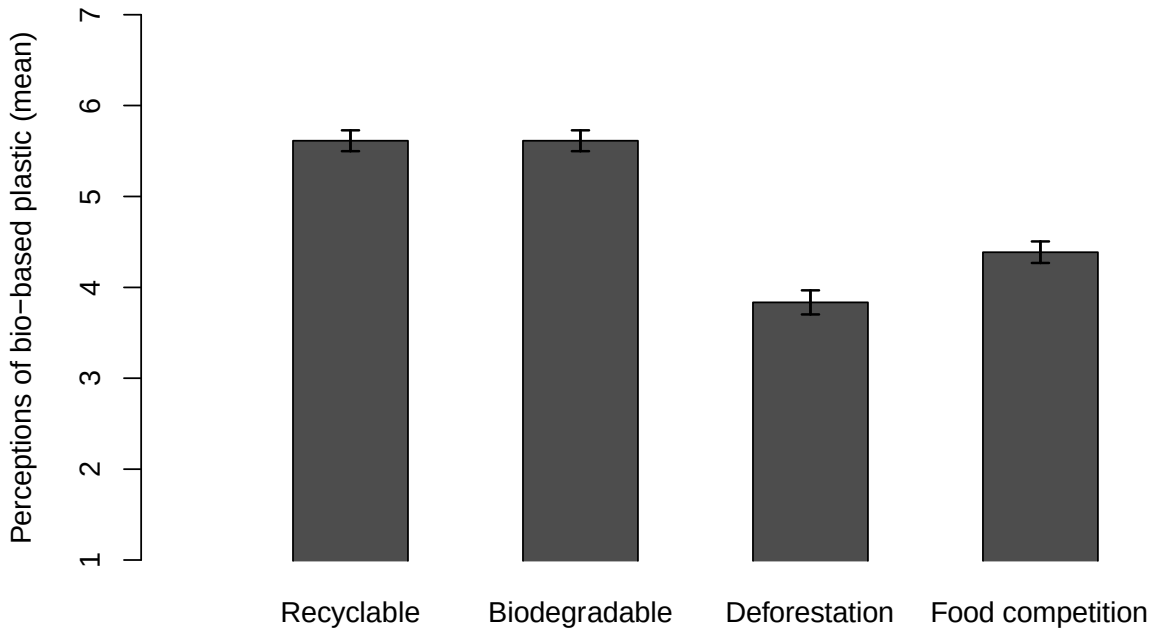

Figure 3. Common perceptions of bio-based plastic. Error bars represent the Standard Error (Study 3, N = 508).

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

Table 2. Response frequencies to the perceptions of bio-based plastic (Study 3, *N = 508*).

	Response frequency (%)			
	Recyclability	Biodegradability	Deforestation	Food competition
1 strongly disagree	3 (0.6 %)	4 (0.8%)	39 (7.7%)	19 (3.7%)
2	6 (1.2%)	8 (1.6%)	58 (11.4%)	23 (4.5%)
3	10 (2%)	7 (1.4%)	86 (16.9%)	40 (7.9%)
4 Neither agree nor disagree	96 (18.9%)	87 (17.1%)	172 (33.9%)	207 (40.7%)
5	92 (18.1%)	100 (19.7%)	81 (15.9%)	121 (23.8%)
6	144 (28.3%)	143 (28.1%)	50 (9.8%)	69 (13.6%)
7 Strongly agree	155 (30.5%)	154 (30.3%)	19 (3.7%)	27 (5.3%)
Total *N*	506 (99.6%)	503 (99%)	505 (99.4%)	506 (99.6%)

2.4.3.3. Willingness to Pay

A large majority of participants (78.6%) indicated that they would be willing to pay a price premium for a bio-based water bottle. On average, participants reported being willing to pay €1.20 for the bio-based plastic bottle (Median = 1.15, *SD* = 0.3). This suggests that they were willing to pay 20% more for a water bottle made from bio-based plastic than for one made from conventional plastic (which costs €1.00).

We also ran a bootstrapped regression (5000 bootstraps) to determine the relationship between participants' attitudes towards conventional and bio-based plastic and their self-reported willingness to pay. The results suggest that both attitude towards conventional plastic (B = -.012, $t(505)$ = -2.49, p = .022, $95\%CI_{Bootstrap}$ [-0.023, -0.002]) and towards bio-based plastic (B = .018, $t(505)$ = 3.22, p = .005, $95\%CI_{Bootstrap}$ [0.006, 0.030]) predict willingness to pay for a bio-based plastic product. Together, the attitudes towards both types of plastic explained 3% of variance of people's reported willingness to pay, R^2 = .029, $F(1, 505) = 7.58$, $p < .001$.

2.4.4. Discussion

In Study 3 we directly replicated that participants were both more positive and less negative towards bio-based compared to conventional plastic. We also found that the assumptions or misconceptions about bio-based plastic found in previous literature (i.e., concerning recyclability, biodegradability, deforestation, and competition with food production) were also present in the current sample, with the incorrect assumption that bio-based products are biodegradable being most prevalent. We also found a strong belief in the recyclability of bio-based plastic, but also replicated that participants found it less important to recycle bio-based compared to conventional plastic products. We again found that participants were willing to pay more for bio-based than fossil-based plastic products. While in Study 2 we only found attitudes towards conventional plastic to be predictive of willingness to pay, in Study 3 we found that attitudes towards both plastic types influenced willingness to pay for a bio-based bottle.

Studies 1-3 were exploratory and correlational, and assessed self-reported willingness to pay rather than objective behaviour. These limitations were addressed in the final study, which was experimental and pre-registered (https://aspredicted.org/blind.php?x=5bw9yz).

2.5. Study 4

Above, participants evaluated bio-based plastic more favourably and reported being willing to pay more for it than for conventional plastic, with some indication of attitudes being related to willingness to pay. Having only assessed self-reported willingness to pay in our previous studies, we also assessed objective behaviour in the form of a donation. We added a measure of objective behaviour because of the well-known inconsistency or 'gap' between what consumers say they are going or willing to do and what they actually do. Research suggests that models that predict behaviour solely based on intentions, are wrong up to 90% of the time [see 30].

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

Study 3 suggested that many participants had misconceptions, especially about the biodegradability of bio-based plastic. It is therefore unclear whether the positive attitudes and willingness to pay are (at least partially) due to their misconception of biodegradability and its consequences (e.g., less marine pollution). Such attitudes that are positive for the wrong reasons may lead to disillusionment among consumers who learn more about the nature of bio-based plastics. Indeed, some research suggests that when confronted with information that bio-based plastic either is not biodegradable, or only under very specific composting conditions (as is the case for biodegradable plastic), consumers can react "shocked and disappointed" [17].

In the present study, we investigated ways through which such disillusionment may be avoided. We manipulated the amount of information about bio-based participants received in order to vary misconceptions. The main question was whether people still feel positive towards and are willing to pay more for bio-based plastic after learning that not all bio-based plastic is biodegradable and that its true advantage is lowering CO_2 emissions. We again focus on bio-based plastic that is not biodegradable. This allows us to distinguish between participants' attitudes towards bio-based plastic from their attitudes towards biodegradability [5][10].

2.5.1. Conditions and Hypotheses

We used three conditions (control, negative, balanced) in which we varied the amount of information about bio-based plastic participants received, with the aim to reduce misconceptions about biodegradability. In particular, we wanted to be able to distinguish between a partial (negative condition) and complete resolution (balanced condition) of misconceptions. While positive attitudes are better than negative ones for the adaptation of more sustainable plastics, positive attitudes based on misconceptions can prove fragile when people learn more about the actual properties of bio-based plastic. In addition, there are good reasons for consumers to be positive about bio-based plastics that are based on renewable resources and reduce CO_2 emissions. While reducing the misconceptions might not lead to as positive of an attitude than the one many people hold before learning more about bio-based plastic, it may lead to more stable attitudes.

2.5.1.1. Control Condition

The control condition was the baseline in which participants received the same information about bio-based plastic as in Study 2 and 3: they read that bio-based plastic is entirely or partially made from biomass and is similar in appearance and function to conventional plastic. Here, we expected the same results as in the previous studies, namely that people feel positive about bio-based plastic. We also expected the majority of participants to believe that bio-based plastic is always biodegradable and we did not expect them to know much about the CO_2 footprint of bio-based plastic (or regular plastic for that matter).

2.5.1.2. Negative Condition

In the negative condition, participants received the same information about bio-based plastic as in the control condition *plus* information that bio-based plastic is not necessarily biodegradable. This condition aimed to remove any misconceptions about the biodegradability of plastic and the linked perceived advantage to marine pollution and wildlife participants might hold. We therefore expected people's attitude about bio-based plastic to become less positive relative to the control condition, but expected their knowledge about biodegradability to increase.

2.5.1.3. Balanced Condition

The balanced condition provided the same information as the negative condition with an *added* description of what makes bio-based plastic more sustainable (i.e., a smaller CO_2 footprint). In this condition, we hypothesised the attitude towards bio-based plastic to be less positive than in the control condition, but more positive than in the negative condition. Because participants in this condition have

[10] We also measured attitude strength in the form of attitude certainty and importance. To reduce length, these results fall outside the scope of this manuscript. The items, analysis and results can be found in the supplementary material.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

more knowledge about both the lack of biodegradability and the CO_2 benefits of bio-based plastic, we expected their attitudes about bio-based plastic to be more balanced and stable. A summary of the conditions and the corresponding hypotheses can be found in Table 3. We did not expect the manipulations to affect attitudes towards conventional plastic.

Table 3. Hypotheses on product knowledge (i.e., biodegradability and CO_2 footprint) and attitudes about bio-based plastic per condition (Study 4, $N = 304$).

		Message Condition		
		Control	Negative	Balanced
Knowledge	Biodegradability	low	correct	correct
	CO_2 footprint	none	none	correct
Attitude		+	-	+/- (stable)

2.5.1.4. Willingness to Pay and Attitudes

We expected that the manipulation of knowledge would have an effect on people's willingness to pay (both self-reported and objective behaviour). In particular, we expected that compared to the control condition, participants would be willing to pay the lowest amount in the negative condition, in which participants are told that not all bio-based plastics are biodegradable. We hypothesised that adding a description of the benefits of bio-based plastic in the balanced condition would lead people to be willing to pay more in this condition than in the negative condition, but less than in the control condition.

We expected more positive attitudes to lead to a higher willingness to pay than negative attitudes. We therefore predicted that attitudes would moderate the relationship between condition and willingness to pay, with participants with positive attitudes being willing to pay more, while participants with negative attitudes towards bio-based plastic would not. Alternatively, overall attitudes could also function as a mediator. Both the moderation and mediation hypotheses were pre-registered.

2.5.1.5. Importance to Recycle

We expected misconceptions about the biodegradability of bio-based plastic to lead people to believe that it is less important to recycle bio-based plastic compared to conventional plastic. We therefore hypothesised that participants in the control condition would find it less important to recycle bio-based products than in the other two conditions. We did not expect regular plastic or knowledge about bio-based plastic's CO_2 footprint to affect perceived importance to recycle.

2.5.2. Method

2.5.2.1. Procedure

After consenting to take part, participants were randomly assigned to one of three conditions: control, negative, and balanced. They were then asked how much knowledge they had about bio-based plastic and read an informational text about bio-based plastic (content depended on condition). This was followed by the manipulation check and the same questions about their attitude as in the previous studies. Participants were also asked how important they thought it was to recycle regular and bio-based plastic, before they indicated their willingness to pay (bottle and donation). Participants then filled out demographic information and were debriefed and paid.

2.5.2.2. Participants.

See Table 1 for sample details. A sensitivity power analysis suggested that the sample size of 304 provided 80% power to detect relatively small effects of $f = 0.18$ ($d = 0.23$) at $\alpha = 0.05$. The participants received £0.85 as compensation for this approximately ten-minute study. We also asked participants about their prior knowledge of bio-based plastic, to test whether the general lack of knowledge about

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

bio-based plastics reported in previous research [5, 13-16] is reflected in participants' self-reported knowledge level. The majority of participants reported having little prior knowledge of bio-based plastic (see Figure 4).

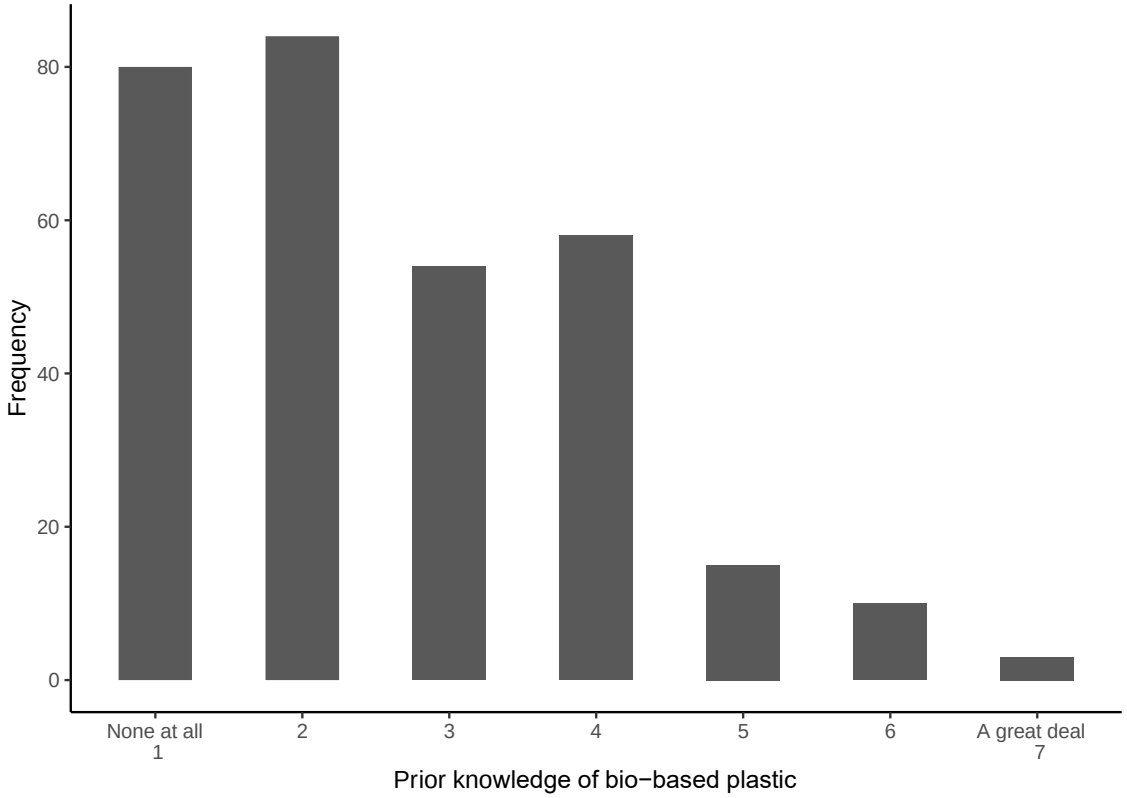

Figure 4. Frequencies of prior knowledge about bio-based plastic (Study 4, $N = 304$).

2.5.2.3. Manipulation.

In the different conditions (control, negative, balanced) participants read informational texts with varying amounts of information about bio-based plastic. The full text for each condition can be found in the supplementary material.

2.5.2.3.1. Manipulation Check

Participants were given a manipulation check to test their knowledge about bio-based plastic after having read the different manipulation texts. On a 7-point Likert scale (*1 = completely untrue* to *7 = completely true*) they indicated how much they believed the following statements to be true: 1) "Bio-based plastic is biodegradable.", 2) "Unlike regular plastic, bio-based plastic does not add any additional CO_2 to the atmosphere." (reverse coded), 3) "Bio-based plastic does not contribute to the 'plastic soup' or marine pollution.", and 4) "Bio-based plastic still contributes to global warming." These statements were presented in a random order. Statements 1 and 3 concerned participants' knowledge about the bio-degradability of bio-based plastic, were strongly correlated $r(302) = 0.69$ $p < .001$ and were combined into one biodegradability score. Statements 2 and 4 assessed participants' knowledge about bio-based plastic's CO_2 footprint and were combined into a CO_2 score, $r(302) = -0.66$, $p < .001$. Depending on condition, participants were expected to have different amounts of knowledge about bio-based plastic: see Table 3.

2.5.3.4. Willingness to Pay

In addition to completing the self-reported bottle measure, participants were asked whether they would like to donate some (or all) of the earnings they receive for participating in this research to help plant real-life trees to reduce CO_2, and if so, how much. Again, this was done using a slider measure, this time reaching from £0 *('I don't want to donate')* to £0.85 (the amount they received for participating in the study).

 doi:10.20944/preprints202012.0230.v1

2.5.3. Results[11]

2.5.3.1. Attitudes

As in the previous studies, we ran a paired-sampled t-tests[12] comparing participants' general attitudes (collapsed across all conditions) towards conventional and bio-based plastic[13]. Participants felt much more favourable towards bio-based plastic than towards conventional plastic, $t(303) = -15.00$, $p < .001$, $d = -0.86$ (for means and standard errors see Figure 1, Study 4). Participants also felt more unfavourable towards conventional plastic than towards bio-based plastic, $t(303) = 11.46$, $p < .001$, $d = 0.65$. This replicates Studies 1-3 and suggests that participants had both more positive and less negative attitudes towards bio-based plastics than towards conventional plastics. As in Studies 2 and 3, we found that participants were more negative than positive towards conventional plastic, $t(303) = -9.79$, $p < .001$, $d = -0.56$, while having more positive than negative evaluations of bio-based plastic, $t(303) = 10.05$, $p < .001$, $d = 0.58$.

2.5.3.2. Manipulation Check

The two items related to biodegradability (items 1 and 3) were combined into a biodegradability score and the two items concerning CO_2 (items 2 and 4) were combined into a CO_2 score, with higher values indicating less knowledge (misconception). In order to determine whether there was a main effect of condition on people's misconceptions, two one-way ANOVAs were performed with condition as the independent variable and the biodegradability score and the CO_2 score as dependent variables.

The manipulation worked as expected: see Figure 5. There were differences between the conditions in misconceptions about bio-based plastics' biodegradability, $F(2, 301) = 124.56$, $p < .001$. A Tukey post-hoc test further revealed that misconceptions were higher in the control condition than in the negative condition, $p < .001$, 95%CI [2.57, 3.59], and the balanced condition, $p < .001$, 95%CI [2.23, 3.21]. There was no difference between the negative and balanced condition ($p = .19$, 95%CI [-0.84, 0.13]).

With regards to people's perceptions of bio-based plastic's CO_2 impact, the results indicated that there was also a difference between conditions, $F(2, 301) = 124.38$, $p < .001$. A Tukey post-hoc test showed that this was driven by participants in the balanced condition having a much better understanding of bio-based plastic's CO_2 advantage than participants in the control, $p < .001$, 95%CI [-2.61, -1.76], or negative conditions, $p < .001$, 95%CI [-3.08, -2.22]. The difference between the control and negative condition was close to the alpha threshold ($p = .043$, 95%CI [0.018, 0.913]).

[11] All analyses were pre-registered unless explicitly declared otherwise.

[12] As some of the distributions were slightly skewed, we also ran related-samples Wilcoxon signed rank tests the results of which can be found in the supplementary material (Table S5). The pattern of the results was the same.

[13] This analysis was not pre-registered.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

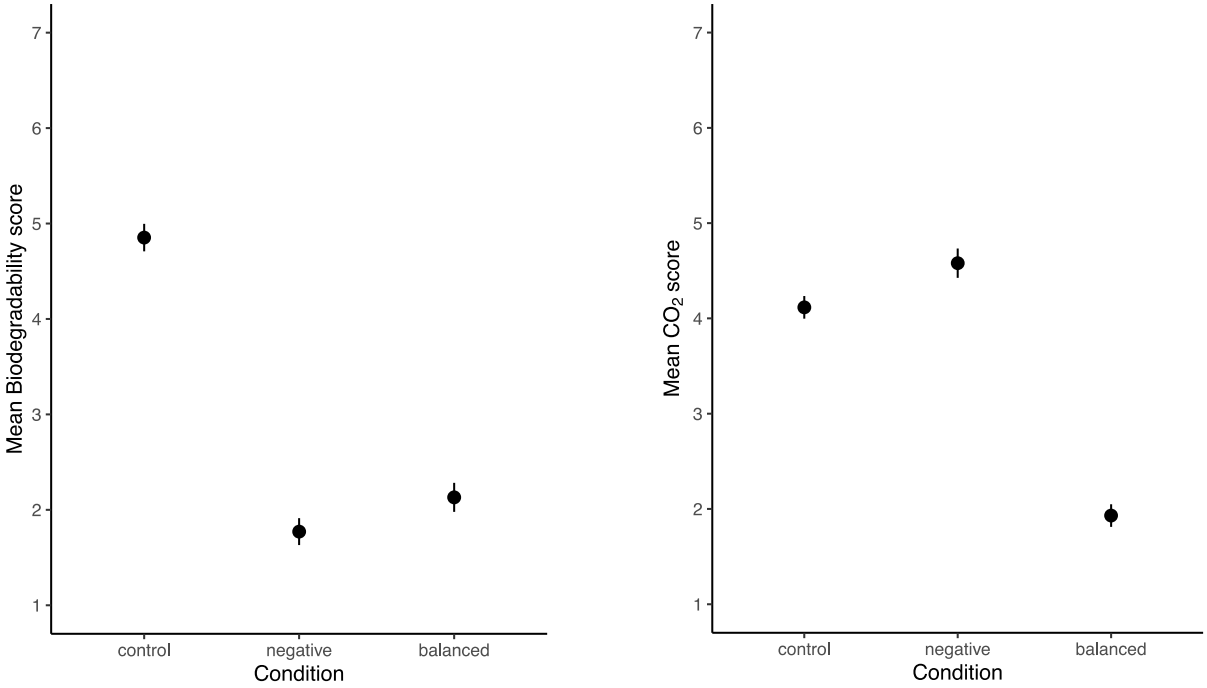

Figure 5. Mean Biodegradability and CO_2 Perception Scores Per Condition (Manipulation Check, Study 4, $N = 304$).
Note. Higher numbers indicate factual incorrectness or misconceptions and the error bars represent the Standard Error.

2.5.3.3. Willingness to Pay and Attitudes

2.5.3.3.1. Effect of manipulation on attitudes

To assess whether the (level of knowledge) manipulation affected people's attitudes towards bio-based (and conventional) plastic, two one-way ANOVAs were conducted with condition as the independent and product attitudes as the dependent variables. As expected, the manipulation had no effect on people's attitudes towards conventional plastic ($F(2, 301) = 1.44$, $p = .238$), but did significantly affect the attitudes people held towards bio-based plastic, $F(2, 301) = 32.59$, $p < .001$.

A Tukey post-hoc test revealed that all conditions differed in attitudes towards bio-based plastic (all p-values < .001). As illustrated in Figure 6, and as hypothesised, attitudes were most positive in the control condition and least positive in the negative condition, with the balanced condition in the middle.

2.5.3.3.2. Overall Willingness to Pay

The majority of participants (64.5%) indicated that they were willing to pay more for a bio-based than conventional plastic bottle. On average, participants reported that they were willing to pay £1.08 (Median = 1.05, $SD = 0.28$) for the bio-based plastic bottle (less than in the previous studies). This suggests that they were willing to pay 8% more for a product made from bio-based plastic than for a bottle made from conventional plastic (which costs £1.00). With regards to objective behaviour, participants donated on average £0.20 (Median = 0.05, $SD = 0.29$), which is 23.8% of the £0.85 they received. The majority of participants (57.6%) were willing to act pro-environmentally by donating some amount of money. An exploratory bootstrapped (5000 bootstraps) two-tailed Pearson correlation between self-reported willingness to pay and objective donation behaviour revealed a small positive correlation, $r(302) = 0.14$, 95% BCa CI[0.009, 0.27], $p = 0.01$.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

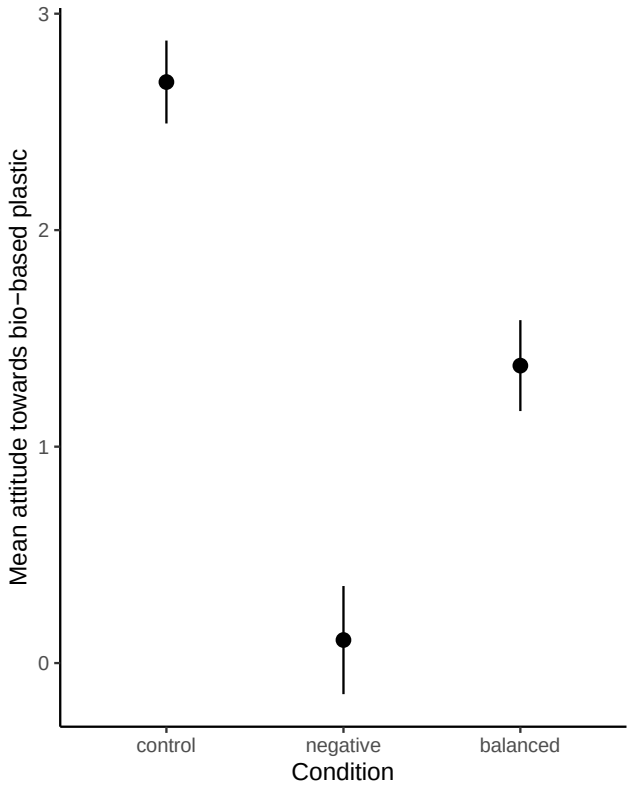

Figure 6. Mean attitudes towards bio-based plastic per condition (Study 4, N = 304). The error bars represent the Standard Error.

2.5.3.3.2. The Effect of Condition on Willingness to Pay

Table 4 shows the descriptives of participants' willingness to pay for both measures. We pre-registered several one-way ANOVAs to determine the effects of condition on the willingness to pay. However, because the data for both the bottle and donation measure were skewed, we conducted non-parametric tests instead.

Table 4. Willingness to pay descriptives per condition (Study 4, *N* = 304).

	Condition	***N***	***M*** (in £)	***SD***
Bottle	Control	95	1.10	0.3
	Negative	94	1.05	0.3
	Balanced	115	1.10	0.3
Donation	Control	95	0.20	0.3
	Negative	94	0.18	0.3
	Balanced	115	0.22	0.3

2.5.3.3.2.1. Bottle

Due to the moderate skew (-0.83) of the self-reported willingness to pay data [31], an independent samples Kruskal-Wallis test showed that willingness to pay for the bio-based plastic bottle was significantly affected by condition $H(2) = 11.06$, $p = .004$. Pairwise comparisons with adjusted p-values showed that participants in the negative condition were willing to pay £0.05 less than in the control condition ($p = .029$, $r = .19$), and in the balanced condition ($p = .005$, $r = -.22$). A one-sample Wilcoxon Signed Rank Test revealed that being willing to pay £1.05 for a bio-based plastic bottle constitutes a

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

significant increase compared to the £1 cost of a conventional plastic bottle, $T = 20913$, $p < .001$, $r = 0.45$. There was no difference in willingness to pay between the control and the balanced condition ($p = 1.00$, $r = -.03$). This suggests that when participants only received the additional information that bio-based plastic was not necessarily biodegradable, participants were less willing to pay. However, when they also read information about bio-based plastic's small CO_2 footprint, participants were willing to pay as much as in the control condition.

2.5.3.3.2.2. Donation

The donation data was highly skewed (1.36) and thus an independent samples Kruskal-Wallis test was performed to determine the effects of condition on willingness to donate. The results suggest that condition did not affect donation behaviour, $H(2) = 0.64$, $p = .73$.

2.5.3.3.3. The Effect of Overall Attitude on Willingness to Pay

We ran a bootstrapped regression (5000 bootstraps) to determine the relationship between participant's attitudes towards conventional and bio-based plastic and their self-reported willingness to pay for the bio-based plastic bottle. Contrary to expectations and to the results of the previous study, neither attitudes towards conventional plastic ($B = -.001$, $t(301) = -0.13$, $p = .900$, $95\%CI_{Bootstrap}$ [-0.015, 0.014]), nor attitudes towards bio-based plastic ($B = .009$, $t(301) = 1.35$, $p = .178$, $95\%CI_{Bootstrap}$ [-0.006, 0.024]) predicted willingness to pay for a bio-based plastic product. The combined attitudes towards both types of plastic did not explain variance in reported willingness to pay, $R^2 = .01$, $F(2, 301) = 0.93$, $p = .40$.

The same analysis was run for the donation measure with the same pattern of results. Neither attitude towards conventional plastic ($B = -.009$, $t(301) = -1.36$, $p = .174$, $95\%CI_{Bootstrap}$ [-0.021, 0.003]), nor towards bio-based plastic ($B = -.004$, $t(301) = -0.58$, $p = .560$, $95\%CI_{Bootstrap}$ [-0.019, 0.010]) predicted willingness to donate to a sustainable cause. Together, the attitudes towards both types of plastic did not explain variance in donation, $R^2 = .01$, $F(2, 301) = 1.36$, $p = .26$.

2.5.3.3.4. The Effect of Attitude on the Condition-Willingness to Pay Relationship

We hypothesised that attitude could potentially work as either a mediator or a moderator of the relationship between condition and willingness to pay. We therefore performed both analyses (5000 bootstraps) using PROCESS version 3 for SPSS [32].

2.5.3.3.4.1. Moderation

As condition only affected the willingness to pay for the bottle measure, this analysis was only conducted for that measure. The moderation analysis revealed that neither attitudes towards conventional, nor towards bio-based plastic moderated the relationship between the manipulated condition and willingness to pay ($b = -0.001$, 95% CI [-0.014, 0.012], $t = -0.13$, $p = .90$ and $b = 0.009$, 95% CI [-0.006, 0.024], $t = 1.35$, $p = 0.18$, respectively).

2.5.3.3.4.2. Mediation

While we found a parametric null effect, the non-parametric results suggested a relationship between condition and self-reported willingness to pay. We therefore ran a mediation analysis to determine whether attitude mediated this relationship. The results revealed that there was no indirect effect of condition on willingness to pay for bio-based plastic attitudes ($b = -0.01$, 95% CI [-0.02, 0.00]).

2.5.3.4. Importance to Recycle

To test whether participants' misconceptions influence perceived importance to recycle, we performed several bootstrapped (5000 bootstraps) regressions. As predicted, knowledge of bio-based plastic's CO_2 emissions did not influence participants' perceived importance of recycling bio-based plastic, $F(1, 302) = 0.38$, $p = .55$, $B = -0.022$, 95% CI [-0.09, 0.048]. However, the stronger participants' misconceptions about bio-based plastic's biodegradability, the less they thought recycling it was important, $F(1, 302) = 12.1$, $p < .001$, $B = -0.108$, 95% CI [-0.17, -0.041]. When it comes to regular plastic, neither participants' knowledge about bio-based plastic's CO_2 advantage, $F(1, 302) = 2.82$, $p = .094$, $B = -$

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

0.037, 95% CI [-0.08, 0.004], nor misconceptions about its biodegradability $F(1, 302) = 0.032$, $p = .86$, $B = -0.003$, 95% CI [-0.04, 0.03] affected how important participants felt it was to recycle conventional plastic. As in Studies 2 and 3, we also tested in an exploratory analysis whether there was a difference in how important participants found it to recycle both types of plastic (see Figure 2C). Reported importance of recycling was overall very high. Because both the distributions were skewed (bio-based plastic: -1.78, regular plastic: -2.68, $SE = 0.14$), we performed a Wilcoxon rank-sum test. The results suggest that participants found it more important to recycle items made from conventional rather than bio-based plastic, $T = 135$, $p < .001$, $r = -0.43$. Given the results described above, this may be driven by those participants who harboured misconceptions about bio-based plastic's biodegradability.

2.5.4. Discussion

In this pre-registered experimental study, we replicated the findings from the previous three studies concerning participants' attitudes towards both conventional and bio-based plastic. We also successfully manipulated participants' level of knowledge about bio-based plastic and found that this influenced the attitudes they had towards bio-based plastic. In particular, participants' evaluations of bio-based plastics were most positive in the control condition (with misconceptions), least positive in the negative condition in which they were informed that not all bio-based plastics are biodegradable, and somewhere in between in the balanced condition in which participants received additional information about the small CO_2 footprint of bio-based plastics.

As in Study 2 and 3, participants reported being willing to pay more for a bio-based product, compared to one made from conventional plastic. However, the willingness to pay was lower than in the previous study, with participants indicating that they would be willing to pay on average £0.05 more for a bio-based bottle. £0.05 might not seem like much, but the production cost for a fossil-based plastic water bottle is between $0.0175 and $0.0375 [33]. Willingness to pay (only the bottle measure) was affected by condition with participants in the negative condition being willing to pay less than in the other two conditions. Contrary to hypotheses, there was no effect of attitude on willingness to pay, nor did attitude influence the relationship between condition and willingness to pay. However, misconceptions about bio-based plastic's biodegradability led participants to think it less important to recycle products made from bio-based compared to those made from conventional plastic.

3. General Discussion

In combatting climate change, the development of more sustainable technologies has to go hand in hand with enhancing consumers' willingness to adopt these technologies. For example, consumer attitudes and perceptions are important when introducing a new technology like bio-based plastic to the market, because cognitions can influence how much people are willing to pay for sustainable alternatives. There are many cases where more sustainable products or new technologies were not readily accepted by consumers, e.g., Nike's line of environmental 'Considered' shoes, car manufacturers switching their wiring from conventional to soy-based plastic, or attitudes towards genetic modification [see 34, 35]. With the present research we tested how this might be avoided for bio-based plastics.

The current results provide insight into consumers' attitudes towards conventional and bio-based plastics. Throughout all four studies we found that participants had more positive and less negative evaluations of bio-based compared to conventional plastic products. Even when participants gained more knowledge about bio-based plastic and its characteristics, their attitudes remained positive (Study 4). However, attitudes alone do not paint the whole picture. We found some indication that attitudes about the different types of plastic directly affect people's willingness to pay (Study 2 and 3). However, those results did not replicate in Study 4.

3.1. Misconceptions

That people have positive attitudes towards bio-based plastics is encouraging. However, throughout our studies, we also found that participants had very little prior knowledge about bio-based plastic and harboured several misconceptions, including that bio-based plastic is by default

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 9 December 2020 doi:10.20944/preprints202012.0230.v1

biodegradable. This potentially makes these positive attitudes unstable, as they are likely based on these misconceptions. Positive attitudes that are based on misconceptions pose a risk for two reasons.

Firstly, learning that they have been positive for the wrong reasons may lead people to become more negative or even feel cheated because they had the wrong assumptions. Previous literature shows that consumers can react shocked and disappointed when told that bio-based plastic does not have all the properties they believed it to possess [17]. This was also demonstrated in in the negative condition of Study 4: when participants were told that bio-based plastics are not by default biodegradable and thus do not alleviate problems such as marine pollution, their attitudes became more negative (see Figure 6).

Secondly, people might attribute positive characteristics to bio-based plastic that are in fact untrue (that bio-based plastic is always biodegradable) and that can have unwanted behavioural consequences, such as littering. Throughout our research, we consistently found that participants perceived it less important to recycle products made from bio-based plastic, compared to those made from conventional plastic. The results of our final study suggest that this is driven by those participants who believe that bio-based plastic is biodegradable.

As a result, we argue that it is important to educate people about the properties of different types of plastic and their uses, and render them as positive about bio-based plastics as they were before, but now in a more stable fashion, i.e., for the right reasons. Bio-based plastic has many advantages such as being made from renewable biomass and having a smaller CO_2 footprint, in addition to possessing similar or better chemical barrier qualities than fossil-based plastic. In our final study we also demonstrated that the information about bio-based plastic does not need to be extensive to successfully dispel misconceptions. In short, we believe that educating consumers about the properties of different types of plastic can lead to a more durable transition to sustainability than ignoring misconceptions about bio-based plastics. Our research indicates that consumers remain willing to pay a price premium and favourably evaluate this new, more sustainable technology.

3.2. Willingness to pay

Previous research suggests that many consumers are willing to pay a premium for environmentally friendly products [see 36]. We found the same results with regards to bio-based products. Participants consistently reported being willing to pay 8-30% more for a bio-based compared to conventional water bottle. Whether this willingness translates into objective behaviour is unknown; we only found a small correlation between participants' self-reported willingness to pay and their objective donation behaviour in Study 4. This might be due to the differing nature of those two pro-environmental tasks (one assessing willingness to pay for a more sustainable plastic bottle and the other asking to donate actual money to help plant real-world trees), or due to a social desirability bias. However, it might also be due to the well-known intention behaviour gap [37], which describes the failure to translate intentions into action.

3.3. Limitations and Future Directions

While attitudes are essential for the acceptance of new technologies such as bio-based plastics, we found inconsistent evidence that attitudes influenced participants willingness to pay and no evidence that attitudes influenced objective behaviour. This suggests that non-attitude factors should be also be investigated. For example, emotions might be a useful tool in encouraging pro-environmental behaviour [21, 38]. Other lines of research also show positive effects of using social norms [39] and commitments [40] to encourage consumers to behave more sustainably. Future research directly comparing the effectiveness of these other factors in addition to attitudes might provide more information about how to encourage consumers to purchase bio-based and other more sustainable products.

Another limitation was the potential disconnect between willingness to pay for a plastic bottle compared to the objective behaviour measure of donation. Participants might not have seen a direct connection between paying more for a water bottle and donating to plant trees, as reflected in the

 doi:10.20944/preprints202012.0230.v1

small correlation between them. Future research should investigate actual consumer behaviour and test whether participants would actually pay as much for a bio-based product as they indicated. The remote nature of the objective behaviour measure might also be the reason why we did not find an effect of attitude on donation behaviour, as the attitude questions were specifically about the different types of plastic.

4. Conclusions

Plastic production and disposal are an often-overlooked contributor to climate change. While consumers are increasingly becoming aware of plastics' negative effects on marine life, many remain unaware of the large amounts of CO_2 that are released during the production and life-cycle of plastic products. One possible solution to this plastic problem is the market introduction of more sustainable products (e.g., bio-based plastics). This transition requires that 1) companies provide these environmentally friendly products and that 2) consumers accept and are willing to purchase them. Across four studies, we showed that consumers are very positive towards bio-based plastics and are willing to pay a price premium for them. However, we also demonstrated that many consumers lack knowledge about the properties of these new plastics and harbour misconceptions, particularly by overestimating biodegradability. We also showed that these misconceptions can be resolved through brief written messages. After being informed about bio-based plastics' properties and benefits, consumers attitudes towards products made of bio-based plastic remain positive and they are still willing to pay a price premium. These are encouraging results with regards to a transition towards sustainability, and the results contribute to the broader literature identifying psychological predictors of pro-environmental behaviour including emotions, values, norms, and beliefs [21, 38-40].

Supplementary Materials: The supplementary materials include all the non-parametric analyses mentioned in the main manuscript, descriptive texts describing (bio-based) plastic as seen by the participants, information about the subject pool and potential skewness of the data, additional analyses that did not make it into the final version of the paper.

Author contributions: Conceptualization, M.V.Z. and F.v.H.; methodology, M.V.Z. and F.v.H.; software, M.V.Z.; validation, M.V.Z., F.v.H. and C.B.; formal analysis, M.V.Z.; investigation, M.V.Z.; data curation, M.V.Z.; writing—original draft preparation, M.V.Z.; writing—review and editing, M.V.Z., F.v.H., C.B. and G-J.G.; visualization, M.V.Z.; supervision, F.v.H., C.B.; project administration, M.V.Z. and F.v.H.; funding acquisition, G-J.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Netherlands Organisation for Scientific Research (NWO) [grant number 731.017.203] in the framework of the Innovation Fund for Chemistry and from the Ministry of Economic Affairs in the framework of the *"TKI/PPS-Toeslagregeling.* The authors would like to thank LEGO SYSTEM A/S and Avantium for co-funding this project. The APC was funded by the University of Amsterdam.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. PlasticsEurope, *Plastic - the Facts 2019: An analysis of European plastics production, demand and waste data*. 2019.
2. Hamilton, L.A., et al., *Plastic & Climate: The Hidden Costs of a Plastic Planet*, A. Kristler and C. Muffett, Editors. 2019, CIEL.
3. RESTCo. *Media Coverage of Plastic Pollution*. 2020 July 2020 [cited 2020 20 July]; Available from: https://www.restco.ca/Plastic_Pollution_Media_Coverage.shtml.
4. Heidbreder, L.M., et al., *Tackling the plastic problem: A review on perceptions, behaviors, and interventions.* Science of The Total Environment, 2019. **668**: p. 1077-1093.

5. Herbes, C., C. Beuthner, and I. Ramme, *Consumer attitudes towards biobased packaging – A cross-cultural comparative study.* Journal of Cleaner Production, 2018. **194**: p. 203-218.
6. European Bioplastics. *Bioplastics market data*. 2019 [cited 2019 17 December]; Available from: https://www.european-bioplastics.org/market/.
7. Bourguignon, D., *Plastics in a circular economy: Opportunities and challenges*. 2017, European Parliamentary Research Service.
8. Ritchie, H. *Plastic Pollution*. Our World in Data [Online Resource] 2018; Available from: https://ourworldindata.org/plastic-pollution.
9. van den Oever, M., et al., *Bio-based and biodegradable plastics – Facts and Figures: Focus on food packaging in the Netherlands*. 2017, Wageningen Food & Biobased Research.
10. Klein, F., et al., *Influencing factors for the purchase intention of consumers choosing bioplastic products in Germany.* Sustainable Production and Consumption, 2019. **19**: p. 33-43.
11. Eerhart, A.J.J.E., A.P.C. Faaij, and M.K. Patel, *Replacing fossil based PET with biobased PEF; process analysis, energy and GHG balance.* Energy & Environmental Science, 2012. **5**(4).
12. Orset, C., N. Barret, and A. Lemaire, *How consumers of plastic water bottles are responding to environmental policies?* Waste Manag, 2017. **61**: p. 13-27.
13. Kainz, U., et al., *Consumer-relevant information about bioplastics*, in *First International Conference on Resource Efficiency in Interorganizational Networks* J. Geldermann and M. Schumann, Editors. 2013, Universitätsverlag Göttingen. p. 391-402.
14. Koutsimanis, G., et al., *Influences of packaging attributes on consumer purchase decisions for fresh produce.* Appetite, 2012. **59**(2): p. 270-280.
15. Lynch, D.H.J., P. Klaassen, and J.E.W. Broerse, *Unraveling Dutch citizens' perceptions on the bio-based economy: The case of bioplastics, bio-jetfuels and small-scale bio-refineries.* Industrial Crops and Products, 2017. **106**: p. 130-137.
16. Dilkes-Hoffman, L., et al., *Public attitudes towards bioplastics – knowledge, perception and end-of-life management.* Resources, Conservation and Recycling, 2019. **151**.
17. Blesin, J.-M., M. Jaspersen, and W. Möhring, *Boosting plastics' image? Communicative challenges of innovative bioplastics.* Journal of Historic Polymeric Materials, Plastics Heritage and History, 2017. **3**: p. 1-5.
18. Ajzen, I. and M. Fishbein, *The Influence of Attitudes on Behavior*, in *The handbook of attitudes*. 2005. p. 173-221.
19. Koenig-Lewis, N., et al., *Consumers' evaluations of ecological packaging – Rational and emotional approaches.* Journal of Environmental Psychology, 2014. **37**: p. 94-105.
20. Sijtsema, S.J., et al., *Consumer perception of bio-based products—An exploratory study in 5 European countries.* NJAS - Wageningen Journal of Life Sciences, 2016. **77**: p. 61-69.
21. Zwicker, M.V., et al., *Applying an attitude network approach to consumer behaviour towards plastic.* Journal of Environmental Psychology, 2020. **69**: p. 101433.
22. Champely, S., et al., *Basic Functions for Power Analysis*. 2020.
23. Thompson, M.M., M.P. Zanna, and D.W. Griffin, *Let's not be indifferent about (attitudinal) ambivalence*, in *Attitude strength: Antecedents and consequences.* 1995, Lawrence Erlbaum Associates, Inc: Hillsdale, NJ, US. p. 361-386.
24. van Harreveld, F., H.U. Nohlen, and I.K. Schneider, *The ABC of Ambivalence: Affective, Behavioral, and Cognitive Consequences of Attitudinal Conflict*, in *Advances in Experimental Social Psychology*. 2015. p. 285-324.

 doi:10.20944/preprints202012.0230.v1