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When transparent communication backfires: The role of ambiguous environmental impacts, techno-optimism and ambivalence on attitudes towards greenhouse horticulture

Hilbert de Groot

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Department of Psychology
University of Groningen
Examiner/Daily supervisor:
Žan Mlakar

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When transparent communication backfires: the role of ambiguous environmental impacts, techno-optimism beliefs and ambivalence on attitudes towards greenhouse horticulture

Abstract

To sustainably feed a growing population in a changing climate, both agro-ecological and technological innovations are needed. While agro-ecological methods are generally well-received, public support for more technological solutions, such as greenhouse horticulture (GH), is less certain. To improve public support in the Netherlands, the GH-sector is considering a transparent communication campaign, which will likely include communicating its mixed environmental impact. However, such ambiguous information may evoke ambivalence in the public, an uncomfortable feeling which might lower support for GH. Importantly, this effect may vary across individuals. Here, I propose that the belief that technological advances can address sustainability issues (techno-optimism) changes people's reaction to ambiguous information. Specifically, I expect people with strong (and weak) techno-optimism beliefs might fall back on their pre-existing attitudes in the face of ambivalence, and thus express higher (and lower) support for GH. In a between-subjects experiment with a representative Dutch sample, techno-optimism indeed moderated the relationship between felt ambivalence and attitudes: the negative effects of ambivalence on attitudes towards GH were buffered for high techno-optimism, and amplified for low techno-optimism. As ambivalence increased, techno-optimists thus remained supportive, while skeptics became increasingly more opposed, leading to attitudinal polarization.While providing information did not increase felt ambivalence directly, it did so via potential ambivalence. The main findings of this study suggest that transparent but ambiguous communication may polarize rather than persuade.

Keywords: ambivalence, techno-optimism, attitude polarization, ambiguous communication, greenhouse horticulture

Introduction

The FAO estimates that a 70% increase in agricultural production will be required by 2050 to fulfill rising needs and changing diets (Searchinger et al., 2019; Wise, 2013). The most straightforward way to increase production would be to simply cultivate more land. However, conventional agriculture exerts a lot of pressure on the environment, for example through soil erosion and pollution (Sabiha et al., 2016). This limits possibilities for further expansion near, for example, urban centres and nature areas (Hossain et al., 2020). Moreover, human-induced climate change will have extensive consequences on agricultural productivity in the near future, potentially reducing crop yields up to 10% per degree Celsius of local warming (Campbell et al., 2016). To fulfill increasing demand for food, there is thus a need for productive, climate resilient, and sustainable agriculture.

In the scientific literature, agro-ecological approaches have often been proposed as the future of sustainable agriculture (e.g., Ewert et al., 2023; Nicholls et al., 2020). In agro-ecology, ecological and social principles (such as species interactions and human communities) are applied to food systems (Francis et al., 2003). Through different management practices, like crop rotation and mimicking natural systems, agro-ecology can help farmers to work in harmony with natural systems, thereby reducing the negative environmental (and sometimes social) impacts of agriculture (Altieri et al., 2017; Francis et al., 2003; Kumaraswamy, 2012). It has been suggested agro-ecology can thus help radically reform agricultural systems (Altieri et al., 2017).

However, agro-ecological farms tend to have lower output compared to conventional farms, and will thus likely require additional land to feed the growing world population (Reganold & Wachter, 2016; Seufert et al., 2012). Moreover, it is still unclear if agro-ecological approaches are effective and resilient in various (rapidly changing) climatological conditions (Azarbad, 2022; Diacono et al., 2017; Khangura et al., 2023). So, while more sustainable, agro-ecological approaches are not as space-efficient as conventional agriculture, and may not always be climate resilient.

Technological solutions may be the key in helping overcome the challenges agro-ecology faces (Khan et al., 2021). One such potentially interesting technology is greenhouse horticulture (GH). GH is a technologically advanced and highly productive form of agriculture, where crops are cultivated in a protected and carefully regulated (e.g., heating or lighting) indoor greenhouse environment. As a result, GH has several benefits over conventional agriculture. First, due to the stable indoor climate, GH is highly productive as crops can be grown year-round. For example, Dutch greenhouses are responsible for 40% of all agricultural production on only 0.5% of agricultural land (Heuvelink et al., 2008). Second, greenhouse climate regulation also allows greenhouses to operate in otherwise barren environments (Goddek et al., 2023). Third, the use of advanced technology and innovation allows for considerable efficiency gains in resource use (such as water and fertilizers) (Koukounaras, 2021). For example, processed waste-water can be integrated into the cultivation process, promoting nutrient recycling and sustainability of food production (Riera-Vila et al., 2019).

However, GH is very energy-intensive and still uses a lot of natural gas to heat greenhouses to grow crops year-round. In fact, the GH-sector was responsible for 10% of all natural gas use in the Netherlands in

2021 (Centraal Bureau voor de Statistiek, 2022, 2023). Conventional agriculture only uses a fraction of that energy (Wageningen University, 2024). Moreover, supplemental lighting used in greenhouses is responsible for considerable nocturnal light pollution, which disturbs wildlife and even human health in the surrounding area (Betteridge, 2023). Greenhouses can thus efficiently and reliably grow large quantities of food regardless of climatological conditions, but have a mixed environmental impact.

In practice, natural, environmentally friendly and sustainable agro-ecology and artificial, reliable, efficient GH complement each-other's strengths and weaknesses, and can therefore both play an important role in the future of sustainable agriculture (Reganold & Wachter, 2016). Public acceptance of these approaches, however, differs. While agro-ecological approaches, like organic farming, are generally already accepted by the public (Rosset & Martínez-Torres, 2012; Roy et al., 2022), GH is perceived as more controversial (Breukers et al., 2008; Rogge et al., 2011). This public acceptance, especially with regards to sustainability, is important for GH to gain a license to operate in society (Ares et al., 2021; Gan et al., 2023; Jürkenbeck et al., 2019). Without public support, the GH sector may face various political challenges (fewer subsidies, unfavorable legislation, etc), and consumer behaviour will likely be negatively impacted as well (Polzin et al., 2023; Rasmussen et al., 2018). As of now, it remains unclear whether GH is sufficiently supported for its long-term success and existence (Blankestijn, 2024; Floral Daily, 2024).

A common approach to improve public opinion is to use communication campaigns (Mina et al., 2023), with the underlying assumption that providing people with more information will lead to a better understanding and acceptance of GH (Schulz, 2002). As sustainability is an important prerequisite for public support (Gan et al., 2023), such a communication campaign will also need to address GH's mixed environmental impact (Glastuinbouw Nederland, 2023, 2025). By discussing both the negative and positive environmental impact, such a communication strategy would be relatively transparent. However, it is unclear how effective such a transparent communication strategy would actually be in practice. Since the environmental impact of GH is conflicting, for many it may be confusing whether the environmental advantages outweigh the costs (or vice versa). For example, how do the low fertilizer and water requirements of GH weigh against its high energy use? And how do high productivity and efficient use of arable land compare to the considerable light pollution caused by GH?

As opposed to more simple one-sided messages (Fischer et al., 2013; Gollust et al., 2009), the literature does not yet provide a clear picture on the potential effects of transparent communication. On the one hand, transparent and honest communication may build trust between consumers and corporations (Kang & Hustvedt, 2014). On the other hand, ambiguous messages may make both risks and benefits salient simultaneously, which has been shown to induce confusion and ambivalence (Fischer et al., 2013; Van Gent et al., 2024). In an attempt to resolve the uncomfortable feelings associated with ambivalence, previous research has shown that some people may commit more strongly to one side of the issue (i.e. becoming more supportive or opposed), thereby increasing attitudinal polarization (Fischer et al., 2013; Lord et al., 1979). However, not everyone reacts this way. People vary in how they experience and resolve ambivalence (Fischer et al., 2013; Simons et al., 2018), and attitudinal polarization is not consistently found in the literature (Fischer et al., 2013; Kuhn & Lao, 1996). While it is clear that individuals react differently to ambiguous information, the psychological mechanisms that explain why some individuals adopt one position over another remain poorly understood.

In the case of GH, I propose that prior beliefs about the role of technology in addressing sustainability challenges (so-called techno-optimism) determine the direction in which ambivalence is resolved, such that individuals align their final evaluation of GH with their initial techno-optimism beliefs. In some cases, this may lead to a backfire effect, where individuals who are already skeptical of technological solutions (like GH) become even more opposed after viewing conflicting information. In other cases, this may lead those who hold positive attitudes towards GH to become even more fervent supporters of GH. This way, transparent communication strategies on the environmental impact of GH may thus polarize rather than persuade. This study examines whether information exposure to the mixed environmental impact of GH indeed leads to attitude polarization, driven by ambivalence resolution that aligns with prior techno-optimism beliefs.

This work provides two important contributions. First, from a practical standpoint, it helps experts from the GH-sector to understand the potential impact and feasibility of a transparent communication strategy. Second, from a theoretical perspective, this work provides insights on how ambivalence that arises from conflicting communication may be resolved, depending on domain-relevant underlying pre-existing beliefs people hold (Kuhn & Lao, 1996; Simons et al., 2018). Generally, the findings may have significant implications for communication aimed at increasing public acceptance of technologies with mixed environmental impacts, including GH, but also, for example, nuclear energy and genetic modification.

Theoretical Background

The role of information and knowledge on acceptance

As previously mentioned, sustainability is important for GH to gain a license to operate in society (Gan et al., 2023). In general, there exist a lot of misconceptions about environmental issues and sustainability (Ricart et al., 2019; Robelia & Murphy, 2012). This may also be the case for the Dutch GH-sector: while the Dutch are often considered frontrunners in sustainability of GH (Glastuinbouw Nederland, 2023; Kempkes et al., 2025), the sector is regularly the target of public scrutiny (e.g., Floral Daily, 2024). It is sometimes thought that providing people with more information can help them overcome misconceptions, skepticism, and negative attitudes, an idea known as the information-deficit model (Quattrin et al., 2015; Schulz, 2002).

However, reality is not so straightforward, as information is often interpreted through the lens of individuals' worldviews (Kim & Kim, 2019), shaped by cognitive biases (Clark et al., 2008), or leads to confusion, especially when the information presented is conflicting (Van Gent et al., 2024). Moreover, perceptions of risk and benefits also play an important role for acceptability of technologies with conflicting impacts (de Groot et al., 2013; Mina et al., 2023). Communication on the environmental impact of GH would make the conflict between risks and benefits salient, likely leading to feelings of confusion and ambivalence. Theory would predict that the feelings of negative affect that are associated with ambivalence lead to lowered attitudes towards GH (Van Gent et al., 2024).

Hypothesis 1: Exposure to conflicting information about the environmental impact of GH has a total negative effect on attitudes towards GH.

Felt ambivalence

Ambivalence exists when people hold both positive and negative opinions towards an attitude object (Buttlar et al., 2025; Van Gent et al., 2024). In this way, ambivalence is closely related to cognitive dissonance, though ambivalence occurs only before decision making, while cognitive dissonance assumes post-decisional conflict (Buttlar et al., 2025). Two forms of ambivalence can be distinguished. First is potential (or objective ambivalence), where a person holds both positive and negative evaluations towards an attitude object (Priester & Petty, 1996; Thompson et al., 1995). If that person becomes aware of this conflict (for example through introspection when self-reporting attitudes) potential ambivalence turns into felt (or subjective) ambivalence (Priester & Petty, 1996; Van Gent et al., 2024).

Intensity of felt ambivalence increases as the amount and availability of inconsistent viewpoints increase (Buttlar et al., 2025; Newby-Clark et al., 2002; Priester & Petty, 1996). For example, people felt more ambivalent about controversial topics like the death penalty when opposing viewpoints could be easily recalled and in equal numbers (Newby-Clark et al., 2002). This would likely also be the case when receiving clear, transparent and thus conflicting information on the environmental impact of GH. Moreover, felt ambivalence is especially strong when inconsistent evaluations are considered as important and relevant (Buttlar et al., 2025; Thompson et al., 1995). This will again likely be the case for GH in the

Netherlands, as the sustainability of Dutch agriculture is seen as an important societal issue (Eldik & Dam, 2024). Taken together, I expect that being exposed to both positive and negative environmental impact of GH increases the number of easily available and relevant viewpoints, thereby increasing felt ambivalence.

Hypothesis 2: Exposure to conflicting statements about the environmental impact of greenhouse horticulture leads to higher levels of felt ambivalence.

Effects of felt ambivalence

Receiving transparent information on the conflicting environmental impact of GH highlights both positive and negative aspects of GH. However, as discussed already, it will likely be difficult to evaluate this complicated environmental impact. For example, how can a non-expert assess how conflicting differences in resource use, pollution, and efficiency impact overall sustainability of GH? This way, information may cause feelings of confusion and ambivalence (McGregor et al., 2001). Because humans prefer to be consistent, these feelings of ambivalence and conflict are experienced as uncomfortable (Festinger, 1957). Even after committing to a certain standpoint, cognitive dissonance may arise when some doubt still remains, leading to even more negative affect (Buttlar et al., 2025). The entire process of resolving ambivalence is thus generally quite unpleasant. These negative feelings can transfer to the way individuals (often subconsciously) make decisions and form judgements (Slovic et al., 2007); GH may become associated with a negative emotional state, lowering support for GH.

Hypothesis 3: Higher levels of felt ambivalence lead to more negative attitudes towards GH.

Prior beliefs, techno-optimism and attitudes

While I expect that felt ambivalence generally reduces support for GH, its impact likely varies across individuals. As previously mentioned, people will want to form attitudes that are consistent (Festinger, 1957). It is therefore reasonable to expect that feelings of ambivalence will be resolved in favor of the perspective that aligns with one's pre-existing beliefs. Indeed, previous research on the acceptability of nuclear energy has demonstrated that people appear to form an overall evaluation on a technology based on prior beliefs first, after which they adapt their reasoning to be congruent with their initial evaluation (Alhakami & Slovic, 1994; de Groot et al., 2013). Since GH distinguishes itself from agro-ecological approaches in its technology use (e.g., Kempkes et al., 2025), attitudes toward technology as a means to address sustainability challenges may be a relevant prior belief that shapes how individuals interpret and resolve conflicting information about GH.

These attitudes toward technology are often referred to as techno-optimism. While the concept lacks a universally agreed-upon definition and remains the subject of philosophical debate, several interpretations exist. For example, some define techno-optimism as the belief that introducing new technologies is preferable to maintaining the status quo (Königs, 2022), or as the view that technology makes the world a good place (Danaher, 2022). Others suggest that techno-optimists are those with a highly positive attitude towards technology, believing that all social and environmental challenges can be solved with technology (Barry, 2016).

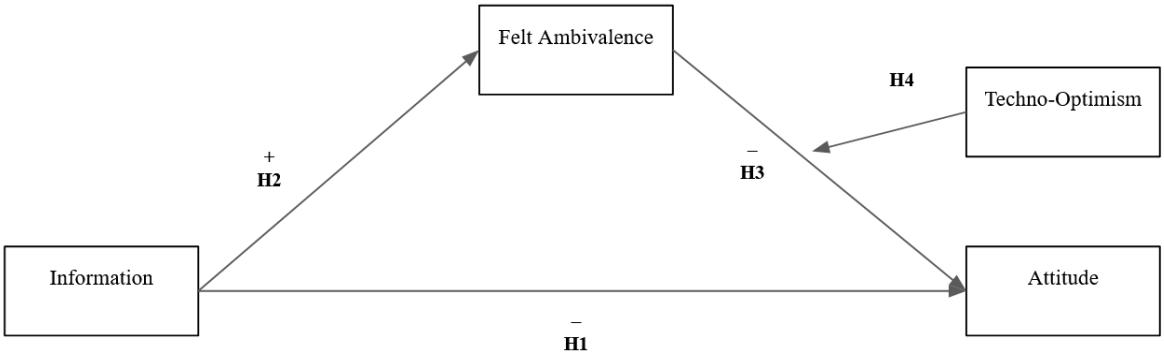
For the purposes of this study, I adopt the latter, more applied definition. This definition aligns more closely with everyday, general impressions of technology and sustainability, rather than abstract philosophical reasoning. This definition has also been used in previous environmental-psychological work (e.g., Gardezi & Arbuckle, 2020). I thus define techno-optimism as "an exaggerated and unwarranted belief in human technological abilities to solve problems of unsustainability while minimising or denying the need for large-scale social, economic and political transformation" (Barry, 2016, p. 3). In other words, techno-optimists trust science and innovation to solve any social or environmental issues humanity may come across. This concept is sometimes also known as techno-fix attitudes in the literature (Cologna et al., 2024).

Techno-optimism likely serves as a key prior belief that shapes individuals' initial attitudes toward GH, which subsequently influences the direction in which feelings of ambivalence are resolved. A boundless trust in technology likely affects many socio-psychological factors that determine public acceptance of technology, such as perceived risks and benefits (Gupta et al., 2012). For instance, a techno-optimist may focus on the sustainability benefits of highly-technological GH and feel enthusiastic about its potential, while downplaying possible environmental risks. In contrast, someone more skeptical of technology as a solution for sustainability is more likely to emphasize GH's environmental downsides and advocate for alternatives like agro-ecology. Thus, ambivalent techno-optimists become more convinced of GH's benefits, while ambivalent skeptics become more opposed to GH. This way, higher levels of felt ambivalence may amplify attitudinal polarization as individuals fall back more heavily on their pre-existing techno-optimism beliefs.

Hypothesis 4: Techno-optimism beliefs will moderate the relationship between felt ambivalence and attitudes towards GH, such that individuals will strengthen their attitudes towards GH in the direction that aligns with prior techno-optimist beliefs, increasing polarization.

Combined, the hypotheses lead to the following conceptual moderated meditation mediation model (Figure 1), where transparent information provision on the environmental impact of GH increases felt ambivalence, which in turn lowers attitudes. The negative impact strength of felt ambivalence is determined by individuals' pre-existing domain-relevant techno-optimism beliefs: those with high techno-optimism beliefs will shift their attitudes to become relatively more favorable of GH, while those with low techno-optimism beliefs will shift their attitudes such that they will become relatively more opposed to GH.

Figure 1: The hypothesized relationships between the ambiguous information on the environmental impact of GH, felt ambivalence, attitudes towards GH, and techno-optimism.



Note: H = Hypothesis; + = expected positive relationship; - = expected negative relationship

Method

Design

The preregistration of this study is available on the Open Science Framework (https://osf.io/t9w62). While the way some variables are interpreted has been adjusted since the preregistration, the study still tests the same underlying ideas and relationships. To test the hypotheses in the conceptual model (Figure 1), I used a between-subjects experimental design.

Participants were randomly but equally assigned to either the control or information treatment group. All participants viewed a brief explanation about the difference between conventional agriculture and GH, stressing that in conventional agriculture crops are grown outside, while with GH crops are grown in greenhouse environments with the help of technology (Appendix 1).

In addition, participants in the information treatment condition were shown six conflicting facts about the environmental impact of GH in random order (see Appendix 1). Three of the facts were positive (e.g., *by using technology, greenhouses generally require less water, fertilizer and pesticides to grow crops compared to outdoor farms.*), and the other three facts were negative (e.g., *greenhouses require lighting and heating, and thus require more energy and natural gas compared to outdoor farms.*). These statements were chosen in consultation with experts from GH-sector, and validated using (gray) literature. Participants could not proceed to the next page for 30 seconds, helping ensure that the participants took the time to read the statements. The control group did not receive this extra information.

Afterwards, participants self-reported their attitudes towards GH, their feelings of ambivalence regarding the environmental impact of GH, and their techno-optimism beliefs. Questions on techno-optimism and ambivalence had multiple items (see below), which were presented in a random order. To ensure the quality of the data, the questions also included an attention check (i.e., "Please fill in 'Strongly disagree' here."). The questionnaire concluded with a manipulation check to verify that respondents read and understood the statements shown in the treatment condition (i.e., "Greenhouse horticulture has a lot of positive and negative impacts on the environment.").

The manipulation check confirmed that the experimental treatment (i.e., exposure to the six conflicting statements) effectively increased participant's perceptions that there were many environmental advantages and disadvantages of using GH. An independent samples *t*-test revealed a significant difference in manipulation check scores between the experimental and control groups, $t(600) = 3.75$, $p < .001$, $d = 0.31$. Participants in the treatment group (M = 4.85, SD = 1.11) reported significantly higher perceptions of conflicting environmental impact of GH than those in the control group (M = 4.52, SD = 1.06).

Measures

Attitudes towards greenhouse horticulture

Respondents rated their attitude towards use of GH in the Netherlands on a 7-point Likert scale ranging from 1 (*strongly disagree)* to 7 *(strongly agree)*. As I was mostly interested in the process behind attitude *change*, and not attitudes themselves, I opted to only use a single item to measure participant's attitudes: "I support the use of greenhouse horticulture in the Netherlands". This item was adapted from a study by De Groot et al. (2013) on acceptability of nuclear energy in the Netherlands (which, like GH, is perceived as controversial). Overall, respondents in the final sample were somewhat supportive of the use of GH in the Netherlands (M = 5.19; SD = 1.21).

Techno-optimism

The respondents' level of techno-optimism was assessed using part of the newly developed general attitudes towards technology (GATT) scale (Cologna et al., 2024). This validated scale measures, among other things, techno-optimism (called techno-fix attitudes in the GATT scale). The scale includes five items (i.e. "Technological innovations will allow us to carry on with our current lifestyles without any limitations"; Appendix 3). Respondents rated their techno-optimism attitudes on a 7-point Likert scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

On average, participants in the final sample were neutral in their mean techno-optimist attitudes (M = 3.78; SD = 1.20). The quality of the measurements of techno-optimism was high. For techno-optimism, a principal component analysis (PCA) revealed a one-factor solution, with all items loading fairly equally (0.41-0.47) and explaining 63.1% of variance. A reliability analysis supported the unidimensional scale of the five techno-optimism items ($\alpha = 0.85$).

Felt ambivalence

Felt ambivalence was measured using a selection of items from the felt uncertainty scale (McGregor et al., 2001). This 19-item scale is based on various other scales measuring ambivalence, uncertainty, and contradictory self-guides. I picked four items that most accurately described feelings of confusion and ambivalence, and adapted them to the topic of GH: "I feel [*torn / conflicted / confused / uneasy*] about the environmental impact of greenhouse horticulture". Respondents again rated their felt ambivalence on a 7-point Likert scale ranging from 1 (*strongly disagree)* to 7 (*strongly agree)*.

On average, participants in the final sample were neutral in their mean felt ambivalence (M = 3.72; SD = 1.29). A PCA revealed that the items had a one-factor solution, with all four items loading fairly equally (0.47-0.52) and explaining 75.5% of variance. This was supported by a reliability analysis ($\alpha = 0.89$).

Procedure and participants

During the end of March and early April 2025, an online questionnaire was published. The questionnaire was constructed in Qualtrics (Provo, UT). Participants were recruited through an online panel provider using quota sampling to approximate the distribution of age, sex, education level, and urban density of the Dutch adult population. A full overview of quota targets and number of completed responses can be found in Table 1. Respondents were financially compensated for their cooperation. On the basis of a checklist developed by the EC-BSS at the University of Groningen, the study was exempt from full ethics and privacy review.

Beforehand, participants were informed about their rights and the general nature and potential risks of the study, and then asked for their active informed consent to participate and process their demographic data. If participants consented, they were asked for their age group, gender, highest attained level of education (low, middle, high), and urban density in place of residence (rural or urban). These were used to fill representative quotas (Table 1). After being assigned to either the control or information treatment and viewing the corresponding text, participants self-reported their attitudes towards GH, felt ambivalence, and techno-optimism. Participants were then debriefed and given the chance to leave remarks.

In total, I collected 1468 questionnaire responses. 702 respondents were screened-out because they either (1) did not consent to participate or have their data processed (n = 146), (2) were underage (n = 13), (3) refused to provide demographic information (n = 11), (4) did not fully complete the questionnaire (n = 98), and/or (5) because one of the quotas they fell in already being filled (n = 435). An additional 164 respondents failed the attention check, and were excluded from the analysis. Note that a statistical analysis revealed that there existed significant differences in dropout and attentiveness for the control and information treatment group (Appendix 2). A total of 602 (41% of total) participants with valid responses made up the final sample (Table 1).

The distribution of women and men of the final sample was fairly equal, with 307 (51%) women (Table 1). Mean age could not be accurately calculated as age data was grouped, but followed the age distribution of the general Dutch population (Table 1). The distribution of highest attained education levels was mixed: 17.6% completed only low-level education, 37.2% completed a middle-level education, and 45.2% completed higher education (Table 1). Participants in the final sample lived mostly in cities, with 32.7% living in rural areas, and 67.3% in urban areas (Table 1).

Quotas were determined using data from European and Dutch statistics institutions. Data for the distribution of age and gender for the Dutch population was retrieved from the “Population on January 1 by age group and sex” Eurostat dataset for 2024 (Eurostat, 2025b). I aggregated the available age-groups by sex into 10-year blocks. As the dataset only included biological sex, participants who were non-binary or identified as a different gender were randomly assigned as either male or female. I obtained data on education level for the Dutch adult population (age 25-64) for 2023 from the “Population by educational attainment level, sex and age (%)” Eurostat dataset (Eurostat, 2025a). Data on urban density was obtained from the Dutch Central Bureau for Statistics, where individuals living in areas with fewer than 1000 addresses/km2 are considered rural (Centraal Bureau voor de Statistiek, 2025).

Sample size and power calculation

To determine the required sample size, I performed a power calculation using G*Power version 3.1.9.7 (Faul et al., 2007). In a moderated mediation model (Figure 1), there are two regression models. One is predicting the mediator (felt ambivalence), and the other is predicting the outcome variable (attitudes towards GH). For the moderated mediation to be supported, both regressions must yield statistically significant effects. Assuming statistical independence between the two paths, the overall power to detect the moderated mediation effect is the product of the power estimates for the two separate regression models.

I expect different effect sizes for the two regression models. Specifically, I assumed a moderate effect size ($f^2 = 0.15$; Cohen, 1988) of the information treatment on felt ambivalence, and a conservative small moderation effect on attitudes towards GH ($f^2 = 0.02$; Cohen, 1988). Because the smallest effect limits overall power, I started the power calculation with this smaller moderation effect.

With four predictors, for 80% power and a significance level of $\alpha = 0.05$, a sample size of 602 participants is required for this multiple regression (F-test, fixed model, R^2 deviation from 0). A second power calculation revealed that this sample size yields 100% power for detecting a moderate effect of the information treatment on felt ambivalence. Multiplying the two yields 80% overall power, meaning that 602 participants are sufficient for testing both components of the model with adequate statistical power.

Analysis

First, I tested the total effect of the information treatment (Hypothesis 1) using linear regression. I then tested the full conceptual model (Figure 1) using structural equation modelling (SEM) using the lavaan package (Rosseel, 2012) in R 4.4.3 (R Core Team, 2025). The model specified felt ambivalence and techno-optimism as latent variables, as measured by their respective items. I tested whether the information treatment indirectly affected attitude via felt ambivalence (Hypothesis 2 and 3). I included an interaction term between felt ambivalence and techno-optimism to test for moderation effects (Hypothesis 4) using the modsem package (Slupphaug et al., 2024). The interaction variables were mean centered. I estimated the model using full-information maximum likelihood (FIML) to account for a total of three missing ambivalence item observations of two participants. I estimated latent interactions using the latent moderated structural equations (LMS) method.

Table 1: Quota groups, targets and actual responses for the final sample of the online questionnaire. Deviations in the actual response rate and representative distributions are in italics.

Quota Group	Fraction of the Population	Representative Quota Target	Response Rate (final sample)
Age x Gender			
M20-29	0.0841	51	*50*
M30-39	0.0835	50	50
M40-49	0.0745	45	45
M50-59	0.0881	53	*52*
M60-69	0.0785	47	47
M70+	0.0846	51	51
F20-29	0.0817	49	49
F30-39	0.0813	49	49
F40-49	0.0751	45	*46*
F50-59	0.0884	53	53
F60-69	0.0798	48	*49*
F70+	0.1005	61	61
Education			
Low	0.193	116	*106*
Middle	0.364	219	*224*
High	0.443	267	*272*
Urban Density			
Rural	0.330	199	*197*
Urban	0.670	403	*405*
Total			
Total sample	1.000	602	602

Notes: for Age x Gender, M = Male, F = Female, and numbers indicate the age group in years. Fractions of the population were corrected for excluded parts of the population (e.g., minors). Representative quota targets were calculated by multiplying the corresponding fraction of the population with the total required sample size of 602, as per power calculation.

Results

To begin, I explored whether the information treatment caused an overall shift in participants' attitudes towards GH (Appendix 4). A simple linear regression (regressing attitudes towards GH on the information treatment) showed that this was not the case: the treatment had virtually no impact on attitudes, with $R^2 < .01$, $F(1, 600) = 0.05$, $p = .830$. The information treatment thus did not have a significant total effect on attitudes towards GH, meaning that Hypothesis 1 is not supported.

I then tested the full theoretical model (Figure 2) using a structural equation model. The resulting model (Figure 2; Appendix 4) fit the data well: $\chi^2(360) = 978.95$, $p < .001$; comparative fit index (CFI) = .965; Tucker–Lewis index (TLI) = .954; root mean square error of approximation (RMSEA) = .053; standardized root mean square residual (SRMR) = .080. These fit indices suggest an overall good fit between the statistical model and the observed data.

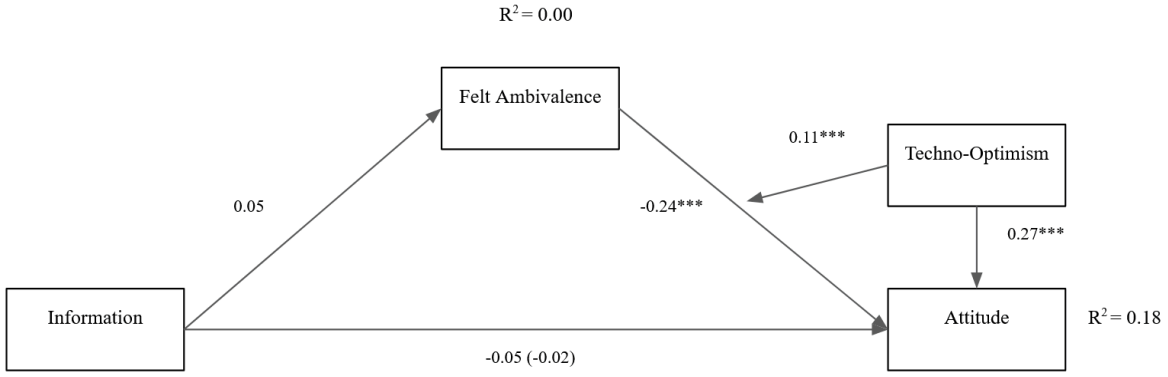
Despite this good fit, the information treatment did not significantly influence participants' feelings of ambivalence ($\beta = 0.05$, $p = 0.623$). Hypotheses 2, which predicted that the information treatment would induce feelings of ambivalence, is thereby not supported. Similarly, there was no direct effect of the treatment on attitudes toward ($\beta = -0.05$, $p = 0.577$). Overall, information treatment thus did not appear to influence ambivalence and attitudes.

Regardless of the treatment, higher levels of felt ambivalence were associated with more negative attitudes toward GH ($\beta = -0.24$, $p < 0.001$). In other words, for an average level of techno-optimism, higher feelings of ambivalence led to lower attitudes towards GH. This finding supports Hypothesis 3, finding evidence that felt ambivalence indeed lowers people's attitudes towards GH.

Importantly, this relationship was not the same for all participants (Figure 3). Techno-optimism moderated the impact of felt ambivalence on attitudes towards GH ($\beta = 0.11$, $p < 0.001$). Specifically, the negative effect of ambivalence on attitudes was strongest among participants low in techno-optimism. In other words, low techno-optimism beliefs thus amplified the negative impact of felt ambivalence on attitudes towards GH. In contrast, those who held more optimistic views about technology were less affected in their attitudes through ambivalence. For them, techno-optimism buffered the negative impact of felt ambivalence.

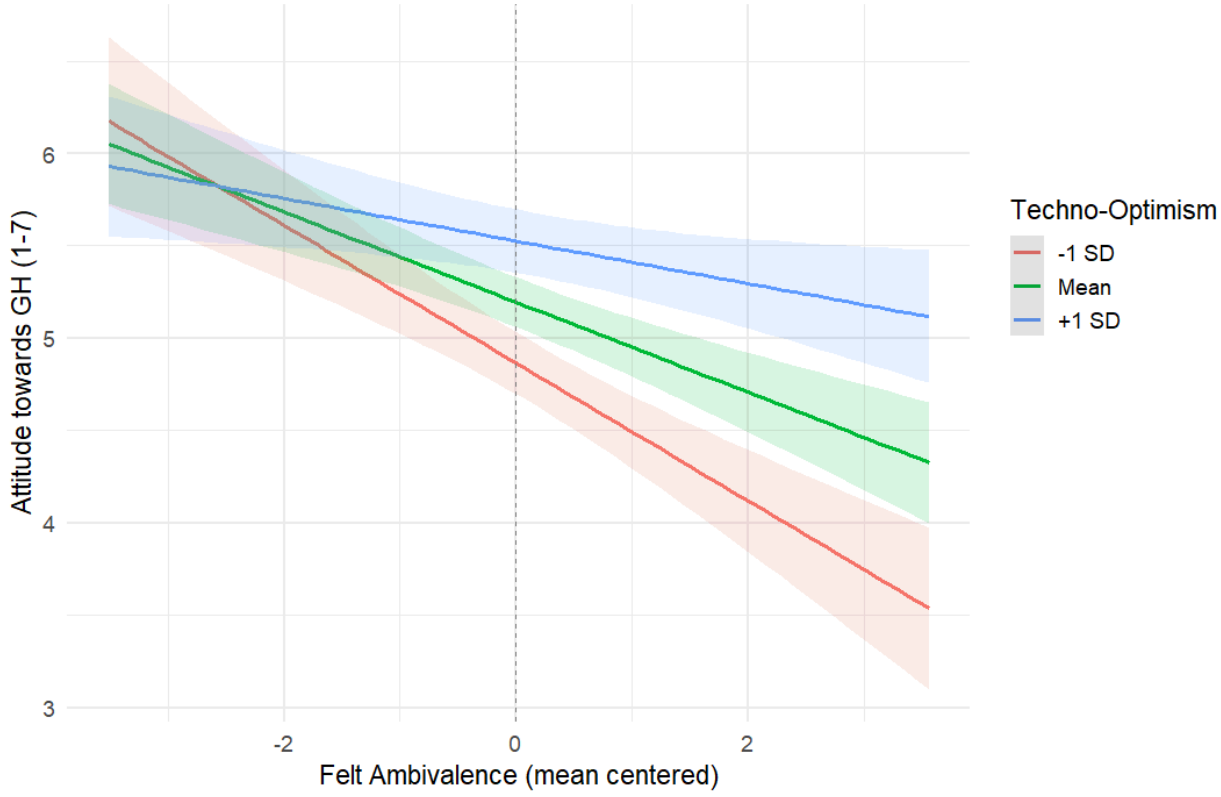
As ambivalence increased, a polarization effect emerged (Figure 3). With increasing ambivalence, those low in techno-optimism beliefs became even more critical of GH, while techno-optimists showed little or no change in their attitudes towards GH. Overall, prior techno-optimism beliefs thus moderated the relationship between felt ambivalence and attitudes towards GH in such a way that attitudes became increasingly polarized at higher levels of felt ambivalence, in line with Hypothesis 4.

Figure 2: Path model of the relationships between information manipulation, felt ambivalence, techno-optimism and attitudes.



Note: Felt ambivalence and techno-optimism were mean centered. Total effects are presented in parentheses.

Figure 3: Interaction plot with 95% confidence intervals showing the effects of different levels of techno-optimism (mean and +/- 1SD) on the relationship between felt ambivalence on attitudes towards GH.



Note: felt ambivalence and techno-optimism were mean centered.

Finally, I examined the index of moderated mediation of the full theoretical model. The index of moderated mediation was not significant, $\beta = 0.00$, 95% confidence interval [-0.01, 0.03]. Overall, I thus found no evidence for moderated mediation. These results suggest that felt ambivalence operated independently within the model. While the information treatment did not significantly influence felt ambivalence, the latter still had a significant effect on attitudes, and was moderated by techno-optimism

At first glance, the results thus seem to indicate that the information treatment was unsuccessful in eliciting feelings of ambivalence, as well as influencing attitudes in general. This was surprising, as the manipulation check confirmed that participants in the information treatment perceived significantly more positive and negative environmental impacts of GH than those in the control condition. Given that the manipulation check worked, what changed about participants if not their felt ambivalence? To explore potential answers to this question, I conducted two additional exploratory analyses.

Exploratory analysis 1: potential ambivalence

In this additional analysis, I was interested in exploring the role of potential ambivalence on attitudes and felt ambivalence. Specifically, one would expect that conflicting *perceptions* (potential ambivalence) that arise in the information treatment would lead to conflicting *feelings* (felt ambivalence), especially when being asked to take a position on GH (Buttlar et al., 2025; Van Gent et al., 2024). Potential ambivalence should thus be a precursor of felt ambivalence (Van Gent et al., 2024), and so I added this as an additional mediation step in the main model. Since the manipulation check measured whether people *perceived* that GH had many positive and negative effects on the environment, I used this measure as a proxy for potential ambivalence. As before, I first tested the total effect of potential ambivalence on attitudes, and then tested the full model using SEM.

A linear regression model, regressing attitudes towards GH on the information treatment and potential ambivalence revealed that potential ambivalence had a weak but significant total effect on attitudes, $R^2 = .015$, $F(1, 599) = 4.49$, $p = .012$ (Appendix 5). Interestingly, this effect was *positive* ($\beta = 0.14$, $p = .003$). In other words, those who perceived more positive and negative environmental impacts of GH thus appear to hold more positive overall attitudes towards GH.

Next, I tested the new full exploratory model using SEM, now including potential ambivalence as an additional mediator (Figure 4; Appendix 5). The exploratory model again demonstrated good fit to the data: $\chi^2(390) = 1038.59$, $p < .001$, CFI = .96, TLI = .95, RMSEA = .053, SRMR = .078.

The model yields various interesting results. First, like in the main analysis, the information treatment again did not directly influence felt ambivalence ($\beta = -0.04$, $p = .681$; removed from the model), and also did not have a significant direct effect on attitudes ($\beta = -0.12$, $p = 0.203$). However, as expected, being exposed to the conflicting information was associated with increased potential ambivalence ($\beta = 0.33$, $p < .001$). In other words, the information treatment only increased *perceptions* of positive and negative environmental effects of GH.

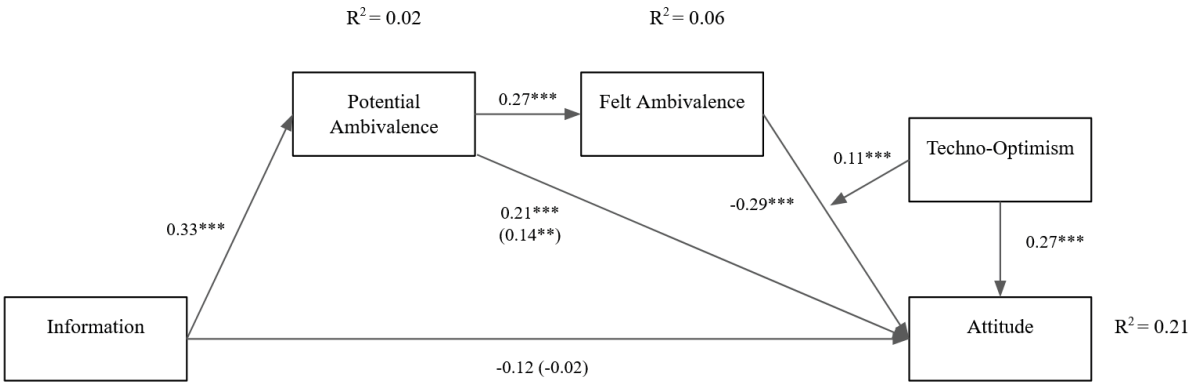
In turn, these perceptions (i.e., potential ambivalence), had two effects. First, potential ambivalence had a direct effect on attitudes towards GH. The model showed that potential ambivalence increased attitudes towards GH directly ($\beta = 0.21$, $p < .001$). In other words, through some unknown mechanism, conflicting perceptions of the environmental impact of GH directly improved support for GH.

Second, potential ambivalence may have been a missing link in the mediation model. Increased potential ambivalence led to higher felt ambivalence ($\beta = 0.27$, $p < .001$). Subsequently, as in the main analysis, higher felt ambivalence then led to lower attitudes towards GH ($\beta = -0.29$, $p < .001$). This pathway had a small but significant overall mediation effect ($\beta = -0.03$, $p = .004$).

The moderating effect of techno-optimism found in the main analysis was still significant in this exploratory analysis ($\beta = 0.11$, $p < .001$). As in the main analysis, those who were low in techno-optimism beliefs were more strongly affected by the negative effects of felt ambivalence on their attitudes towards GH, while techno-optimists were less affected. Techno-optimism thus again buffered and amplified the effects of felt ambivalence on attitudes depending on prior techno-optimism beliefs, leading to the same pattern of polarization as observed in Figure 3.

Overall, increased perceptions of positive and negative environmental impacts of GH may play a dual role in shaping attitudes. On the one hand, it lowers attitudes towards GH by increasing felt ambivalence. On the other hand, it creates higher attitudes towards GH, through a different mechanism.

Figure 4: The new path model of the relationships between information manipulation, felt ambivalence, techno-optimism, attitudes, and potential ambivalence.



Note: techno-optimism and felt ambivalence were mean centered. Potential ambivalence is a proxy, measured by the manipulation check. Total effects are presented in parentheses.

Exploratory analysis 2: non-linear effects

Non-linear effects may be an additional or alternative explanation for the non-significant relationship between information treatment and felt ambivalence in the main model. As ambivalence is mostly felt when conflicting perceptions are perceived as personally relevant (Buttlar et al., 2025; Thompson et al., 1995), it may be possible that not all participants viewed the topic of GH as equally important. In particular, those with stronger pre-existing views (such as individuals at the opposite ends of the techno-optimism spectrum) may perceive GH as more personally significant. As a result, these individuals may be more prone to experience ambivalence when exposed to conflicting information. This suggests a potential non-linear relationship, where individuals with more extreme beliefs experience more ambivalence than those in the middle. Consequently, if only a subset of participants responded to the information as personally relevant, the overall effect of the information treatment on felt ambivalence may have been obscured.

In this additional analysis, I explored whether techno-optimism also moderated the relationship between the information treatment and felt ambivalence. I compared the newly hypothesized non-linear moderation model with the originally hypothesized unmoderated relationship between the information treatment and felt ambivalence using linear regression. Using linear regressions and Akaike's Information Criterion (AIC), it is possible to compare the quality of different statistical models by weighing model complexity against explained variance (Akaike, 1973; Cavanaugh & Neath, 2019). Lower AIC-values indicate better model fits, with a $\Delta AIC > 10$ indicating a significantly better model fit (Cavanaugh & Neath, 2019). As the felt ambivalence and techno-optimism items measured the same construct ($\alpha = 0.89$ and $\alpha = 0.85$ respectively), I calculated the mean values for these two variables and centered them. When calculating the mean value for felt ambivalence, I omitted two participants, as a total of three felt ambivalence item responses for these participants were missing.

The results of this analysis are summarized in Table 2. The original hypothesized model, which tested whether the information treatment predicted felt ambivalence, was again not significant, $R^2 = .00$, $F(1, 600) = 0.01$, $p = .914$, AIC = 2016. As discussed before, this indicates that the information treatment alone did not influence participants' feelings of ambivalence.

In contrast, when the model was extended to include a non-linear (quadratic) interaction term for techno-optimism, the overall model was statistically significant, $R^2 = .03$, $F(5, 596) = 4.13$, $p = .001$, AIC = 2004. Within this model, individuals with more extreme techno-optimism beliefs did *not* feel more ambivalent after reading the information (there was no significant interaction term; Table 2). Instead, the squared term for techno-optimism was significantly associated with felt ambivalence (Table 2). In other words, participants who had either very low or very high levels of techno-optimism reported greater felt ambivalence than those with more moderate beliefs, regardless of having read the information. The information treatment again had no effect on felt ambivalence. The reduction in AIC ($\Delta AIC = 12$) suggests that the non-linear model provides a significantly better fit to the data compared to the linear one, indicating the presence of a quadratic relationship between techno-optimism and felt ambivalence.

Table 2: Regression results comparing the original hypothesized model to an alternative model testing non-linear moderation effects of techno-optimism on the relationship between the information treatment and felt ambivalence.

Outcome Variable	Predictor	Estimate	SE	*t*-value	*p*
Original hypothesized relationship					
Felt Ambivalence	Information treatment	0.011	0.105	-0.214	.914
Techno-optimism as non-linear moderator					
Felt ambivalence	Information treatment	0.041	0.130	0.316	.752
	Techno-optimism	0.037	0.064	0.580	0.562
	Techno-optimism²	0.136	0.040	3.381	<.001
	Information treatment × techno-optimism	0.060	0.087	0.690	.491
	Information treatment × techno-optmism^2	-0.047	0.055	-0.845	.399

Note: SE = standard error. Techno-optimism^2 is the quadratic techno-optimism term. The interaction terms are labeled as Felt ambivalence × techno-optimism(^{2}). Techno-optimism and ambivalence were mean centered.

Discussion

GH may play a key role in the future of resilient and productive agriculture. However, public support for GH remains uncertain, especially when communication highlights both its environmental benefits and drawbacks. This between-subjects experimental study investigated how exposure to conflicting information about GH's environmental impact influences felt ambivalence, and whether general but domain-relevant prior techno-optimism beliefs shape how individuals resolve that ambivalence.

The information treatment did not affect participants' attitudes towards GH, nor the ambivalence they felt. However, while information provision did not directly increase felt ambivalence, it did so via increased perceptions of the positive and negative environmental impacts of GH. Moreover, techno-optimism also affected felt ambivalence non-linearly, such that those with very low or high techno-optimism beliefs felt more ambivalent than those with more moderate techno-optimism beliefs.

Regardless of the variable preceding it, higher felt ambivalence, in turn, was associated with lower attitudes towards GH, and this relationship was moderated by techno-optimism. Low techno-optimism beliefs amplified the negative effects of felt ambivalence on attitudes towards GH, while high techno-optimism beliefs buffered this relationship. Overall, prior techno-optimism beliefs created a polarization effect, where initial differences in techno-optimism beliefs resulted in increasingly divergent attitudes towards GH as felt ambivalence increased.

The role of potential and felt ambivalence

Contrary to Hypothesis 1, exposure to conflicting information did not have a significant total negative effect on attitudes. Some literature has similarly reported a lack of total effect of conflicting information on attitudes (Conner & Armitage, 2011; Fischer et al., 2013). One possible explanation for this finding is that individuals who are confronted with conflicting information may shift their attitudes in either positive or negative direction, thereby not leading to an average shift in attitudes (Fischer et al., 2013).

The main analysis also did not support Hypothesis 2, as the information treatment failed to directly induce felt ambivalence. This suggests that the experimental manipulation may not have worked as intended. In two exploratory analyses, I explored potential explanations for this finding.

In the first exploratory analysis, I found that potential ambivalence may have been a missing mediating variable. Here, the information treatment *did* induce felt ambivalence, but only through increased perceptions that GH had both positive and negative environmental impacts (used as a proxy for potential ambivalence). What could explain this result? In the literature, objective ambivalence is considered as a necessary precursor to felt ambivalence: people can only *feel* ambivalent after *perceiving* the environmental benefits and drawbacks of GH (Buttlar et al., 2025; Van Gent et al., 2024). In this study, potential ambivalence mediated the effect of the information treatment on felt ambivalence, suggesting that the information treatment's impact was transmitted via the perception of conflicting environmental impact of GH. This helps explain why no direct effect of the information treatment on felt ambivalence was observed. That being said, the information treatment still only explained a small amount of variance,

suggesting that attitudes toward GH are influenced by a broader range of factors (e.g., individual differences, prior knowledge, etc.) beyond just exposure to conflicting information.

Potential and felt ambivalence are conceptually distinct (Armitage & Arden, 2007; Ng et al., 2023), and had opposing effects on attitudes in this study. First, potential ambivalence increased felt ambivalence, which was associated with more negative overall attitudes towards GH (discussed in more detail below). However, unexpectedly, higher potential ambivalence also directly increased attitudes towards GH. What mechanism could explain this relationship? Potential ambivalence has been linked to greater openness to persuasive messaging, which may help explain its positive association with attitudes (Armitage & Arden, 2002, 2007). One plausible interpretation is that participants may have primarily learned new positive information from the information treatment. As media coverage of GH has tended to focus on its negative aspects (Blankestijn, 2024; Floral Daily, 2024; Glastuinbouw Nederland, 2024), participants might have been surprised or reassured by the positive environmental impacts that were presented in the information treatment, improving attitudes towards GH. Alternatively, balanced communication, showing both the upsides and downsides of GH, may increase feelings of trust towards the GH-industry. Trust in industry has been linked to heuristic information processing, lowering risk perceptions and increasing attitudes (Trumbo & McComas, 2008). Regardless of the underlying mechanism, the found direct pathway of potential ambivalence was a surprising find, as a recent systematic review assumed no direct positive effects of potential ambivalence on environmental behaviours (Van Gent et al., 2024). Potential ambivalence may thus have more complex impacts than initially anticipated.

In the second exploratory analysis, I was interested in seeing whether individuals reacted differently to the information treatment, which may have had an obscuring effect. Here, I found that those with more extreme techno-optimism beliefs did not react differently to the information treatment than those with more moderate beliefs. Instead, I found that participants with very low or very high techno-optimism beliefs felt more ambivalence than those with more moderate beliefs, regardless of reading the information.

How can these findings be explained? The sustainability of agriculture is already a highly salient issue in the Netherlands (Eldik & Dam, 2024), which is likely even more personally relevant for those with strong extreme techno-optimism beliefs (Buttlar et al., 2025; Thompson et al., 1995). Personal relevance has been shown to be associated with higher levels of information seeking (Liu & Yang, 2023). As a result, those with low and high techno-optimism beliefs may have been more aware of the strengths and limitations of GH and agro-ecology respectively (Altieri et al., 2017; Betteridge, 2023; Koukounaras, 2021; Reganold & Wachter, 2016). Awareness of these conflicting viewpoints may already have increased felt ambivalence by itself (Buttlar et al., 2025). However, this prior knowledge may also have highlighted the outcome uncertainty of these agricultural approaches: is GH sustainable enough, and can agro-ecological approaches produce enough food in a changing climate? Interestingly, previous research has shown that people may deliberately cultivate felt ambivalence in the face of such outcome uncertainty (Reich & Wheeler, 2016). By remaining more ambivalent, people can strategically protect their feelings in case they do not obtain their desired target (Reich & Wheeler, 2016). Those with strong beliefs may thus remain ambivalent, just in case their preferred, though imperfect solution is unsuccessful. The findings in this study thus suggest that prior (techno-optimism) beliefs may not only influence how people respond to felt ambivalence, but also influence how likely ambivalence is to arise in the first place.

This notion is supported by the finding that individual differences often play a larger role in shaping ambivalence than information itself (Simons et al., 2018).

Regardless of the variables preceding it, higher felt ambivalence was associated with lower attitudes towards GH, providing support for Hypothesis 3. This is generally in line with ambivalence theory (Buttlar et al., 2025; Van Harreveld et al., 2009), as well as experimental studies (Van Gent et al., 2024; Wang et al., 2022). However, it should be noted that a majority of studies focussed on the negative effects of ambivalence on pro-environmental behaviour, not attitudes (e.g., Van Gent et al., 2024). While I hypothesized that negative affect was behind the negative impact of felt ambivalence on attitudes, this study did not actually disentangle this mechanism precisely (e.g., see Wang et al., 2022).

Prior beliefs and polarization

In line with Hypothesis 4, techno-optimism moderated the negative relationship between felt ambivalence and attitudes in all examined model specifications: individuals high in techno-optimism maintained more stable or less negative attitudes as ambivalence increased, while those low in techno-optimism showed more negative attitudes. This suggests that prior beliefs may indeed buffer or intensify the effects of felt ambivalence on attitudes, leading to attitudinal polarization as ambivalence increases.

This is generally in line with the existing literature. For example, classical studies like those from Lord et al. (1979) have long suggested that people with strong beliefs tend to accept information that agree with their standpoints on complex issues at face value, while rejecting information that opposes these views (for more recent studies, see for example Clark et al., 2008; van Strien et al., 2014). While some studies do not find evidence for polarization effects (e.g., Guess & Coppock, 2020), these studies often employed one-sided (i.e. either positive or negative) counter-attitudinal messages, as opposed to the ambiguous information used in this study. The two-sided message in this study may have made arguments in favor of one's position more easily available, facilitating motivated reasoning instead of critical reflection (Newby-Clark et al., 2002; van Strien et al., 2014)

While it has been suggested that more general beliefs (or gut feelings) about a complex topic may influence the way people process conflicting information (de Groot et al., 2013), research on this topic was still lacking. This study integrated domain-relevant prior beliefs with existing biased processing and ambivalence frameworks, and demonstrated that individuals tend to process their ambivalence by strengthening attitudes towards GH in the direction that aligns with prior techno-optimism beliefs. In this way, differences in prior beliefs can lead to increasingly divergent attitudes toward GH as felt ambivalence intensifies: a polarization effect. Domain-relevant pre-existing beliefs may thus function similarly to political ideologies, where biased information processing has been shown to accelerate and amplify attitudinal polarization (Kashima et al., 2021).

Implications

The current findings have important implications for communication on topics with conflicting (environmental) impacts, especially for GH. Although previous work has mostly focussed on the persuasiveness of messages or how conflicting information may cause ambivalence, the work that studies how ambivalence resolves into specific attitudes for different individuals is still limited. The findings in this study highlight that general but domain-relevant prior beliefs influence how individuals handle ambivalence when forming attitudes. Communication on both risks and benefits may inadvertently lead to ambivalence and thus increased polarization, which may spark contentious debates that hinder public or political support for GH. In other words, instead of convincing skeptics, transparent communication may actually backfire by entrenching existing viewpoints. Communicators should thus be careful in blindly assuming that "honest" and "transparent" communication will help convince the public to support their cause. This is especially relevant for the GH sector in the Netherlands, as it is rolling out a communication program focussed on clarity and transparency to improve public perceptions of GH (Glastuinbouw Nederland, 2025), which will likely include discussing its mixed environmental impact. As opposed to earlier findings of public opposition (Rogge et al., 2011), participants were generally quite supportive of GH in this study (M = 5.19 on a 7-point Likert scale, as described in the method). In this case, communication may do more harm than good.

Possible limitations and avenues for future research

This study has several limitations. First, with regards to used measures, operationalizations of potential and felt ambivalence vary greatly in the field of psychology (Van Gent et al., 2024). While I did not follow a development procedure for the felt ambivalence scale used in this study, the deviating operationalization of potential ambivalence in the additional exploratory analysis (i.e., using the manipulation check) may be especially problematic. Specifically, the manipulation check ("Greenhouse horticulture has a lot of positive and negative impacts on the environment.") was designed to assess whether people read and understood the information treatment, not to capture the number or strength of conflicting evaluations typically required to determine potential ambivalence (Van Gent et al., 2024). As such, this measure may lack both construct validity and the sensitivity necessary to accurately reflect potential ambivalence. The results from the first exploratory analysis should thus be interpreted with care. Future research could benefit from making a clearer distinction between potential and felt ambivalence, and investigate how both constructs affect attitudes. Specifically, it would be interesting to further explore and test what might explain the positive effect of potential ambivalence on attitudes. The proposed trust in the industry and positive surprises due to selective media coverage pathways discussed would be a good starting point (Armitage & Arden, 2007; Trumbo & McComas, 2008).

Second, significant differences in dropout and attentiveness between the two experimental conditions may have introduced bias. Specifically, participants in the treatment condition (who were asked to read additional information) dropped out at a higher rate (Appendix 2). This suggests that those who remained may have been more intrinsically motivated or interested in the topic, potentially skewing the sample toward individuals already more engaged or knowledgeable about environmental issues or GH. Conversely, participants in the control condition, who were not required to read the extra material,

showed lower levels of attentiveness. Participants may thus have self-selected to some degree, meaning that the two groups are not perfectly comparable. To mitigate dropout and attentiveness biases in future research, researchers should consider pre-screening for topic interest. Moreover, equalizing the cognitive load across different conditions might help reduce self-selection based on task efforts, for example by having participants in the control condition read additional but unrelated material.

Third, it remains unclear what the long-term and practical implications of attitude change are. How long does polarization persist, and how do attitudes and polarization translate to real-life outcomes (purchasing intentions of greenhouse produce, collective action against GH, policy support etc.)? The literature does not provide a clear answer to this. For example, some studies suggest that self-reported attitudes are a poor reflection of actual polarization, but still find some cases in which reading information that was incongruent with initial attitudes led to actual and persistent polarization (Kuhn & Lao, 1996). To further complicate matters, ambivalence may resurface, even after having made a decision (Buttlar et al., 2025). For future studies, I recommend increasing ecological validity by tracking the long-term effects of ambiguous communication using a within-subjects experimental design with one or more follow-up measures

One more interesting avenue for future research would be to study the potentially complex relationships between ambiguous communication, ambivalence, prior beliefs, and attitudes. As discussed, additional mediation steps and initially unexpected (non-linear) relationships emerged from the additional exploratory analyses. Especially prior knowledge may be an important variable to include in the model (Tamar et al., 2020). First of all, it may help explain potentially large individual differences in how people experience ambivalence after being exposed to conflicting information (Simons et al., 2018). Second, as previously discussed, future research could investigate whether participants were surprised by the positive aspects of the conflicting information (possibly due to predominantly negative critical coverage) which might explain the positive effect of potential ambivalence on attitudes (Armitage & Arden, 2007; Blankestijn, 2024). Third, it may explain how felt ambivalence translates into attitudes (Tamar et al., 2020). For example, Wallace et al. (2020) found that ambivalence only undermines attitudes when participants were relatively knowledgeable on the topic. Fourth, like prior beliefs, knowledge tends to shape the way people process information as well (Clark et al., 2008; Itzchakov et al., 2020). So by including both knowledge and prior beliefs into a single model, it may be possible to more accurately understand how people will react to ambiguous information. Similarly, the non-linear association of techno-optimism with felt ambivalence warrants further investigation in confirmatory research as well.

Conclusion

In summary, this research provides evidence that prior beliefs shape the direction in which ambivalence influences attitudes. Individuals with more favorable views toward using technology to address sustainability issues were less negatively (or even positively) affected by the discomfort of ambivalence when evaluating GH. In contrast, those with more skeptical beliefs became significantly less supportive of GH in the face of such ambivalence. These findings suggest that nuanced, transparent messaging about both the risks and benefits of new technologies may not always persuade, and may even backfire by reinforcing existing divisions. Additionally, an exploratory analysis highlighted the potentially distinct roles of potential and felt ambivalence in shaping attitudes, as well as non-linear effects of prior beliefs, opening new avenues for future research. This study thus contributes to the growing, yet still evolving, field of ambivalence research. In conclusion, well-intentioned efforts to cultivate support for innovation through transparent communication likely do more harm than good by deepening the roots of pre-existing beliefs. Policy makers and communicators should thus exercise caution when designing communication strategies, and not assume that transparency is the key to persuasion.

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Appendix 1: Information treatment

All participants viewed the general information, while only those in the information treatment received the additional information (below the horizontal line) on the mixed environmental impact of GH. The additional information consisted of three blocks (Resources, Pollution, Use of space), each containing one environmental advantage and one environmental disadvantage of GH. These blocks were presented in a random order to the participants.

General information

Broadly speaking there are two forms of agriculture. The first is outdoor agriculture (akkerbouw), where crops are grown outside on fields, as they traditionally have been. A second form of agriculture is so-called greenhouse horticulture (glastuinbouw). Here, crops are grown inside greenhouses with the help of technology.

Greenhouses have both positive and negative impacts on the environment. Below you can find some examples. You can only go to the next page after 30 seconds have passed, so please take your time to carefully read the examples.

Resources
PRO: By using technology, greenhouses generally require less water, fertilizer and pesticides to grow crops compared to outdoor farms.

CON: Greenhouses require lighting and heating, and thus require more energy and natural gas compared to outdoor farms.

Pollution
PRO: Greenhouses leak fewer chemicals and fertilizer into the environment compared to outdoor farms because greenhouses are separated from the natural environment.

CON: Greenhouses emit more greenhouse gases and cause more light pollution than outdoor farms because the greenhouses require heating and lighting.

Use of space
PRO: By using heating and lighting, greenhouses can grow crops all year, which means greenhouses take up less space than outdoor farming to grow the same amount of food. This means that there is less space required for agriculture, which provides more room for nature.

CON: There is no room for nature at all at the location of the greenhouses themselves, while outdoor farms can share their space with nature.

Appendix 2: Dropout, attention, and timing for the different treatments

There were significant differences in dropout and inattentiveness for the two treatments (Table A1). For dropout, 34 participants dropped out in the control group, while 64 dropped out of the treatment group. A Pearson's Chi-squared test with Yates' continuity correction revealed that this is a significant difference between the two groups, $X^2(1) = 9.7$, $p = 0.002$. For attentiveness, 98 respondents failed the attention check in the control group, while only 66 respondents failed this check in the treatment group. This is again a significant difference, $X^2(1) = 4.7$, $p = 0.030$. Corrected for time spent reading the additional text in the treatment group, median time spent on the survey was 154 seconds and 173 seconds for the control and treatment group respectively. I chose to use the median as there were substantial differences in time spent on the survey, with some respondents taking over a full day to complete the survey. However, regardless of such outliers, a linear regression analysis, correlating time spent on the questionnaire with treatment groups, did not reveal a statistically significant model, $R^2 < 0.01$, $F(1, 600) = 2.21$, $p = 0.14$. There were thus no significant differences in time spent on the questionnaire for the different experimental groups.

Table A1: Dropout, inattentiveness, and valid responses after informed consent and quota screenouts.

	Number of dropouts	Number of attention check fails	Total number of invalid responses	Number of valid responses
Control group	34	98	132	300
Treatment group	64	66	130	302

Appendix 3: Techno-optimism items

The items used to measure techno-optimism beliefs in the online questionnaire were drawn from the techno-fix attitudes subscale of the GATT-scale (Cologna et al., 2024). Note that while the GATT-scale also includes a separate techno-optimism subscale, it reflects a different conceptualization of techno-optimism than the one adopted in this study.

1. Technological innovations will allow us to carry on with our current lifestyles without any limitations.
2. Thanks to technological progress we do not need to change our behavior at all.
3. Technological solutions can solve all our problems.
4. Technological solutions are the most effective way of solving society's problems.
5. Technological innovations are more effective at solving society's problems than individual behavioral changes.

Appendix 4: Regression table main analysis

Regression table of the total effect of the information on attitudes towards GH and the full hypothesized structural equation model of the main analysis.

Outcome Variable	Predictor	Estimate	SE	*t* / *z*	*p*
Total effect					
Attitude towards GH	Information treatment	-0.021	0.099	-0.214	.830
Hypothesized structural equation model					
Felt ambivalence	Information treatment	0.050	0.101	0.492	.623
Attitude towards GH	Felt ambivalence	-0.244	0.043	-5.689	< .001
	Techno-optimism	0.269	0.043	6.296	< .001
	Felt ambivalence × techno-optimism	0.105	0.027	3.955	< .001
	Information treatment	-0.051	0.092	-0.557	.577

Note: SE = standard error. The interaction term is labeled as Felt ambivalence × techno-optimism. The *t* / *z* column represents the t-values and z-values for the linear regression of the total effect and the z-values from the structural equation model respectively. Techno-optimism and felt ambivalence were mean-centered.

Appendix 5: Regression table exploratory additional analysis

Regression table of the total effect of potential ambivalence on attitudes towards GH and the full exploratory model, including potential ambivalence as an additional mediator.

Outcome Variable	Predictor	Estimate	SE	*t / z*	*p*
Total effect					
Attitude towards GH	Information treatment	-0.066	0.099	-0.666	.506
	Potential ambivalence	0.136	0.045	2.990	.003
Exploratory structural equation model					
Potential ambivalence	Information treatment	0.331	0.088	3.759	< .001
Felt ambivalence	Potential ambivalence	0.270	0.046	5.905	< .001
Attitude towards GH	Felt ambivalence	-0.293	0.044	-6.679	< .001
	Techno-optimism	0.266	0.042	6.341	< .001
	Felt ambivalence × Techno-optimism	0.110	0.026	4.204	< .001
	Potential ambivalence	0.207	0.043	4.772	< .001
	Information treatment	-0.116	0.091	-1.273	.203

Note: SE = standard error. The interaction term is labeled as Felt ambivalence × techno-optimism. The *t / z* column represents the t-values for the linear regression of the total effect and the z-values for the structural equation model respectively. Potential ambivalence is a proxy, measured by the manipulation check. Techno-optimism and felt ambivalence were mean-centered.