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# What if consumers saw the bigger picture? Systems thinking and the adoption of bio-based consumer products

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ABSTRACT

Systems thinking (ST) represents an important cognitive paradigm for the transition towards a circular bio-economy, as greater awareness of the environmental impact of fossil-based products may lead to a switch to sustainable alternatives produced from secondary biomass which is not used as feed or food. However, the relationship between ST and the adoption of bio-based products, as well as the general mechanism of how ST affects environmental behavior, is not yet well-understood. The present study therefore aims to close these research gaps by conducting a survey-based experiment with a ST-motivated treatment, in which participants are asked to list as many consequences of their consumption behavior as possible (N=446 US consumers). Our findings suggest that the treatment is able to slightly activate a ST perspective, along with indirectly affecting consumer intentions to buy bio-based products by means of ST. Subsequent mediation analyses further reveal that an ecological worldview as well as variables from the norm-activation model function as mediators of the relationship between ST and purchase intention.

## 1. Introduction

Complex environmental issues such as climate change and resource depletion are increasingly challenging the well-being of humans, animals, and the biosphere (Meadows et al., 2004). Various scholars have argued that one of the major causes of such problems is that humans ignore the environmental consequences of their behaviors, e.g. of their purchasing choices (Liening, 2013; Randle & Stroink, 2018). In this vein, systems thinking (ST) offers one approach which allows people to perceive the complex, interconnected nature of reality and, thus, to better grasp how their individual behavior connects to the bigger picture of the natural system (Meadows et al., 1972; National Research Council, 2012; Davis & Stroink, 2015; Lezak & Thibodeau, 2016). We argue that ST represents an important cognitive paradigm for a transition towards a circular bio-economy, wherein consumers need to switch from fossil-based to innovative bio-based products (Lewandowski et al., 2018; Urmetzer et al., 2020). The central idea here is that people who are more aware of the social and environmental consequences of consuming fossil fuels are more likely to prefer bio-based cosmetics, detergents or plastics over fossil-based alternatives – especially when those bio-based products are manufactured on the basis of secondary biomass which does not conflict with food or feed production (Schwartz, 1977; Urmetzer et al., 2020). However, the relationship between ST and consumer willingness to buy bio-based products is not yet empirically tested. Moreover, despite growing interest in ST, the psychological mechanisms of how systems thinking affects pro-environmental decision-making is not firmly understood (Lezak & Thibodeau, 2016; Davis et al., 2017; Ballew et al., 2019).

Thus, this study investigates whether ST is associated with consumer intentions to buy bio-based products and how ST interacts with pro-environmental values, environmental worldviews, beliefs, and norms. To this end, we conducted an online survey with 446 US consumers, which applied a between-subject design to test the causal effect of a ST-motivated treatment in which participants are asked to enumerate the consequences of their consumption behavior. The contributions of this study are twofold. First, we explore ST as a driver for consumer intentions to purchase products based on secondary biomass which is not used as food or feed. Prior studies investigating consumer preferences for bio-based products mainly look at socio-demographic characteristics and product attributes as explanatory variables (Peuckert & Quitzow,

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2017; Reinders et al., 2017; Scherer et al., 2017, 2018b). Few studies also assess internal behavioral motivations like attitudes, trust, environmental awareness, and social norms (Onwezen et al., 2017; Klein et al., 2019; Russo et al., 2019). However, to our knowledge, this is the first study to investigate the role of a ST mindset for consumer preferences in a context of the transition towards a sustainable bio-economy. Second, this study advances our understanding of how ST relates to pro-environmental motivations, that is, whether this factor offers unique explanatory potential alongside values, worldviews, beliefs, and norms (Davis & Stroink, 2015; Lezak & Thibodeau, 2016; Thibodeau et al., 2016; Davis et al., 2017; Ballew et al., 2019). By means of mediation analysis, this study specifically provides an empirical illustration of the mechanism by which ST influences consumer behavior. Such insights can be employed by policy-makers and marketers to better customize their strategies to increase consumption of bio-based products.

The article is organized as follows: the next two sections summarize the literature and derives hypotheses on the relationship between consumer intentions to buy bio-based products on the one hand, and the interplay of ST, values, beliefs, and norms on the other. The methods section outlines the experimental procedure, including the treatment that is used, the procedure of (serial) mediation analysis, and the sample characteristics. Next, we present the results of the mediation analyses and, finally, discuss theoretical and practical implications as well as limitations of our research.

## 2. Literature review

### 2.1. The role of systems thinking for the bio-economy transition

Implications of systems theory have just recently spilled over into social science from interdisciplinary approaches of cybernetics, systems modeling and quantum physics (Bateson, 1972; Senge, 2010; Waddell et al., 2015; Nature Editorial Board, 2020). General systems theory aims to explain phenomena in the world as outcomes of complex systems which consist of independent, but interconnected parts that work together to fulfill a common function. The relationships between the elements in these highly dynamic systems are characterized by non-linearity, exponential growth, random variation and indirect effects (Meadows, 2008; Murphy, 2012). Based on this theory, systems thinking (ST) provides a mindset which enables people to understand complex systems by envisioning an ostensibly distinct set of processes, such as those in nature, as a set of interrelated elements oriented by a dynamic structure that is constantly changing (Hmelo-Silver & Green Pfeffer, 2004; Meadows, 2008).

In sustainability research, the importance of ST has been increasingly recognized ever since the Club of Rome released their report on “The Limits to Growth”. In this report, Meadows et al. (1972) applied systems theory to model the long-term effects of the exponential population growth by computer simulation. Thereby, the authors were able to warn about the future limits of the world’s resources (Meadows et al., 1972). Since then, systems theory has been regularly applied to understand sustainability transitions, e.g. by using modeling approaches based on causal loop diagrams (Bassi et al., 2021) or by exploring social tipping point dynamics related to individual behavior and other social processes (Otto et al., 2020).

For a successful transition of the current fossil-based towards a bio-based economy, a ST perspective needs to be adopted beyond the scientific community by all relevant actors in the socio-economic system (Urmetzer et al., 2020; Nature Editorial Board, 2020). When guiding the bio-economy transition, policy-makers could benefit from ST by considering systemic characteristics of change such as non-linear progress and the existence of tipping points, e.g. climate tipping points (Murphy, 2012; Nature Editorial Board, 2020; Lenton et al., 2019). Beside the relevance of top-down governance, consumers can also lead the transition from the bottom-up by changing their consumption patterns and by getting involved in research and development processes (Schlaile et al., 2018; Mustalahti, 2018; Sanz-Hernández et al., 2019). In this case, it seems also important that consumers increasingly engage in ST as this would allow them to better understand how the economic system and their individual purchasing behavior ultimately result in environmental outcomes (Urmetzer et al., 2020). The capability of understanding the interdependencies is especially important in the bio-economy transition as not all bio-based products that consumers might find on the market are per se sustainable, e.g. due to the competition for land with food production (Pfau et al., 2014). Thus, system thinkers might be more aware of the complex consequences of their individual purchase behavior and, thus, buy more pro-environmental products (Davis & Stroink, 2015).

### 2.2. Antecedents of pro-environmental behavior

In the environmental psychology domain, motivations for pro-environmental behavior have been mainly studied from three different theoretical perspectives: 1) altruistic values (Schwartz, 1977; Rokeach, 1980; Stern & Dietz, 1994), 2) ecological worldview (Stern et al., 1995; Dunlap et al., 2000); and 3) moral norms (Schwartz, 1977; Davis & Stroink, 2015). In specific, values and worldviews are assumed to serve as antecedents for rather specific beliefs which, in turn, shape moral norms to engage in pro-environmental behavior (Stern et al., 1999).

Value orientations direct people’s attention towards valuable objects and, thus, shape their attitudes towards them as well as guide their behavior (Rokeach, 1980; Stern & Dietz, 1994; Nordlund & Garvill, 2002). More specifically, social-altruistic and biospheric-altruistic value orientations, both of which reflect concern for the well-being of other individuals, species and the biosphere, have been found to drive pro-environmental behavior (Stern et al., 1995; Nordlund & Garvill, 2002; Steg, 2016; Ünal et al., 2018).

Worldviews reflect general beliefs about reality in a specific domain of life. In contrast to values, worldviews are understood to be less stable and open to questions with regard to their accuracy in understanding reality (Stern et al., 1995). The most widely studied type of worldview involving the relationship between humans and the environment is the new ecological paradigm (NEP) (Dunlap et al., 2000). The NEP reflects the beliefs that humans are part of the natural system which is very delicate and has limited resources (Stern et al., 1995; Dunlap et al., 2000).

Personal moral norms are defined as feelings of moral obligations to engage in specific behaviors (Schwartz, 1977). The norm-activation model (NAM) (Schwartz, 1977; Schwartz & Howard, 1981) specifically uses the construct of personal norms to explain altruistic behavior. Applied to the environmental domain, NAM postulates that moral obligations to act pro-environmentally are activated when individuals become aware of the consequences of their behavior for the environment (problem awareness or PA beliefs) and believe that their actions can adversely affect these consequences (outcome efficacy or OE beliefs).

## 3. Development of hypotheses

Systems thinking is assumed to be an important cognitive paradigm for the transition towards a bio-based economy (Urmetzer et al., 2020). As system thinkers are more aware of the consequences of their behavior, past research indicates that the existence of a ST mindset is associated with more pro-environmental behavior (Davis & Stroink, 2015). In consumer research, the ability and tendency to better grasp the consequences of one’s behavior has been called perceived consumer effectiveness (PCE; Antil & Bennett, 1979). Prior studies reveal that those with higher perceived consumer effectiveness are more likely to engage in sustainable purchase behavior, as they are convinced that this can help to alleviate environmental threats (Coelho et al., 2017; Hooge et al., 2017; Joshi and Rahman, 2019). However, there is currently a lack of research regarding the effect of a ST perspective on consumer

willingness to buy bio-based products. Thus, this paper makes use of a treatment which aims to activate ST by drawing participants' attention to the interconnectedness between their own behavior and external consequences (Hmelo-Silver et al., 2017; Cox et al., 2019). Additionally, this study tests the relationship between ST and consumer intention to buy bio-based products. Thus, we propose the following hypothesis:

H1:The treatment will activate participants' systems thinking which is, in turn, associated with consumer intentions to buy bio-based products.

Although systems thinking seems to be a powerful precondition for pro-environmental behavior, its integration into current theories in environmental psychology is still missing. Thus, this paper aims to explore how systems thinking might be related to antecedents of pro-environmental behavior which are currently discussed in the literature: altruistic values (Schwartz, 1977; Rokeach, 1980; Stern & Dietz, 1994), ecological worldview (Stern et al., 1995; Dunlap et al., 2000); and moral norms (Schwartz, 1977; Davis and Stroink, 2015).

We propose that altruistic values can serve as an antecedent of ST, since people with altruistic values will focus on the consequences of their behavior for others and the biosphere (Steg, 2016). In contrast to values, ST is defined as a worldview with general beliefs about the nature of reality (Davis & Stroink, 2015). Stern et al. (1995) explicitly assume that general beliefs may evolve as a result of a combination of existing value orientations and individual experiences over the life-course (Stern et al., 1995). In this vein, prior research indicates that altruism has a positive effect on consumer intentions to purchase bio-based products (Klein et al., 2019). The nature of the relationship between altruistic values and consumer intentions to purchase bio-based products might therefore be explained through ST, leading us to the following hypothesis:

H2:The relationship between altruistic values and consumer intentions to buy bio-based products is mediated by systems thinking.

Prior studies have established a positive relationship between NEP and the valuation of pro-environmental products and services (Stern et al., 1999; Cordano et al., 2003; Halkos & Matsiori, 2017; Yi, 2019). In contrast to the NEP, ST not only reflects specific cognitive beliefs about the relationship between humans and the ecological system but also domain-general beliefs about economic and social systems (Davis & Stroink, 2015; Randle & Stroink, 2018). Thus, it can be argued that from a theoretical perspective, an ecological paradigm might be a component of a general systemic worldview (Davis & Stroink, 2015). Indeed, studies have shown that ST shares a positive relationship with the NEP (Davis & Stroink, 2015; Ballew et al., 2019). A recent study even found that the NEP fully mediates the relationship between ST and more concrete global warming beliefs (Ballew et al., 2019). Based on these findings, we hypothesize that:

H3:The relationship between systems thinking and consumer intentions to buy bio-based products is mediated by an ecological worldview.

The NAM has been found to successfully explain a wide range of pro-environmental behaviors (Guagnano et al., 1995; Nordlund & Garvill, 2002; Abrahamse et al., 2007). To date, no empirical study has however investigated the relationship between ST and personal norms to engage in pro-environmental behavior. Prior studies have however looked at how ST relates to individual concerns vis-à-vis the environmental consequences which, according to NAM, serve as the preconditions for moral obligations to act pro-environmentally (Davis & Stroink, 2015; Lezak & Thibodeau, 2016; Ballew et al., 2019). More specifically, the existence of a ST mindset was found to be associated with perceptions of climate change-related risks (Lezak & Thibodeau, 2016) and the general belief that climate change is happening (Ballew et al., 2019). In view of the argument by Davis and Stroink (2015) that concerns about environmental consequences[1] mediate the relationship between ST and pro-environmental behaviors, we hypothesize that:

H4:The relationship between systems thinking and consumer intentions to buy bio-based products is mediated by problem awareness, outcome efficacy and personal norm, in that order.

Figure 1 provides an overview of the hypothesized mediation models in this study.

## 4. Methods

This study uses an online survey with a between-subject design approach to assess whether pro-environmental values, worldview, belief and norms explain the relationship between ST and consumer intentions to purchase bio-based products.

### 4.1. Participants

Data was collected in March 2019 using Qualtrics and respondents were financially compensated for their participation. Due to the lack of empirical studies about the adoption of bio-economy innovations in the US, we chose to target consumers in this context, screening criteria was solely based on age including adults (≥18 years). To account for a representative US consumer sample, quotas were set on age and gender in accordance with current US data from Statista. From N = 2170 individuals who opened the link to the survey, n = 1111 actively dropped out of the survey and n = 168 were filtered out as they were < 18 years old or over quota for age and gender. For data quality reasons, n = 445 were removed as they failed to pass the attention checks.[2] Thus, a total of 446 respondents were employed for the statistical analysis. In this group, 50 % of participants took more than 15.25 minutes to finish the survey (IQR = 7.79 minutes).

### 4.2. Procedure

The online survey was organized in five parts as depicted in Fig. 2.

The first section consisted of an informative text about bio-based products as consumers are generally not familiar with these type of products (Sijtsema et al., 2016). The text provides participants with a definition and several examples of bio-based products. The provided definition underlines that this study focuses on bio-based products which are manufactured on the basis of biomass which is otherwise not used as food or feed (see Appendix A). In the second section, participants were randomly assigned to the control or to the treatment group, respectively dividing the sample into those that continued with the third part of the survey and those which received a treatment (please see Section 4.3 for more details). In the third part, participants could voluntarily choose to read more information about bio-based products (see Appendix B). This opportunity is given to the participants to reflect the reality in which some consumers actually collect more information to form an attitude towards novel products and others do not (Rogers, 2003). The next part consisted of several measures of the latent

[1] Davis and Stroink (2015) define this variable as 'biospheric values'. However, based on Schwartz (1977), we define individual concerns about consequences of environmental problems instead as 'beliefs'.

[2] If the participants did not answer "*somewhat disagree*" to the trap question ("*For quality purposes, please click "somewhat disagree"*"), did not correctly answer the questions that demonstrate their understanding of the informative text (Appendix A) or did not answer the open questions properly, they were understood to not have paid sufficient attention to the questions and were thus excluded from the dataset.

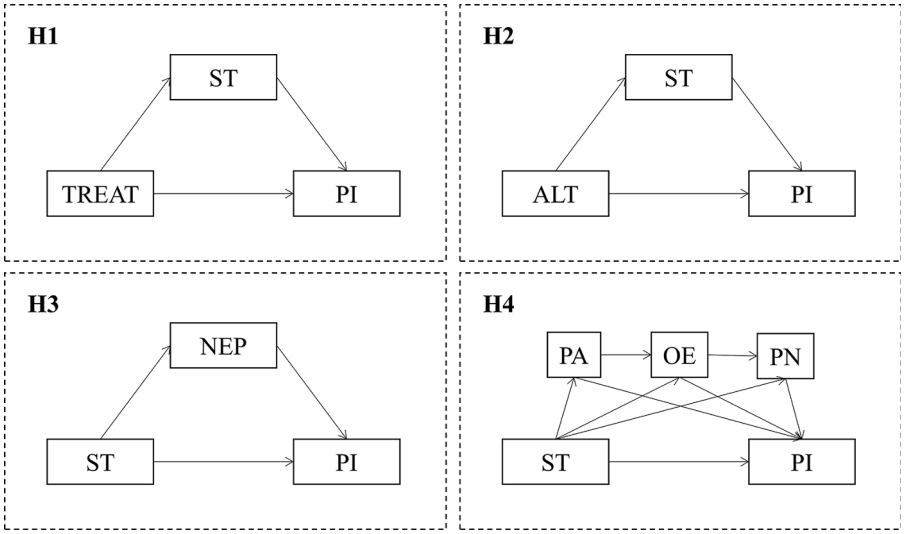


**Fig. 1.** Overview of hypothesized mediation models.
Note: ALT = Altruism, NEP = New Ecological Paradigm, OE = Outcome Efficacy, PA = Problem Awareness, PN = Personal Norm, ST = Systems Thinking, TREAT = Treatment, PI = Purchase Intention

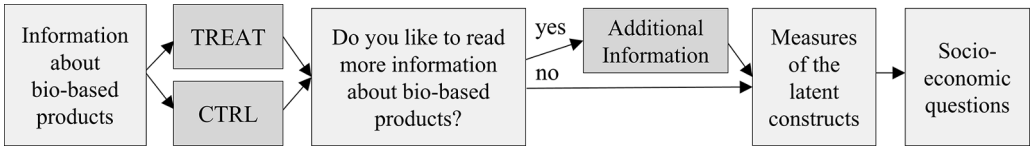


**Fig. 2.** Overview of experimental survey procedure.

constructs which are presented in section 4.4. In the last section, participants were asked about socio-demographic factors such as education level, employment status and household income.

### 4.3. Treatment

Participants were randomly assigned to the control group (hereafter CTRL) or to the treatment group (hereafter TREAT). In CTRL, participants did not receive any task and simply continued with the survey. In TREAT, they were asked to list as many consequences as possible: 1) related to their buying decisions and 2) if they were to (hypothetically) purchase bio-based products more frequently (see Appendix C). A qualitative content analysis[3] revealed that respondents listed up to five consequences related to their buying decisions (M = 1.90, SD = 1.60) and up to seven consequences for when they would buy bio-based products (M = 1.52, SD = 1.18). Looking at the responses into more detail, some of the participants list at least one consequence related to themselves (49.09%), other people (12.20%), animals (20.61%) and the environment (80.00%). A manipulation check indicated that the treatment had a small effect on ST, with TREAT participants reporting higher values of ST compared to those in CTRL ($M_{TREAT} = 4.41$, S.D. = 0.62 vs. $M_{CTRL} = 4.27$, S.D. = 0.56, $t(444) = 4.27$, $p < 0.05$, Cohen d = -0.24).

### 4.4. Measures

The participants completed several validated scales from the literature to measure purchase intentions (Ajzen, 1991); systems thinking (Davis & Stroink, 2015); altruism[4] (Stern et al., 1999; Groot & Steg, 2007); ecological worldview (NEP, Dunlap et al., 2000) and the NAM-variables (Groot & Steg, 2007; Ünal et al., 2018). Items employed a 6-point scale, from 1 = strongly disagree to 6 = strongly agree.[5] The results of the internal reliability analyses indicate that all measures show acceptable to good reliability: purchase intentions (α = 0.914), systems thinking (α = 0.736), altruism (α = 0.884), NEP (α = 0.853), problem awareness (α = 0.911), outcome efficacy (α = 0.882), personal norm (α = 0.925). Appendix D gives an overview of these measures by presenting the items.

### 4.5. Data analysis

To test the hypotheses, we fitted mediation models using the PROCESS 3.4 macro for SPSS developed by Hayes (2018). Mediation generally assumes that a predictor variable (X) affects a second variable (M) that, in turn, affects the outcome variable (Y), so that M mediates the relationship between X and Y. The regression-based procedure developed by Hayes (2018) allows us to estimate both the direct effects between X, M and Y and the indirect effect of X through M on Y. The indirect effect coefficient is represented by the product of the two path coefficients between X and M, and M and Y.

In this study, the first mediation model assessed whether the effect of TREAT (X) on PI (Y) is mediated by ST (M). The second model explored the extent to which the effect of ALT (X) on PI (Y) can be explained by ST (M). Third, we assessed if NEP (M) explained the impact of ST (X) on PI

[3] Based on Mayring (2014), text responses in TREAT were coded into four categories depending on whether respondents mention consequences for 1) themselves, 2) other people, 3) animals and 3) the environment. Moreover, the number of mentioned consequences were counted and depicted in an additional variable

[4] In line with Stern et al. (1999), we model social and biospheric value orientations jointly as altruistic values.

[5] The items to measure altruism are scaled from 1 = Not at all important to 6 = Extremely important

**Table 1**
Sample characteristics in percentages.

| Variable | TOTAL | CTRL | TREAT | Chi square Test Statistics |
|---|---|---|---|---|
| Area | | | | |
| Midwest | 26.01 | 25.54 | 26.79 | $X^2 = 0.26$, $p = 0.97$ |
| Northeast | 29.60 | 29.14 | 30.36 | |
| South | 32.06 | 32.73 | 30.95 | |
| West | 12.33 | 12.59 | 11.90 | |
| Gender | | | | |
| Female | 60.99 | 60.07 | 62.50 | $X^2 = 2.00$, $p = 0.37$ |
| Male | 38.79 | 39.93 | 36.91 | |
| Divers | 0.22 | 0.00 | 0.59 | |
| Age | | | | |
| 18 – 24 years | 14.57 | 15.47 | 13.10 | $X^2 = 1.51$, $p = 0.91$ |
| 25 – 34 years | 22.20 | 21.94 | 22.62 | |
| 35 – 44 years | 15.92 | 16.91 | 14.29 | |
| 45 – 54 years | 9.87 | 9.35 | 10.71 | |
| 55 – 65 years | 16.82 | 15.83 | 18.45 | |
| Over 65 years | 20.63 | 20.50 | 20.83 | |
| Education | | | | $X^2 = 0.20$, $p = 0.98$ |
| No School completed | 3.14 | 3.24 | 2.98 | |
| High School Diploma | 37.44 | 36.69 | 38.69 | |
| Practical Training | 25.78 | 25.90 | 25.59 | |
| University Degree | 33.64 | 34.17 | 32.74 | |
| Household yearly income | | | | $X^2 = 2.30$, $p = 0.51$ |
| Up to $ 29,999 | 33.41 | 35.97 | 29.17 | |
| $ 30,000 – 59,999 | 35.20 | 33.45 | 38.09 | |
| $ 60,000 – 89,999 | 18.61 | 18.35 | 19.05 | |
| Over $ 90,000 | 12.78 | 12.23 | 13.69 | |
| No. of Observations | 446 | 278 | 168 | |

(Y). Finally, the fourth model explored if the relationship between ST (X) and PI (Y) is mediated by PA, OE and PN (M). The significance of the indirect effect is tested by using the non-parametric bootstrapping technique which generates a distribution of 10.000 estimates. If the lower level (LLCI) and upper level (ULCI) of the 95 % confidence interval are above zero, the indirect effect is assumed to be positive to a degree which can be compared to statistical significance (Hayes, 2018).

The variable of consumer intentions to purchase bio-based products (PI) represents the outcome variable for all four estimated mediation models. Before testing the models, we analyzed the distribution of the outcome variable by using the Kolmogorov-Smirnov test which indicates that PI does not follow a normal distribution, $D(446) = 0.086$, $p < 0.00$. Therefore, we applied a log transformation in order to reduce positive skew (Field, 2013) and use the transformed PI variable in the mediation models.

As the level of PI might also be influenced by other variables not listed in the hypotheses, we also included some covariates. First, we control for the impact of the situation that some participants gathered additional information about bio-based products and others did not. This condition is depicted by a dichotomous dummy-variable which takes a value of 1 for respondents who gathered more information, and 0 otherwise. Second, the mediation models depicted in H2, H3 and H4 also controlled for the treatment effect using the dummy variable as described above.

In order to make sure that the predictors in the regression models are not strongly correlated with each other, we also tested for multicollinearity based on the variance inflation factor (VIF). According to Craney and Surles (2002), values higher than 5 indicate strong linear relationships between predictors. In this study, VIF values range between 1.103 and 2.529, suggesting the mediation models are not biased by multicollinearity. Moreover, Harman's One Factor Test was used to check for potential common method variance. Exploratory factor analysis was conducted with all study items, revealing that the eigenvalue of the first component accounted for less than 50% of variance (Podsakoff & Organ, 1986). Thus, participants' responses did not seem to be biased due to method-specific variance.

### 4.6. Sample characteristics

A more detailed look at the sample shows that the number of respondents in CTRL ($n = 278$) is higher than in TREAT ($n = 168$). The higher dropout rate here could relate to the length of the task in TREAT. In order to ensure that any differences in the treatment groups do not reflect composition effects, however, we conducted chi-square tests for each socio-demographic factor to see if the respective means differ. Table 1 reports the socio-demographic characteristics for both respondents in CTRL and TREAT, as well as results of the chi-square tests.

The gender distribution in both CTRL and TREAT indicates that more female than male respondents participated. As females are usually responsible for household purchases (Flagg et al., 2014), we do not consider the distribution to be problematic for this study. Moreover, our sample is slightly younger than the national average, notably lacking respondents between 45-54 years (Statista, 2018). In terms of educational attainment, our sample is nearly proportionate to the US as a whole with regard to those with a university degree (Statista, 2019b), though it is over-representative at lower levels of annual household income (Statista, 2019a). Finally, the results of the chi-square tests suggest that the null hypothesis of equality between treatment groups cannot be rejected at the 5% significance level. This implies that the demographic variables are similarly distributed in CTRL and TREAT.

In total, 36.55% of the participants voluntarily chose to read more information about bio-based products ($n = 163$). There is no significant difference between the number of participants using this opportunity in the CTRL, 39.57% and TREAT, 31.55% treatments ($X^2 = 2.91$, $p = 0.09$). Descriptive results for measured variables in both CTRL and TREAT are presented in Table 2. Various t-Tests indicate that the treatment only seems to activate participants' systems thinking.

**Table 2**
Variable means, standard deviations and confidence intervals.

| | | CTRL | TREAT | t-Test Statistics | Cohen's d |
|---|---|---|---|---|---|
| Purchase Intention | M (Std.) | 4.51 (1.09) | 4.68 (1.04) | $t(444) = -1.56$ | -0.15 |
| | CI | [4.37 – 4.64] | [4.53 – 4.84] | $p = 0.12$ | |
| Systems Thinking | M (Std.) | 4.27 (0.56) | 4.41 (0.62) | $t(324) = -2.38$ | - 0.24 |
| | CI | [4.20 – 4.33] | [4.31 – 4.50] | $p = 0.02$ | |
| Altruism | M (Std.) | 5.05 (0.81) | 5.08 (0.78) | $t(444) = -0.34$ | -0.03 |
| | CI | [4.96 – 5.15] | [4.96 – 5.20] | $p = 0.73$ | |
| NEP | M (Std.) | 4.62 (0.89) | 4.78 (0.91) | $t(444) = -1.75$ | -0.17 |
| | CI | [4.52 – 4.72] | [4.62 – 4.91] | $p = 0.08$ | |
| Problem Awareness | M (Std.) | 4.50 (1.28) | 4.72 (1.19) | $t(444) = -1.83$ | -0.18 |
| | CI | [4.34 – 4.64] | [4.53 – 4.90] | $p = 0.07$ | |
| Outcome Efficacy | M (Std.) | 4.28 (1.07) | 4.43 (1.00) | $t(444) = -1.51$ | -0.15 |
| | CI | [4.15 – 4.40] | [4.28 – 4.58] | $p = 0.13$ | |
| Personal Norm | M (Std.) | 4.12 (1.32) | 4.35 (1.24) | $t(444) = -1.79$ | -0.18 |
| | CI | [3.96 – 4.27] | [4.17 – 4.55] | $p = 0.07$ | |
| | N | 278 | 168 | | |

Variable scores range from 1 to 6, where 1 = strongly disagree, and 6 = strongly agree. Numbers in parentheses are Confidence Intervals (CI) using 1,000 bootstrapped means, ALT = Altruism, NEP = New Ecological Paradigm, OE = Outcome Efficacy, PA = Problem Awareness, PN = Personal Norm, ST = Systems Thinking, TREAT = Treatment, PI = Purchase Intention

## 5. Results

To investigate the set of hypotheses, we fitted four mediation models following the approach specified by Hayes (2018). The mediation effects are tested using the bootstrapping technique with 10,000 bootstrap samples. All estimated mediation models also included the covariates TREAT and INFO as described above. The results of the mediation models are presented in Fig. 3 and in Table 3. Details on the results for the covariates are presented in Appendix E.

First, we assessed if the effect of TREAT on PI is mediated by ST in order to establish the broad effectiveness of our novel treatment (H1). As already noted, the effect of TREAT was assessed using a dummy variable taking the value 1 for respondents in the treatment group, and 0 otherwise. Results show that TREAT has a significant effect on ST and, in turn, ST is positively associated with PI. Although the direct effect of TREAT on PI is not significant, the analysis indicated that there is a significant indirect effect of TREAT on PI, mediated through ST. Overall, the mediation model had significant explanatory power for PI, $R^2 = 0.16$, $F = 28.51$, $p < 0.00$.

Second, we explored the relationship between ALT, ST and PI to understand the specific role of altruism in this context (H2). Results indicated that ALT significantly predicted ST, which is, in turn, significantly related to PI. The direct effect of ALT on PI was also significant, thus revealing partial mediation. Moreover, TREAT served as a significant covariate for ST and INFO for PI. Most importantly, analysis of the indirect effect using bootstrapped confidence intervals confirmed that the relationship of ALT and PI is mediated by ST. This mediation model also had significant explanatory power for PI, $R^2 = 0.23$, $F = 32.06$, $p < 0.00$.

Third, we assessed the interrelationships between ST, NEP and PI in order to better understand the relevance of environmental concern (H3). According to the results, ST significantly predicted NEP, which, in turn, significantly predicted PI. ST was further revealed to have a significant direct effect on PI, thereby pointing to partial mediation of ST on PI through NEP. This finding is reinforced by the bootstrapped confidence intervals of the indirect effect. Overall, the mediation model also had significant explanatory power for PI, $R^2 = 0.22$, $F = 31.58$, $p < 0.00$.

Fourth, we explored the inter-relationships between ST, PA, OE, PN and PI using a serial mediation model, given the importance of these factors in the environmental psychology literature (H4). The results suggest that ST significantly predicted PA and OE, but not PN; PA significantly predicted OE, but not PI; OE significantly predicted PN and PI; and PN significantly predicted PI. With regard to the covariates, we found that INFO has a positive impact on PA and PI. Moreover, ST also had a significant direct effect on PI, and that the total indirect effect of ST on PI, in that order, through PA, OE and PN is significant. The whole model, again, has significant explanatory power for PI, $R^2 = 0.41$, $F = 50.39$, $p < 0.00$.

## 6. Discussion

The present research aimed to explore the relationship between systems thinking and consumer intentions to purchase bio-based products. Moreover, we investigated the accompanying roles of altruistic values, ecological worldviews, and personal norms in this context in order to situate our findings in relation to the wider literature on environmental psychology, and thereby better illustrate the potential importance of systems thinking. A summary of the hypotheses is presented in Table 4. Based on the findings of this study, we are able to make several theoretical and practical contributions which are presented in the following.

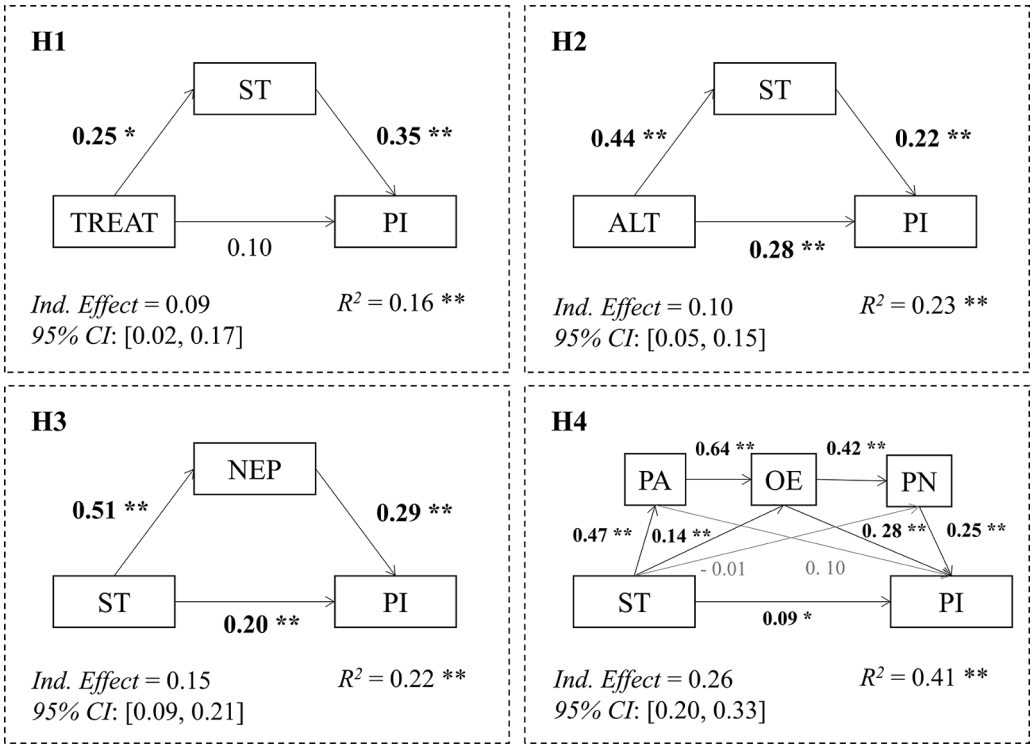


**Fig. 3.** Standardized regression coefficients for the mediation models.
Single and double asterisk (*, **) indicate statistical significance at the 5 % and 1 % level, respectively.

**Table 3**
Empirical results of the mediation models, with bootstrapped confidence intervals.

| Hypotheses | | Coeff. (SE) | St. Coeff. | t | p-value | Boot LLCI | Boot ULCI |
|---|---|---|---|---|---|---|---|
| H1 | TREAT → ST | 0.15 (0.06) | 0.25 | 2.55 | 0.01 | 0.03 | 0.26 |
| | ST → PI | 0.07 (0.01) | 0.35 | 7.93 | 0.00 | 0.06 | 0.09 |
| | TREAT → PI | 0.01 (0.01) | 0.10 | 1.07 | 0.29 | -0.01 | 0.03 |
| Ind. | TREAT → ST → PI | 0.01 (0.01) | 0.09 | - | - | 0.00 | 0.02 |
| H2 | ALT → ST | 0.33 (0.03) | 0.44 | 10.35 | 0.00 | 0.26 | 0.39 |
| | ST → PI | 0.05 (0.01) | 0.22 | 4.74 | 0.00 | 0.03 | 0.07 |
| | ALT → PI | 0.04 (0.01) | 0.28 | 6.00 | 0.00 | 0.03 | 0.06 |
| Ind. | ALT → ST → PI | 0.02 (0.03) | 0.10 | - | - | 0.01 | 0.02 |
| H3 | ST → NEP | 0.78 (0.06) | 0.51 | 12.50 | 0.00 | 0.66 | 0.90 |
| | NEP →PI | 0.04 (0.01) | 0.29 | 5.86 | 0.00 | 0.03 | 0.05 |
| | ST → PI | 0.04 (0.01) | 0.20 | 4.07 | 0.00 | 0.02 | 0.06 |
| Ind. | ST → NEP → PI | 0.03 (0.01) | 0.15 | - | - | 0.02 | 0.05 |
| H4 | ST → PA | 1.00 (0.09) | 0.47 | 11.34 | 0.00 | 0.83 | 1.17 |
| | ST → OE | 0.25 (0.07) | 0.14 | 3.78 | 0.00 | 0.12 | 0.38 |
| | ST → PN | -0.03 (0.08) | -0.01 | -0.38 | 0.71 | -0.19 | 0.13 |
| | PA → OE | 0.53 (0.03) | 0.64 | 16.74 | 0.00 | 0.47 | 0.59 |
| | PA → PI | 0.01 (0.01) | 0.10 | 1.72 | 0.09 | -0.00 | 0.02 |
| | OE → PN | 0.52 (0.06) | 0.42 | 9.24 | 0.00 | 0.41 | 0.63 |
| | OE → PI | 0.03 (0.01) | 0.28 | 4.81 | 0.00 | 0.02 | 0.05 |
| | PN→ PI | 0.02 (0.01) | 0.25 | 4.51 | 0.00 | 0.01 | 0.04 |
| | ST → PI | 0.02 (0.01) | 0.09 | 2.05 | 0.04 | 0.00 | 0.04 |
| Ind. | ST→PA→OE→PN→PI | 0.06 (0.01) | 0.26 | - | - | 0.04 | 0.07 |

St.Coeff. = Standardized Coefficients, SE = Standard Error, LLCI = Bootstrapped lower level of 95 % confidence interval; ULCI = Bootstrapped upper level of 95 % confidence interval, "Ind" refers to "indirect path", ALT = Altruism, NEP = New Ecological Paradigm, OE = Outcome Efficacy, PA = Problem Awareness, PN = Personal Norm, ST = Systems Thinking, TREAT = Treatment, PI = Purchase Intention.

**Table 4**
Summary of hypotheses testing.

| Hypotheses | | Result |
|---|---|---|
| H1 | The treatment will activate participants' systems thinking which is, in turn, associated with consumer intentions to buy bio-based products. | √ |
| H2 | The relationship between altruistic values and consumer intentions to buy bio-based products is mediated by systems thinking. | √ |
| H3 | The relationship between systems thinking and consumer intentions to buy bio-based products is mediated by an ecological worldview. | √ |
| H4 | The relationship between systems thinking and consumer intentions to buy bio-based products is mediated by problem awareness, outcome efficacy and personal norm, in that order. | √ |

### *6.1. Theoretical contributions*

The first contribution of this study is to provide empirical evidence of a positive relationship between systems thinking and purchase intentions of bio-based products. This finding is in line with prior research showing that systems thinking is associated with pro-environmental decision making and behavior (Davis & Stroink, 2015; Lezak & Thibodeau, 2016). Moreover, the results of this study indicate that use of a task in which consumers list the consequences of their own consumption behavior is able to slightly activate a systems-thinking perspective which, in turn, affects their purchase intentions (H1). This insight advances the understanding of how systems thinking can be employed, as current research has mainly focused on using linguistic or visual metaphors (e.g. Thibodeau et al., 2017). However, it is important to note that the treatment did not have any direct effect on consumer purchase intentions, and that the indirect effect of the treatment on purchase intentions, through ST, seems to be rather small. One reason for this finding could be that reflecting about the consequences of one's own behavior might only affect the choices of some individuals, i.e. rational decision-makers (Wensing et al., 2020). Future studies therefore need to assess the effect of the interplay between consumers' cognitive styles, e.g. rational vs. intuitive (Cacioppo et al., 1996), and ST on consumer pro-environmental choices.

Second, the results of this research demonstrated that the relationship between altruism and purchase intentions is mediated by systems thinking (H2). The reason for this effect might be that altruistic people base their decisions on consequences for other people and the biosphere (Steg, 2016), which potentially facilitates a more systemic worldview. This insight is relevant as it provides an explanation for prior findings about a positive association between altruism and pro-environmental behavior (e.g. Steg, 2016; Klein et al., 2019). In contrast to our results, Davis and Stroink (2015) found that biospheric values served as a mediator between systems thinking and pro-environmental behavior. However, it is important to note that Davis and Stroink (2015) modelled biospheric values as individual concerns about broad consequences for the environment. Nevertheless, we also tested the sequence suggested by Davis and Stroink (2015), which also fitted to our data (see Appendix F). Hence, future studies are required in order to explore the causal underpinnings of the relationship between altruism and systems thinking into more detail.

Third, this study found evidence that systems thinking is positively associated with an ecological worldview which, in turn, relates to consumer intentions to purchase bio-based products (H3). This result is in line with findings from Ballew et al. (2019). Consequently, systems thinking might encourage people to engage in pro-environmental behavior because a systemic worldview is associated with an ecological worldview (Davis & Stroink, 2015; Randle & Stroink, 2018). Ballew et al. (2019) even speculated about the causal mechanisms at work, hypothesizing that systems thinking might offer the basis for the development of a more ecological worldview. However, as the current study found there to be no significant effect of the ST-motivated treatment on participants' ecological worldviews (see Table 2), the contours of the causal relationship between ST and an ecological worldview remains unclear.

Fourth, findings of this study indicated that the relationship between systems thinking and intentions to buy bio-based products is mediated by consumers' problem awareness, outcome efficacy and personal norms (H4). More specifically, the serial mediation analysis revealed that systems thinking exerts a strong effect on consumers' problem awareness and outcome efficacy, while not directly influencing personal norms. Instead, systems thinking impacts personal norms only indirectly, through these other factors – a finding ultimately in line with the norm activation model (NAM) from Schwartz (1977). Accordingly, in addition to the direct effect of systems thinking on purchase intentions,

this analysis is also able to identify a complementary path whereby systems thinking, through its (positive) influence on the problem awareness and outcome efficacy of consumers, manages to (positively) influence personal norms. Given that not only personal norms but also outcome efficacy are found to be strongly related to consumer purchase intentions, this analysis suggests that (i) causal mechanisms of systems thinking are potentially more intricate than those directly relating to purchase intentions and (ii) only looking at direct effects runs the risk of understating the potential benefits of initiatives and treatments that target systems thinking. Moreover, these insights are relevant as they advance knowledge about how systems thinking intersects with the NAM model, in view of its wide use for predicting pro-environmental behavior (Schwartz, 1977; Harland et al., 2010; Ünal et al., 2018).

Finally, the overall significance of our study is that integration of systems thinking into existing models from environmental psychology literature can improve explanation of consumer intentions to buy bio-based products, and thereby enhance efforts to engage with consumers. Synthesizing our results, we conclude that the model depicted in H4 which combines systems thinking with the NAM performs best in explaining consumer intentions to purchase bio-based products. This model proposes that systems thinking positively influences consumers' problem awareness and outcome efficacy which, in turn, affect consumer personal norms and purchase intentions. Compared to the other mediation models depicted in H2 and H3, this model had the highest explanatory power for consumer purchase intentions. Moreover, statistical analysis indicated that expanding the model by including NEP could not further increase predicted variance or the strength of the indirect effect of ST on PI (see Appendix G). As such, we look forward to further explorations and emerging empirical evidence from the relevance of systems thinking, and its interaction with other models from environmental psychology, in a variety of other domains.

### 6.2. Limitations and implications for further research

The present research has five main limitations which, in turn, highlight avenues for further research. First, this study explored specific pathways through various mediation models, but most variables were not manipulated, so that we are not able to draw causal inferences based on the data. Thus, experimental designs have to be conducted which activate variables such as altruism by providing participants with different tasks or information (e.g. Steg & de Groot, 2010). Even though the causal effect of altruism on systems thinking can thereby be explored, this approach rather reflects aspects of 'linear thinking'. Future studies need to find ways to explore the value of systems thinking by using research methods in line with a systems thinking mindset such as mental modeling or complex computer simulations (e.g. Gonzalez et al., 2005; Jones et al., 2011).

Second, the sample of US consumers might be biased as more respondents dropped out of the treatment group than out of the control group. These drop-outs might have been systematic and, thus, confounded the results of this study. However, also in practice, the treatment can only be successful if the participants are willing to conduct the task. Therefore, those people who dropped out would probably also avoid this kind of reflection about the consequences of their behavior in real life. However, this assumption still requires empirical evidence. To tackle this issue, further studies should therefore employ control 'treatments' that demand similar time and cognitive effort to the main treatment. For example, participants could be asked to list things that are not related to the consequences of their behavior.

Third, the designed treatment related only to how the survey participants thought about the consequences of their purchasing decisions. However, a fully ST-informed perspective would reflect not only the awareness of consequences of one's own decisions but also, more precisely, would include more general cognitive beliefs about the complex and interconnected nature of reality such as the existence of climate tipping points (Randle & Stroink, 2018; Murphy, 2012; Lenton et al., 2019). Thus, future research needs to find more advanced strategies to activate a ST perspective, e.g. by using games that simulate complex interdependencies related to climate change (Wu & Lee, 2015).

Fourth, as the variables in this study relied on self-reported data, this might, for example, result in overestimation of the observed relationships between the variables. However, the conducted Harman's One Factor Test indicates that data did not seem to be biased due to common method variance. Next, we only measured participants' intentions to purchase bio-based products, which is assumed to be a good predictor of actual behavior, but the potential for bias still exists (e.g. Morrison, 1979). Moreover, self-reported measures potentially suffer from social desirability bias. Although Milfont (2009) only found a small effect of social desirability on self-reported environmental attitudes and behaviors, future studies need to tackle this issue. For example, systems thinking and pro-environmental beliefs could be measured using decision-making tasks (e.g. Thibodeau et al., 2016), implicit-association tests (e.g. Panzone et al., 2016), or neuropsychological measures (Fulmer & Frijters, 2009).

Fifth, the sample for this study consisted of US consumers, and as such it is not clear to what extent the results are generalizable to other countries (e.g. Grebitus et al., 2016). Indeed, given that prior studies have explored the impact of systems thinking in the context of US and Canada (Davis & Stroink, 2015; Ballew et al., 2019), similar studies need to be conducted in other parts of the world to validate and compare the findings. Moreover, the activating role of ST also needs to be explored in other consumption settings such as those involving a more health-oriented preventative lifestyle (Khedkar et al. 2017) as well as generally beyond consumption behavior. For example, future studies could explore the impact of involving a ST-motivated workshop on sustainability-oriented decision making of researchers, policymakers and industry representatives.

### 6.3. Managerial and policy contributions

The transition towards a bio-based economy strongly depends on, inter alia, the willingness of consumers to purchase novel bio-based products (Golembiewski et al., 2015). Hence, understanding the preconditions of consumer intentions to buy bio-based products can help policy-makers and marketers to develop appropriate strategies with a view toward increasing demand. In this vein, the present research makes three relevant practical contributions.

First, this study demonstrated that consumers generally intend to purchase bio-based products. This is in line with prior consumer studies in the bio-economy domain (Scherer et al., 2018a; Klein et al., 2019; Wensing et al., 2020). Although data about real consumer choices are still missing, these findings provide an indication for policymakers and companies planning to invest in the development of bio-based products.

Second, the results of this research provide empirical evidence that systems thinking is a cognitive paradigm playing a pivotal role in the transition towards a bio-based economy. Consequently, systems thinking could potentially be considered as a subject taught in schools and universities (Urmetzer et al., 2020), for instance in a role similar to that of civics education, in order to facilitate a broader cultural transition. Indeed, previous studies show that systems thinking is generally malleable to educational interventions, e.g. role-plays (Sterman et al., 2015) or the use of conceptual representations and diagrams (Hmelo-Silver et al., 2017; Cox et al., 2019).

Third, the success of the novel treatment in the present study illustrates that a systems-thinking mindset can even be activated by a subtle prime. For marketers of bio-based products, this reveals that drawing consumers' attention to the beneficial environmental consequences of bio-based products might strengthen their purchase intentions. In practice, this could be achieved by pro-environmental product labels or informative brochures (Schubert, 2017).

## 7. Summary

Systems thinking represents an important cognitive paradigm for the bio-economy transition, but research exploring the relationship between ST and consumer willingness to purchase bio-based products is still missing. Thus, the present study closes this gap by conducting a survey-based experiment with a novel ST-motivated treatment, in which participants are asked to list as many consequences of their consumption behavior as possible. Results of the study suggested that the treatment slightly activates a ST perspective, and that it can indirectly affect consumer intentions to buy bio-based products through ST. Subsequent mediation analyses further revealed that an ecological worldview as well as variables relating to the norm-activation model function as mediators of the relationship between ST and purchase intention. Thus, this study theoretically advanced the understanding of how ST and pro-environmental behavior relate to each other, and thus how ST relates more generally to findings in the environmental psychology literature. Moreover, from a practical perspective, our findings indicate that a broader adoption of bio-based products could be established if policy-makers, marketing managers, and educators were to focus more on ST, its wider and more intricate relationships with ecological world-views, altruism, and many other similar variables.

## Acknowledgements

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## Appendix A. Informative text in the survey

Bio-based products are products that are either wholly or partially derived from biomass. Biomass here refers to the residual materials from plants which are not otherwise used for food or feed.
Nowadays, textiles, plastic packaging, cleaning products or cosmetics are, among other products, predominantly produced by using chemicals which are based on fossil fuels (e.g. oil or gas). Thus, bio-based products provide a plant-based alternative to those conventional fossil derived products.
Some examples of bio-based products include: t-shirts made from coffee grounds, shoes from algae, toys from bioplastic, compostable shopping bags or plant-based paint, laundry detergents and body lotion.

## Appendix B. Voluntary additional information in the survey

The sustainability of bio-based products depends on multiple factors, such as source of biomass, design of production process, choice of disposal option, etc.
Using residual material as feedstock combined with sustainable production processes can lead to goods which are improved versions of traditional fossil-based alternatives or completely new items.
Thus, bio-based products can
- reduce the economy's dependence on fossil resources
- make a positive contribution to stop climate change
- reduce waste
- help create green jobs and
- help drive innovation.

If you want to get an idea of the wide variety of bio-based products already available, the product database from the US Department of Agriculture (USDA) can help you. The BioPreferred® Program promotes the purchase and use of bio-based products, which have a specified amount of bio-based content, including those making use of plant or animal resources. In its catalogue USDA designates the minimum content of bio-based materials used in products.
You can find the catalogue by clicking on the following link: USDA Catalogue.

## Appendix C. Treatment

In the following, we would like you to think about the consequences of your purchasing behavior. In doing so, please consider consequences for yourself, other people, plants and animals as well as for the environment as a whole.
Please list as many consequences as you can think of that result following your general purchasing behavior.

_____
_____

Please list as many consequences as you can think of that would result if you purchased bio-based products more frequently.

_____
_____

## Appendix D. Overview of measures of the questionnaire

| Measure | Item(s) |
|---|---|
| Purchase intention | 1. If I had to choose, I would buy bio-based instead of fossil-based products. |
| $\alpha = 0.914$ | 2. If I had access to both, I would prefer bio-based over fossil-based products. |
| | 3. I am willing to buy more bio-based products in the future. |
| | 4. In the future, I intend to buy bio-based products. |
| Systems thinking | 1. When I have to make a decision in my life I tend to see all kinds of possible consequences to each choice. |
| $\alpha = 0.736$ | 2. Social problems, environmental problems, and economic problems are all separate issues. (R) |
| | 3. I like to know how events or information fit into the big picture. |
| | 4. Only very large events can significantly change big systems like economies or ecosystems. (R) |
| | 5. All the Earth's systems, from the climate to the economy, are interconnected. |
| | 6. Everything is constantly changing. |
| | 7. Adding just one more, small farm upstream from a lake can permanently alter that lake. |
| | 8. When a boom or a crash happens in part of the world's economy, it is because someone intentionally planned or designed for it to run that way. (R) |
| | 9. Ultimately, we can break all problems down to what is simply right and wrong. (R) |
| | 10. The Earth, including all its inhabitants, is a living system. |
| | 11. Rules and laws should not change a lot over time. (R) |
| | 12. If I make plans and control my behavior I can accurately predict how my life will unfold. (R) |
| | 13. Seemingly small choices can ultimately have major consequences. |
| | 14. My health has nothing to do with what is happening in the world. (R) |
| | 15. It is possible for a community to organize into a new form that was not planned or designed by an authority or government. |
| Altruism | How important are the following values for you as a guiding principle in your life? |
| $\alpha = 0.884$ | 1. Social justice |
| | 2. Unity with nature |
| | 3. A world of peace |
| | 4. Helpfulness |
| | 5. Preventing pollution |
| | 6. Respecting the earth |
| | 7. Protecting the environment |
| New ecological paradigm | 1. We are approaching the limit of the number of people the Earth can support. |
| $\alpha = 0.853$ | 2. When humans interfere with nature it often produces disastrous consequences. |
| | 3. Humans are seriously abusing the environment. |
| | 4. Plants and animals have as much right as humans to exist. |
| | 5. Despite our special abilities, humans are still subject to the laws of nature. |
| | 6. The Earth is like a spaceship with very limited room and resources. |
| | 7. The balance of nature is very delicate and easily upset. |
| | 8. If things continue on their present course, we will soon experience a major ecological catastrophe. |
| Problem awareness | 1. I am concerned about CO2 emissions resulting from manufacturing fossil-based products. |
| $\alpha = 0.911$ | 2. The CO2 emissions resulting from manufacturing fossil-based products are a serious problem. |
| | 3. The economy's dependence on fossil feedstocks is a serious problem. |
| | 4. I am concerned about the economy's dependence on fossil feedstocks. |
| | 5. Climate Change resulting from the increase of CO2 emissions is a serious problem. |
| | 6. I am concerned about climate change resulting from the increase of CO2 emissions. |
| Outcome efficacy | 1. It is worthwhile to buy bio-based products to reduce CO2 emissions. |
| $\alpha = 0.882$ | 2. My personal purchasing decisions can contribute to the reduction of CO2 emissions. |
| | 3. My personal purchasing decisions can contribute to the reduction of CO2 emissions. |
| | 4. My personal purchasing decisions can reduce the economy's dependence on fossil feedstocks. |
| | 5. I think me buying bio-based products will not be effective to reduce the economy's dependence on fossil feedstocks. (R) |
| | 6. I think me buying bio-based products will not be effective to reduce CO2 emissions. (R) |
| Personal norm | 1. I feel a personal obligation to buy more bio-based products. |
| $\alpha = 0.925$ | 2. People like me should buy more bio-based products. |
| | 3. I feel a sense of personal obligation to take action to reduce the economy's dependence on fossil feedstocks. |
| | 4. People like me should do whatever we can to reduce CO2 emissions. |
| | 5. I feel guilty if I would not buy more bio-based products. |

(R) indicates a reverse coded item

## Appendix E. Results for the covariates in the mediation analyses

| Hypotheses | | Coeff (SE) | St.Coeff | t | p-value | LLCI - ULCI |
|---|---|---|---|---|---|---|
| H1 | INFO → ST | 0.09 (0.06) | 0.07 | 1.48 | 0.14 | -0.03 – 0.20 |
| | INFO → PI | 0.04 (0.01) | 0.17 | 3.89 | 0.00 | 0.02 – 0.07 |
| H2 | INFO → ST | 0.02 (0.05) | 0.02 | 0.35 | 0.73 | - 0.08 – 0.12 |
| | INFO → PI | 0.04 (0.01) | 0.14 | 3.40 | 0.00 | 0.02 – 0.06 |
| | TREAT → ST | 0.13 (0.05) | 0.11 | 2.56 | 0.01 | 0.03 – 0.23 |
| | TREAT → PI | 0.01 (0.01) | 0.06 | 1.29 | 0.20 | -0.01 – 0.04 |
| H3 | INFO → NEP | 0.14 (0.08) | 0.08 | 1.86 | 0.06 | -0.01 – 0.29 |
| | INFO → PI | 0.04 (0.01) | 0.15 | 3.50 | 0.00 | 0.02 – 0.06 |
| | TREAT → NEP | 0.06 (0.08) | 0.03 | 0.74 | 0.46 | -0.09 – 0.21 |
| | TREAT → PI | 0.01 (0.01) | 0.04 | 0.90 | 0.37 | -0.01 – 0.03 |
| H4 | INFO → PA | 0.34 (0.12) | 0.13 | 3.20 | 0.00 | 0.13 – 0.55 |
| | INFO → OE | 0.06 (0.07) | 0.03 | 0.86 | 0.39 | -0.02 – 0.21 |
| | INFO → PN | 0.09 (0.09) | 0.03 | 1.04 | 0.30 | -0.08 – 0.26 |
| | INFO → PI | 0.02 (0.01) | 0.09 | 2.46 | 0.01 | 0.01 – 0.04 |
| | TREAT → PA | 0.11 (0.11) | 0.04 | 1.04 | 0.30 | -0.10 – 0.32 |
| | TREAT → OE | 0.01 (0.07) | 0.00 | 0.06 | 0.95 | -0.14 – 0.15 |
| | TREAT → PN | 0.07 (0.09) | 0.03 | 0.79 | 0.43 | -0.10 – 0.23 |
| | TREAT → PI | 0.01 (0.01) | 0.02 | 0.56 | 0.58 | -0.01 – 0.02 |

Note: St.Coeff. = Standardized Coefficients, SE = Standard Error, LLCI = Bootstrapped lower level of 95 % confidence interval; ULCI = Bootstrapped upper level of 95 % confidence interval, "Ind" refers to "indirect path", ALT = Altruism, NEP = New Ecological Paradigm, OE = Outcome Efficacy, PA = Problem Awareness, PN = Personal Norm, ST = Systems Thinking, TREAT = Treatment, PI = Purchase Intention

## Appendix F. Test of alternative mediation sequence

| Relationships | Coeff. (SE) | St. Coeff. | t | p-value | Boot LLCI | Boot ULCI |
|---|---|---|---|---|---|---|
| ST → ALT | 0.60 (0.06) | 0.44 | 10.35 | 0.00 | 0.49 | 0.71 |
| ALT → PI | 0.04 (0.01) | 0.28 | 6.00 | 0.00 | 0.03 | 0.06 |
| ST → PI | 0.05 (0.01) | 0.22 | 4.74 | 0.00 | 0.03 | 0.07 |
| INFO → ALT | 0.15 (0.07) | 0.09 | 2.19 | 0.03 | 0.02 | 0.29 |
| INFO → PI | 0.04 (0.01) | 0.14 | 3.40 | 0.00 | 0.02 | 0.06 |
| TREAT → ALT | -0.04 (0.07) | -0.03 | -0.63 | 0.53 | -0.18 | 0.09 |
| TREAT → PI | 0.01 (0.01) | 0.06 | 1.29 | 0.20 | -0.01 | 0.04 |
| ST → ALT → PI (ind.) | 0.03 (0.01) | 0.13 | - | - | 0.02 | 0.04 |
| $R^2 = 0.23$, $F = 32.06$, $p < 0.00$ | | | | | | |

Note: St.Coeff. = Standardized Coefficients, SE = Standard Error, LLCI = Bootstrapped lower level of 95 % confidence interval; ULCI = Bootstrapped upper level of 95 % confidence interval, "Ind" refers to "indirect path", ALT = Altruism, NEP = New Ecological Paradigm, OE = Outcome Efficacy, PA = Problem Awareness, PN = Personal Norm, ST = Systems Thinking, TREAT = Treatment, PI = Purchase Intention

## Appendix G. Results of additional mediation analysis.

| Hypotheses | Coeff. (SE) | St. Coeff. | t | p-value | Boot LLCI | Boot ULCI |
|---|---|---|---|---|---|---|
| ST → NEP | 0.78 (0.06) | 0.51 | 12.50 | 0.00 | 0.66 | 0.90 |
| ST → PA | 0.25 (0.08) | 0.12 | 3.36 | 0.00 | 0.11 | 0.40 |
| ST → OE | 0.23 (0.07) | 0.13 | 3.34 | 0.00 | 0.10 | 0.37 |
| ST → PN | -0.01 (0.08) | -0.00 | -0.11 | 0.91 | -0.17 | 0.15 |
| NEP → PA | 0.96 (0.05) | 0.69 | 19.29 | 0.00 | 0.86 | 1.05 |
| NEP → OE | 0.07 (0.06) | 0.06 | 1.16 | 0.24 | -0.05 | 0.19 |
| NEP → PN | -0.07 (0.07) | -0.05 | -1.01 | 0.31 | -0.22 | 0.69 |
| NEP → PI | -0.01 (0.01) | -0.04 | -0.70 | 0.49 | -0.02 | 0.01 |
| PA → OE | 0.50 (0.04) | 0.60 | 11.55 | 0.00 | 0.41 | 0.59 |
| PA → PN | 0.44 (0.06) | 0.42 | 7.53 | 0.00 | 0.32 | 0.55 |
| PA → PI | 0.01 (0.01) | 0.13 | 1.82 | 0.07 | -0.00 | 0.03 |
| OE → PN | 0.52 (0.06) | 0.42 | 9.28 | 0.00 | 0.41 | 0.64 |
| OE → PI | 0.03 (0.01) | 0.28 | 4.85 | 0.00 | 0.02 | 0.05 |
| PN → PI | 0.02 (0.01) | 0.25 | 4.46 | 0.00 | 0.01 | 0.04 |
| ST → PI | 0.02 (0.01) | 0.10 | 2.16 | 0.03 | 0.00 | 0.04 |
| ST→NEP→PA→OE→PN→PI (ind.) | 0.05 (0.01) | 0.26 | - | - | 0.04 | 0.07 |
| $R^2 = 0.41$, $F = 43.21$, $p < 0.00$ | | | | | | |

Note: St.Coeff. = Standardized Coefficients, SE = Standard Error, LLCI = Bootstrapped lower level of 95 % confidence interval; ULCI = Bootstrapped upper level of 95 % confidence interval, "Ind" refers to "indirect path", ALT = Altruism, NEP = New Ecological Paradigm, OE = Outcome Efficacy, PA = Problem Awareness, PN = Personal Norm, ST = Systems Thinking, TREAT = Treatment, PI = Purchase Intention

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