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The role of affect in attitude formation toward new technologies: The case of stratospheric aerosol injection

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The role of affect in attitude formation toward new technologies: The case of stratospheric aerosol injection

Christine Merk, Gert Pönitzsch

Abstract:

This paper analyzes determinants of technology acceptance and their interdependence. It highlights the role of affect in attitude formation toward new technologies and examines how it mediates the influence of stable psychological variables on technology acceptance. Based on theory and previous empirical evidence, we develop an analytical framework of attitude formation. We test this framework using survey data on the acceptance of stratospheric aerosol injection (SAI), a technology that could be used to counteract global warming. We show that affect is more important than risk and benefit perception in forming judgment about SAI. Negative and positive affect directly alter the perception of risks and benefits of SAI and its acceptability. Furthermore, affect is an important mediator between stable psychological variables – like trust in government, values, and attitudes – and acceptance. A person's affective response is thus guided by her general attitudes and values.

Keywords: technology acceptance; stratospheric aerosol injection; climate engineering; affect; attitudes; values; trust

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1. INTRODUCTION

Fighting climate change is one of the major global challenges of the 21st century. However, even timely and substantial cuts in greenhouse gas emissions may fail to limit global warming to 2°C above preindustrial levels (IPCC 2014). Against this background, new technologies to limit global warming, known as climate engineering or geoengineering, entered the scientific and political debate. Climate engineering technologies could be an effective way to cool atmospheric temperatures and prevent massive damages from climate change. However, many of these technologies carry substantial risks. Stratospheric aerosol injection (SAI), for example, could change precipitation patterns or induce abrupt temperature changes in case of its termination (for an overview see Rickels et al. 2011).

Public concern about climate engineering technologies is substantial (Bellamy and Hulme 2011; Borick and Rabe 2012; Macnaghten and Szerszynski 2013; Merk et al. 2015) and has been voiced in protests against research projects on SAI and ocean iron fertilization (Stilgoe et al. 2013; Schäfer et al. 2015). Given the far reaching social, ethical, and environmental implications of research or deployment of climate engineering, public perceptions will remain influential in the debate about it (Pidgeon et al. 2013). The aim of studying public acceptance is not to guarantee acceptance but to identify public concerns early on (Pidgeon et al. 2013), enable informed decisions on research and possible deployment (Carr et al. 2013), and improve communication strategies (Huijts et al. 2012).

In the present study, we analyze the factors that determine the acceptability of climate engineering for the case of SAI. This paper extends previous research and develops a new framework describing attitude formation toward new technologies that carry potentially large risks. We use German survey data to test the framework. Our analysis is guided by the following questions:

(1) How do stable psychological variables – i.e., values, environmental attitudes and risk attitudes, and trust in government – influence technology acceptance? Do they enter attitude formation via cognitive or affective pathways?

(2) What is the relative importance of affect, and the perception of risks and benefits in attitude formation?

Previous studies of the acceptability of new technologies often highlighted the isolated impact of a single stable psychological variable like trust in institutions (Siegrist 2000; Siegrist et al. 2000; Terwel et al. 2009; van Dongen et al. 2013) or values (De Groot et al. 2013). Recent advances incorporated several

determinants into the analysis of technology acceptance and allowed for mediation between different determinants in attitude formation (Midden and Huijts 2009; Whitfield et al. 2009; Huijts et al. 2014). However, none of these studies looked more closely at the relationship between affect, the perception of risks and benefits, and several stable psychological variables. Furthermore, the relative importance of these factors in attitude formation remains unclear.

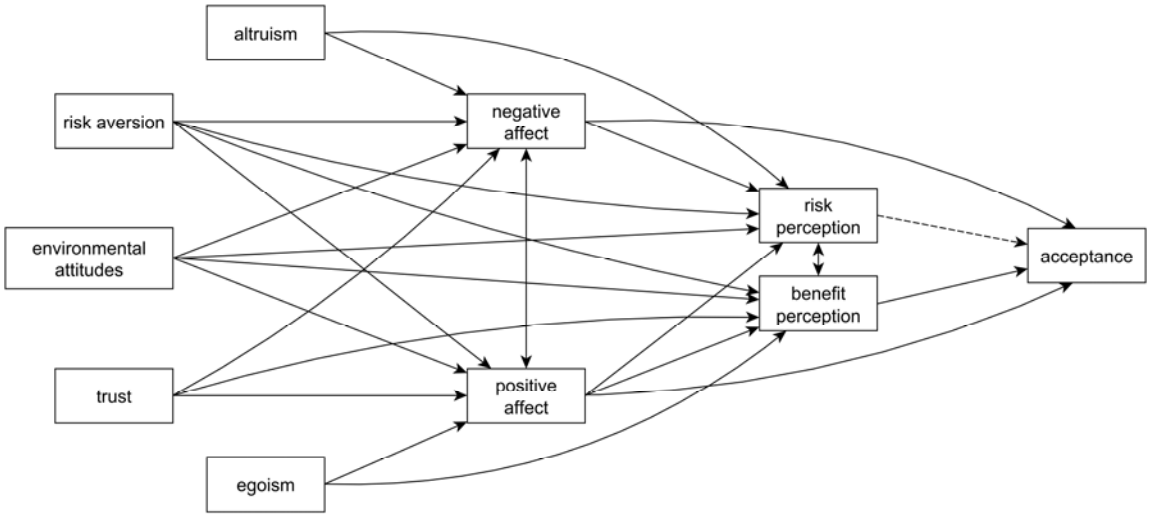
The rest of the paper is structured as follows. In Section 2, we derive the analytical framework for our analysis. We lay out the survey, the measurement concepts, and the details of the analysis in Section 3. The results are shown and discussed in Section 4. Section 5 concludes and discusses implications for future research.

2. ANALYTICAL FRAMEWORK

Our model builds on established theories of risk perception and attitude formation and combines them into a comprehensive framework. It accommodates the value-belief-norm theory (Stern 2000) and the theory of planned behavior (Ajzen 1985) in assuming that the acceptance of a technology is determined by domain-specific beliefs – i.e. perceived benefits and risks of the technology - that derive from a person's values. These domain-specific beliefs, in turn, may be influenced by stable psychological variables, such as values, environmental attitudes, and trust. In addition, the framework accommodates the affect heuristic (Finucane et al. 2000) and the risk-as-feeling hypothesis (Loewenstein et al. 2001) that highlight the influence of affect in decision making. It hence allows positive and negative affect to influence acceptance. It is further assumed that affect, in turn, may be influenced by stable psychological variables.

By including both domain-specific beliefs and affect, the framework can address whether a person's stable psychological variables – her altruistic and egoistic values, her environmental attitudes, her trust, and her risk attitude – influence attitude formation via the cognitive pathway, the affective pathway, or both. The full framework is depicted in Figure 1. Its components are described below together with previous empirical evidence.

Figure 1: Analytical framework for the acceptance of environmental technologies



2.1. Risk and Benefit Perception

Attitudes form in part from a weighing of risks and benefits (Ajzen 1985). Consequently, the perceptions of risks and benefits of a technology are direct antecedents of acceptance. Their impact, however, is not equally strong. De Groot et al. (2013) found a positive impact of perceived benefits as well as a negative impact of perceived risks on the acceptance of nuclear power. The effect of perceived risks, however, was smaller. Terwel et al. (2009) demonstrated that perceived benefits are more relevant than perceived risks in predicting CCS acceptance. In the context of SAI, Mercer et al. (2011) showed that the rating of the importance of risks is not significantly different between respondents who are in favor of SAI and those who are against it. The rated importance of benefits, however, was higher for supporters of the technology than for opponents.

A precise account of the relationship between acceptance and perceived risks and benefits, however, relies on the consideration of affective pathways. Accounting for affect in attitude formation, Midden & Huijts (2009) showed that perceived risks do not significantly impact acceptance of CO_2-storage. Acceptance of CO_2-storage in general is based only on perceived benefits and affect. Acceptance of local storage, by contrast, is completely determined by affect. To test the relevance of both risk and benefit perception when affect is accounted for, we include paths from both variables to acceptance in our analytical model. We thereby deviate from Huijts et al. (2014), who aggregate perceived risks and benefits in one variable.

2.2. Affect

Affect is an important component determining the perception of risks and benefits of new technologies. In particular when knowledge about a technology is low, people tend to rely on affect rather than cognition evaluating risks and benefits of a technology (Lee et al. 2005; Slovic et al. 2007; Midden and Huijts 2009). Affect serves as an initial overall evaluation of the technology that provides a basis for the assessment of its risks and benefits (Zajonc 1980; Alhakami and Slovic 1994; Finucane et al. 2000; Loewenstein et al. 2001; Slovic et al. 2004; Slovic et al. 2007).

Affect towards objects can simultaneously be positive and negative (Peters and Slovic 2007). Both affective directions should be analyzed separately, as they each have a distinct role in shaping technology acceptance. Midden & Huijts (2009), for example, found that positive affect toward CO_2-storage increases perceived benefits and reduces perceived risks of storage, while negative affect only increases perceived risks but does not influence perceived benefits. Also the strength of the affective directions is asymmetric. Huijts et al. (2014) showed that perceived costs, risks, and benefits of a local hydrogen fuel station depend more strongly on positive affect than on negative affect.

In addition to influencing domain-specific beliefs, affect also influences attitudes directly (Ajzen 2001). This direct pathway has also been demonstrated in the context of technology acceptance. Midden & Huijts (2009) found that both positive and negative affect directly influence attitudes toward CO_2-storage. Explaining attitude toward acting in favor of a local hydrogen fuel station, Huijts et al. (2014) found that positive affect but not negative affect has a direct influence on attitudes. Our model allows for direct and indirect pathways and hence includes paths from positive and negative affect to risk and benefit perception and to acceptance.

2.3. Trust in Government

Trust in institutions associated with the technology is a consistent predictor of technology acceptance (Flynn et al. 1993; Siegrist et al. 2000; Midden and Huijts 2009; Earle 2010). Especially when knowledge about the technology is insufficient, trust stemming from a perceived similarity of values (e.g., Siegrist et al. 2000) or from a positive assessment of organizational competence (e.g., Terwel et al. 2009) is used to assess a technology's risks and benefits. Trust in relevant institutions generally increases acceptance, as it increases benefit perception and reduces risk perception. This has been shown for the acceptance of gene technology (Siegrist 2000; Barnett et al. 2007), nuclear power (Siegrist et al. 2000; Siegrist and

Cvetkovich 2000; Visschers and Siegrist 2013), hydroelectric power (Siegrist and Cvetkovich 2000), and CCS (Terwel et al. 2009).

The influence of trust on risk and benefit perception is likely mediated by affect. Analyzing purchase decisions of nanotechnology foods, Siegrist et al. (2007) suggested that trust in government influences risk and benefit perception indirectly via affect. Their model, however, does not allow for a direct effect of trust on risk and benefit perception. In a model explaining attitudes toward CO_2-storage, Midden & Huijts (2009) also found that trust in government influences affect. Over and above the influence via affect, trust directly influences perceived benefits, but does not directly influence perceived risks of CO_2-storage. Montijn-Dorgelo & Midden (2008) demonstrated the same pattern in perceptions of hydrogen systems. Huijts et al. (2014) showed both direct and indirect effects of trust in the municipality on perceived risks and benefits of hydrogen fuel stations, but combined perceived risks and benefits into one factor. Our model includes paths from trust to perceived risks and benefits and to positive and negative affect.[1] As government agencies are the only institutions that would currently be involved in international decision-making regarding SAI, our model focuses on trust toward government.

2.4. Egoistic and Altruistic Values

Values are guiding principles in the life of a person (Schwartz 1992). As stable characteristics they direct attention and form beliefs and attitudes across an array of contexts (Stern, Kalof et al. 1995). For environmental behavior, egoistic and altruistic values are particularly relevant (Stern 2000). In attitude formation toward technologies with environmental consequences, these values guide a person's focus in weighing perceived risks and benefits (De Groot and Steg 2007; De Groot and Steg 2008). People with strong egoistic values display a preference for social power, wealth, authority, and influence; they tend to mainly consider perceived risks and benefits for themselves. By contrast, people with strong altruistic values display a preference for equality, world peace, and social justice and tend to focus on perceived risks and benefits for others.

The influence of values on technology acceptance will thus depend on the technology's distribution of risks and benefits. In the context of nuclear energy, which is cheap but carries health risks for many

[1] This causal model of trust is particularly suitable for assessments of new technologies on which people have little information but are knowledgeable of actors involved (Earle 2010). The associationist model of trust, by contrast, supposes that the acceptability of a hazard influences perceived risks and trust in authorities. The associationist model is particularly suitable if people are knowledgeable about a hazard, but not about actors involved. For example, the acceptability of a hazard may be used to assess the trustworthiness of regulatory authorities (Poortinga and Pidgeon 2005; Bronfman et al. 2008).

people, egoistic values have been shown to increase its perceived benefits, while altruistic values increase its perceived risks (De Groot et al. 2013). Other studies found no effect of egoistic values but showed that altruistic values reduce the acceptability of nuclear energy (Whitfield et al. 2009) and increase concern about different ecological risks (Slimak and Dietz 2006). In the context of climate engineering, Corner & Pidgeon (2014) demonstrated a positive effect of egoistic (or self-enhancing) values on the support of climate engineering, but no effect of altruistic (or self-transcending) values. However, they did not include perceived risks or benefits in their analysis.

Based on previous findings, we expect a positive influence of egoistic values on the perceived benefits of SAI and a positive influence of altruistic values on the perceived risks of SAI. It remains an open question, whether values acting as cognitive filters not only influence perceived risks and benefits directly, but also indirectly via affect. Our model allows for both pathways.

2.5. Environmental Attitudes

The assessment of environmental consequences is shaped by environmental attitudes (Stern 2000; De Groot and Steg 2008; De Groot et al. 2013). These attitudes are often measured by the New Ecological Paradigm – NEP (Dunlap and van Liere 1978; Dunlap et al. 2000). It encompasses attitudes toward the following facets: (1) balance of nature, (2) limits to growth, (3) risk of an eco-crisis, (4) anthropocentrism and (5) humans' ability to control nature.

The NEP's facets are significantly correlated with risk ratings of environmental hazards, such as global warming (Sjöberg 2003). The NEP, as a combined measure, also helps to explain concern about ecological risks and has strong explanatory power in the evaluation of global risks (Slimak and Dietz 2006). In addition, respondents with higher NEP scores, i.e., a stronger environmental concern, focus more strongly on ecological impacts when evaluating environmental hazards (Willis and Dekay 2007) and are more willing to take pro-environmental action (Stern, Dietz et al. 1995).

The NEP's facets should also influence the attitude toward SAI. Involving massive human intervention into the climate system, its risks and benefits are intricately linked to on the one hand beliefs about the balance of nature, limits to growth, the risk of an eco-crisis, and on the other hand anthropocentrism and humans' ability to control nature. Environmental attitudes may have an ambiguous effect on the acceptance of new technologies like SAI that carry environmental benefits and environmental risks at the same time. SAI could reduce global warming, but may, for example, significantly alter the hydrological cycle (Rickels et al. 2011). It also manipulates nature to an extent that is often perceived as unacceptable

(Mercer et al. 2011; Corner et al. 2013; Merk et al. 2015). Despite an acute concern about climate change, environmentalists might therefore remain skeptical about SAI. Yet, previous studies show a small positive effect of environmental values on the support of solar radiation management, in general, (Pidgeon et al. 2012) and SAI, in particular (Merk et al. 2015).

Studies that looked at the interdependency between determinants showed no direct effect of environmental values on risk or benefit perception. De Groot et al. (2013) found that biospheric values, like preventing pollution and protecting the environment, explain neither benefit nor risk perception of nuclear energy directly. They are linked to acceptance only via their correlation with altruistic values. Also Whitfield et al. (2009) found no direct effect of environmental attitudes, measured by the NEP, on the perception of nuclear risk or the acceptability of nuclear energy. Their model suggests a negative indirect effect via a reduction in trust. However, these models do not include affective pathways and thus cannot show whether environmental attitudes enter attitude formation via affect. We include environmental attitudes, measured by the 5 facets of the NEP into our model and allow them to influence both negative and positive affect and risk and benefit perception.

2.6. Risk Aversion

Acceptance of technologies involving risk should also be influenced by a person's risk aversion. Risk aversion has previously been shown to impact general risk taking behavior (Dohmen et al. 2011) and, more specifically, occupational choice (Bonin et al. 2007) as well as migration decisions (Jaeger et al. 2010). It is also related to the acceptance of field research on SAI (Merk et al. 2015). Risk aversion may enter attitude formation either via cognitive reasoning - risk and benefit perception - or via feelings - positive or negative affect (Loewenstein et al. 2001). We include both possibilities in our model.

2.7. Acceptance

Aerosol injection is yet only little known and protesting or supporting behavior has not yet evolved. We hence follow the approach of L'Orange Seigo et al. (2014) and focus on expressed preference for the technology as the single outcome variable, which we call acceptance.

3. METHOD

3.1. Procedure and Respondents

Respondents were recruited using a German online panel. The survey was conducted in December 2012. Respondents are representative of the German population with respect to state of residence, age, and gender. The working sample consists of 927 cases. 52% of respondents are male. The mean age is 47 (min 18, max 81). The share of respondents with a higher education entrance certificate - 52% - lies above the share in the German population - 27% (Destatis 2015).

3.2. Content of the Survey

A video informed respondents about climate change and stratospheric aerosol injection during the survey.[2] The video contained infographics that were accompanied by a German voice-over with the following content[3]:

> *Sunlight warms the Earth and the Earth's atmosphere. Greenhouse gases in the atmosphere, such as CO_2, ensure that a certain amount of heat remains close to the Earth's surface. This makes the Earth warm enough for humans, animals, and plants to survive.*
>
> *Since the beginning of industrialization around the year 1850, humans have emitted large amounts of greenhouse gases, for example, by burning coal, oil, and gas. These gases trap additional heat in the atmosphere and cause a gradual increase in the average global temperature.*
>
> *Since 1900, the global temperature has risen on average by approximately 0.8°C. Almost all countries agree that the increase in the average global temperature should not exceed 2°C compared to the temperature at the beginning of the industrialization. This is referred to as the 2°C goal.*
>
> *A future temperature increase between 0.9°C and 5.4°C is expected by 2100. The outcome depends especially on the amount of greenhouse gases emitted in the future. To reach the 2°C goal, the current level of emissions would have to decrease by more than half by 2050. By 2100, almost no greenhouse gases should be emitted.*
>
> *Climate change will almost certainly cause a rise in sea levels. It is very likely that both the frequency of heat waves and the number of heavy precipitation events will increase in many regions. In the future, it is likely that more areas will be affected by longer droughts and that the frequency and the intensity of tropical cyclones will increase. In addition, because oceans absorb some of the CO_2 in the atmosphere, they will become more acidic.*
>
> *There are different ways to deal with climate change:*

[2] Participants were not able to skip or fast forward the video. Participants, whose technical devices were not apt to show the video or play the voiceover, were screened out at the beginning of the survey.

[3] The survey used the broader term solar radiation management to refer to the technology of stratospheric aerosol injection.

We can reduce greenhouse gas emissions or adapt to the new climate – for example, by building dikes or using more robust plants in agriculture. Another option is to reduce the global temperature by deploying solar radiation management (SRM).

Through SRM, a portion of the sunlight is reflected before it can warm the Earth. This can be achieved by, for example, spraying sulfate particles into the atmosphere at a high altitude.

A similar phenomenon is observed in nature. When large volcanoes erupt, similar particles are distributed across wide areas of the Earth's atmosphere, which cools the Earth.

The particles remain in the higher regions of the atmosphere for about two years. To prevent the Earth from heating up again, spraying would have to be continued until the cause of global warming is removed. Because the emitted CO_2 stays in the atmosphere for a very long time, SRM might have to be used for several centuries. Ocean acidification will not be halted by using SRM. However, the 2°C goal could be met regardless of future greenhouse gas emissions by deploying SRM. Currently, researchers are investigating the risks, benefits, and feasibility of SRM.

The use of SRM entails benefits as well as risks. One benefit is that global warming might be slowed more quickly compared to cutting greenhouse gas emissions. This would provide humankind with additional time to remove the cause of climate change, i.e., the high concentration of greenhouse gases in the atmosphere. Massive and irreversible changes in the climate could be stopped before too much damage is done. Furthermore, it would be possible to stop climate change even if certain countries refused to reduce their greenhouse gas emissions. Deploying SRM would be cheaper than reducing the consumption of fossil fuels.

The risks include a change in the amount of precipitation in most regions. In particular, arid regions would have to cope with even less rain. If the deployment of SRM were suddenly halted, the global temperature would rise abruptly. The speed of this temperature rise might lead to severe problems for humans and the environment. Because possible side effects would occur across international boundaries, the use of SRM might cause international conflicts. Once used, SRM might take away people's motivation to change their lifestyle and the emission of greenhouse gases would continue to increase. Furthermore, there would be the threat of other unknown and unforeseeable risks.

The aim was to present respondents with a neutrally framed and clear description of the technology. When asked whether the video was clearly understandable[4] and whether respondents thought it was neutral or biased in favor or against aerosol injection[5], only 7 out of 927 participants thought the video was not clearly understandable. 13% said it was biased in favor of the technology, while less than 1% perceived video as biased against SAI. 81% of respondents understood the video at least well and thought it was neutral toward aerosol injection. For more information on the sources for the video's content see Merk et al. (2015).

[4] "Do you think the information you just saw was clear or do you think it was unclear? completely clear (1) – completely unclear (4)".

[5] "Do you think the information you just saw was biased in favor or against solar radiation management or was it neutral? - It was biased in favor of solar radiation management. - It was neutral. - It was bias against solar radiation management."

3.3. Measures

Risk aversion and environmental beliefs were elicited before the video. After the video, respondents were asked about their acceptance, their risk and benefit perception as well as their affective response to aerosol injection. Finally, altruistic and egoistic values were elicited.

All variables except for trust in government and risk aversion were measured via several items; they are included in the analysis as unweighted, standardized mean scores. The analysis adjusts for the reliability of these exogenous variables via Cronbach's α.

3.3.1. Risk and Benefit Perception

We measured the risk and benefit perception via the respondents' ratings of five specific risks and four specific benefits. The risks and benefits were introduced and explained in the video. Risks (α=.71) were rated on a scale from `negligible' (1) to `very serious' (4). Benefits (α=.85) were rated from `very small' (1) to `very large' (4).

Risks

It changes the amount of precipitation.

It can take away people's motivation to change their lifestyle.

There is the possibility of further unknown and unforeseeable risks.

The abrupt increase of Earth's temperature in case of a sudden stop of SRM can lead to severe problems for humans and the environment.

The use of SRM could cause international conflicts.

Benefits

Global warming is slowed down more quickly than by cutting greenhouse gas emissions.

Massive and irreversible changes in the climate can be stopped before too much damage is done.

It is cheaper than reducing the consumption of fossil fuels.

Even if certain countries do not want to reduce their greenhouse gas emissions, it is possible to stop climate change.

3.3.2. Positive and Negative Affect

We measured positive and negative affect by asking respondents how strongly they felt 11 different positive and negative emotions when thinking about SAI. In line with Midden & Huijts (2009), we

combine worry, fear, sadness, powerlessness, anger, and annoyance into `negative affect' (α=.88) and delight, happiness, satisfaction, hopefulness, and relief into `positive affect' (α=.93). The response scale ranged from `not at all' (1) to `very strongly' (4).

3.3.3. Trust in Government

Trust in government was measured by the question `How much do you trust that the federal government will act in the interest of the environment and the society?' We thus used a broad definition of general trust in good intentions for society and the environment. The 4-point response scale ranged from `do not trust at all' (1) to `trust completely' (4).

3.3.4. Egoistic and Altruistic Values

Egoistic and altruistic values were assessed with the Schwartz Personal Value Questionnaire (PVQ5X) (Schwartz et al. 2012). In the PVQ5X, persons with distinct characteristics, which stand for a specific aspect of a value, are described in one sentence. Respondents had to state their similarity with the person described on a 4-point Likert scale from `dissimilar' (1) to `similar' (4). Each value was measured by 4 items (see Table A-1 in the appendix). Egoistic values contained the aspects social power, wealth, authority, and influential (α=.80). Altruistic values contained the aspects equality, world at peace, social justice, and helpful (α=.74). The items correspond to the items used by De Groot et al. (2013)[6].

3.3.5. Environmental Attitudes

Environmental attitudes were assessed via the facets of the NEP scale. The NEP measures a pro-ecological worldview encompassing perspectives on humankind's relationship with nature and was developed and revised by Dunlap et al. (2000). We used 5 of the instrument's 15 items, each representing one of the NEP's 5 facets: (1) `Humans were meant to rule over the rest of nature.' for anthropocentrism, (2) `Humans will eventually learn enough about how nature works to be able to control it.' for humans' ability to control nature, (3) `The Earth is like a spaceship with very limited room and resources.' for limits to growth, (4) `The balance of nature is very delicate and easily upset.' for the perceived fragility of nature's balance, and (5) `If things continue on their present course, we will soon experience a major ecological catastrophe.' for the possibility of an eco-crisis. The response scale ranged from `strongly disagree' (1) to ` strongly agree' (4).

[6] The paper used an older version of the Schwartz value scale.

An auxiliary factor analysis led to inconclusive results. The Kaiser-Meyer-Olkin-criterion, i.e., the number of eigenvalues larger than 1, supported the existence of one single factor while the scree plot suggested two distinct factors. We use two factors to capture a distinction relevant for SAI: One factor reflects respondents' perspective of humans' relationship with nature, which we call 'control over nature' (α=.63). It is measured by items (1) and (2) on anthropocentrism and humans' ability to control nature. The other factor reflects the perceived state of nature (α=.63), which we call `state of nature'. It is measured by items (3) to (5) on limits to growth, the fragility of nature, and the possibility of an eco-crisis.

3.3.6. Risk Aversion

To assess risk aversion, respondents were asked `Are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?' on an 11-point Likert-scale from `risk averse' (0) to `fully prepared to take risks' (10). This question is used in the German Socioeconomic Panel (GSOEP) and has been shown to correlate well with actual risk taking in several domains (Dohmen et al. 2011). The item was reversely coded for the analysis. Thus, higher values indicate a higher level of risk aversion.

3.3.7. Acceptance

Acceptance was measured via 5 items that capture the acceptance of different types of research and deployment of aerosol injection (α=.88). Participants responded to the following items on 4-point Likert scales from `strongly disagree' (1) to `strongly agree' (4):

> We should cool the Earth by using SRM.
> Scientists should research SRM using theoretical models, simulations and lab experiments.
> Scientists should test SRM using field trials.
> SRM should be used when massive and irreversible changes in the climate system are approaching which cannot be averted otherwise.
> If SRM was possible today, we should use it immediately.

3.4. ANALYSIS

We started the analysis with the initial analytical framework derived in Section 2 (compare Figure 1). Cronbach's alpha was included as a measure for the reliability of the exogenous score variables and thus allowed for error in the measurement of egoistic and altruistic values, control of nature and perceived state of nature (see Cronbach's alpha on the main diagonal in Table 1).

The comparative fit index (CFI) of the initial model was 0.95, indicating a satisfying overall fit of the model (Acock 2013, p. 23). The root mean squared error of approximation (RMSEA) was, however, relatively high at 0.102 indicating an insufficient fit (Browne and Cudeck 1992). The likelihood ratio test was significant ($\chi^2(12)=128.60$; p=0.00). We removed insignificant paths, and tested additional paths. Additional paths were included based on modification indices and theoretical justifications. The likelihood ratio test of the final model was still significant ($\chi^2(22)=78.88$; p=0.00); this indicates that the model does not perfectly reproduce the covariance matrix. The likelihood ratio test can, however, be problematic for complex models because it tests the entire model and can already reject the null hypothesis when only a part of the covariance matrix cannot be reproduced (Backhaus et al. 2011). Therefore, we evaluate the model using additional fit statistics. Both the CFI (=0.98) and the RMSEA (=.045) indicated a close fit (Browne and Cudeck 1992; Backhaus et al. 2011).

Table 1: Pearson's correlation coefficients of exogenous variables; main diagonal: Cronbach's alpha

	egoism	altruism	control over nature	state of nature	risk aversion
egoism	*0.80*				
altruism	-0.06*	*0.74*			
control over nature	0.25***	-0.04	*0.63*		
state of nature	-0.02	0.21***	-0.12***	*0.63*	
risk aversion	-0.16***	0.00	-0.11***	0.01	-
trust	0.21***	-0.04	0.20***	-0.01	-0.05

*Note: * p < 0.10, ** p < 0.05, *** p < 0.01*

Table 1 shows the correlations between these exogenous variables. Egoism and altruism clearly measure different concepts as they are not correlated (-.06*). Egoism is correlated with control over nature (.25***), while altruism is correlated with state of nature (.21***). Egoism is further correlated with risk aversion (-.16***) and trust in government (.21***). These relationships are mirrored in the covariance structure specified in the path model (compare Table 2): Trust and risk aversion were allowed to co-vary with egoism. Trust, risk aversion, and egoism were allowed to co-vary with control over nature while altruism was allowed to co-vary with state of nature. The covariances between the remaining exogenous variables were constrained to zero.

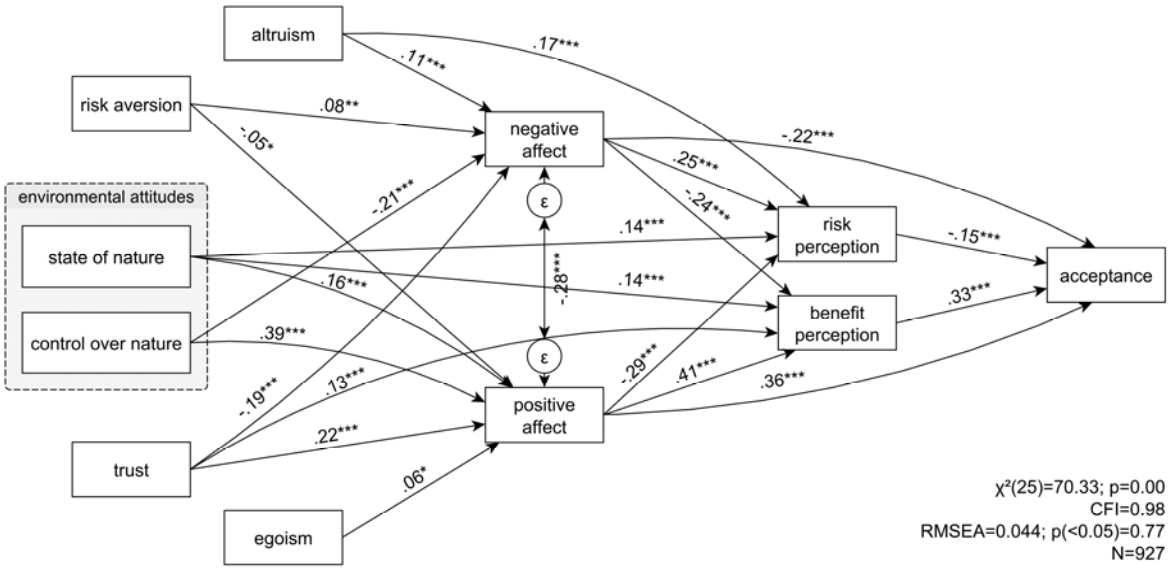
Table 2: Covariance between exogenous variables in path model

			covariance
trust	*	egoism	0.24***
trust	*	control over nature	0.26***
risk aversion	*	egoism	-0.18***
risk aversion	*	control over nature	-0.13***
egoism	*	control over nature	0.34***
altruism	*	state of nature	0.30***
control over nature	*	state of nature	-0.18***

4. RESULTS

The results from the path analysis are displayed in Figure 2. Positive and negative affect, as well as the perception of risks and benefits have a direct effect on acceptance. Furthermore, they mediate the impact of a person's psychological variables on the acceptance of aerosol injection.

Figure 2: Path model explaining acceptance of stratospheric aerosol injection



Note: covariance structure see Table 2.

Some paths of the final model deviate from the initial analytical model. Several paths turned out to be insignificant on the 10-percent level: (1) Risk aversion influences neither risk nor benefit perception. It influences only positive affect (-.05*) and negative affect (.08**). (2) Egoism has no impact on benefit perception and only weakly influences positive affect (.06*). (3) Environmental attitudes are split up into

two categories. For beliefs about humans' control over nature, we do not find the hypothesized influence on risk and benefit perception; they influence only positive and negative affect. Beliefs about the state of nature have no impact on negative affect but have an impact on risk and benefit perception and positive affect. An additional path was included between negative affect and benefit perception (-.24***). The errors of positive and negative affect are correlated (-.28***); while there is no relationship between the errors of risk and benefit perception.

Table 3: Standardized total effects on acceptance

	coefficient	standard error
egoism	0.037*	0.023
altruism	-0.080***	0.017
control over nature	0.333***	0.039
state of nature	0.153***	0.033
risk aversion	-0.045**	0.018
trust in government	0.185***	0.021
negative affect	-0.356***	0.026
positive affect	0.492***	0.025
risk perception	-0.174***	0.026
benefit perception	0.324***	0.024

Affect is the strongest driver in attitude formation (see Table 3). We find that affect influences both risk and benefit perception. While positive affect increases benefit and decreases risk perception, the reverse is true for negative affect. This result is broadly in line with the literature but contrasts the finding of Midden & Huijts (2009) who report no impact of negative affect on the perception of benefits. Affect has a larger influence in attitude formation than perceived risks and benefits. Moreover, positive affect is more influential in the evaluation of the technology than negative affect. This finding supports previous results of Huijts et al. (2014).

Both benefit perception and risk perception influence acceptance significantly. Furthermore, benefit perception is a stronger predictor of acceptance than risk perception. This finding is consistent with previous findings on attitude formation (Siegrist et al. 2007; Terwel et al. 2009; De Groot et al. 2013). Accounting for the affective pathway, Midden & Huijts (2009) previously found no effect of risk perception on acceptance. In our data, risk perception remains a direct antecedent of acceptance. Our data further show that benefit and risk perception have different roles in attitude formation, both as

determinants and mediating factors. Hence, they should be included as distinct concepts in the analysis of technology acceptance.

Apart from direct cognitive or affective influences on acceptance, trust in government has a strong influence in our model. The data show that trust determines acceptance through direct influences on positive and negative affect. It also directly influences the perception of benefits but not the perception of risks. These findings confirm results of Midden & Huijts (2009) and Montijn-Dorgelo & Midden (2008). In contrast to our finding, data of Huijts et al. (2014) suggested that the influence of trust is not mediated by negative affect.

Altruistic and egoistic values determine a person's focus in evaluating risks and benefits. Our data show, for the first time, that their influence on risk and benefit perception is mediated by affect. Altruistic and egoistic values have different impacts. Altruistic values directly increase both negative affect and risk perception. By contrast, egoistic values directly increase only positive affect, and only weakly so. The direction of the total effect of values is in line with the literature. Also previously, altruistic values were shown to increase risk perception and decrease acceptance (Slimak and Dietz 2006; Whitfield et al. 2009; De Groot et al. 2013) and egoistic values were shown either to have no effect (Slimak and Dietz 2006; Whitfield et al. 2009) or to increase benefit perception and acceptance (De Groot et al. 2013; Corner and Pidgeon 2014).

If technologies have both environmental benefits and environmental risks, the effect of environmental attitudes on the acceptance of these technologies is potentially ambiguous. Our model takes a more nuanced look at the effect of environmental attitudes by splitting up the NEP into two separate factors: Firstly, the perceived control over nature, which captures the belief in the human capacity to control and to rule over nature; Secondly, the perceived state of nature, which captures limits to growth, the fragility of nature, and the possibility of an eco-crisis. Beliefs about the control over nature are among the strongest determinants of acceptance, while the impact of beliefs about the state of nature is less pronounced. Furthermore, these factors affect acceptance differently. Control over nature reduces negative affect and enhances positive affect, but does not directly influence risk or benefit perception. Its effect is unambiguous. By contrast, beliefs about the state of nature have a more ambiguous impact. They intensify both risk and benefit perception, plausibly because SAI can be seen both as a cure and a threat to the environment.

In sum, we show that environmental attitudes enter attitude formation. They do so both via affect and via risk and benefit perception. Previous studies did not find a strong impact of environmental attitudes on risk and benefit perception of nuclear power (Whitfield et al. 2009; De Groot et al. 2013), but did not take affective pathways into account. We also find that the impact of both NEP factors is large compared to the impact of altruistic and egoistic values. This contrasts findings for acceptance of nuclear power but mirrors findings for the perception of ecological risk (Slimak and Dietz 2006).

Our results also highlight the benefit of taking a differentiated look at the different facets of environmental attitudes; they confirm previous results that pointed toward nuanced effects of the NEP's different facets on technology acceptance (Sjöberg 2003; Merk et al. 2015). However, the relevance of beliefs about humans' capacity and right to rule over nature likely varies with the perceived scope of the technologies' interference with nature.

5. CONCLUSION

We proposed a technology acceptance framework that captures the interplay between values, attitudes, affect, risk and benefit perception, and the acceptance of new technologies. Using data from a large survey, we successfully tested the framework analyzing the determinants of the acceptance of stratospheric aerosol injection.

Our data show evidence of both affective and cognitive pathways in attitude formation. Acceptance is directly influenced by positive and negative affect, as well as perceived risks and benefits. People are, however, more strongly guided by affect than by their perception of risks and benefits. Furthermore, affect is the most important mediator between psychological variables – such as trust, values, and attitudes – and acceptance. All variables influence acceptance partly through an altered affective evaluation. Only trust, altruism, and state of nature change the perceived effects of the technology not only via affect but also directly.

Our study adds to a growing literature about the importance of affect in guiding judgement (Zajonc 1980; Finucane et al. 2000; Loewenstein et al. 2001; Lerner et al. 2015). In contrast to this literature, we not only show the relevance of affect, but also how affect is influenced by a person's characteristics. We show that it is in part shaped by a person's values, attitudes, trust, and risk aversion. Hence, affect, as automatic emotional reaction, seems to express a person's core values and attitudes applied to a specific situation. In this sense, it is essential to and supports rational action. Our result also speaks to literature

that shows reductions in the quality of decisions when affective evaluations are impaired (Wilson and Schooler 1991; Wilson et al. 1993; Damasio 1994; Bechara et al. 1997).

In our survey, we provided neutrally framed, unbiased information. Only few respondents had heard about aerosol injection before the survey and there has not yet been a broad public discourse about the topic. Hence, the effects we found are likely to be characteristic of attitude formation toward a topic of low familiarity. Once a technology becomes more mature, the relevance of the factors influencing perception might shift. This might, for example, be reflected in a reduced impact of the affective component. Future research should thus test our model with more familiar technologies to evaluate the stability of the pathways indicated by our study. Furthermore, future studies might include experimental variation or longitudinal data to further substantiate causality of the relationships.

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Appendix

Table A-1: Items measuring egoism and altruism from Schwarz et al. (2012), Cronbach's α

In the following we describe different people. Please state for each case how similar or dissimilar the described person is to you.	dissimilar (1) - similar (4)
Egoism (α=.80)	
She wants people to do what she says.	
Being wealthy is important to her.	
It is important to her to be the one who tells the others what to do.	
It is important to her to be the most influential person in any group.	
Altruism (α=.74)	dissimilar (1) - similar (4)
She thinks it is important that every person in the world have equal opportunities in life.	
She works to promote harmony and peace among diverse groups	
Protecting society's weak and vulnerable members is important to her.	
Caring for the well-being of people she is close to is important to her.	