The More You Know:

The Role of Knowledge in Public Acceptability of Climate Change Mitigation Pathways

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Abstract

Traditionally, the information deficit model has held that attitudes towards science-based policy are dependent upon public understanding of science. In the field of scientific communication, the ability to change attitudes through education has appealed to policymakers because of its simplicity. Our study analysed the link between knowledge of climate change and the acceptability of two climate change mitigation pathways, and how this relationship was affected by perceiving climate change as a risk. These climate change mitigation pathways were made by the Intergovernmental Panel on Climate Change to map proposed changes to current lifestyle and energy systems. They aim to mitigate the climate-related risks caused by global warming. Little research has been done on the attitudes towards policy that encompasses widespread changes to many aspects of modern life. To effectively mitigate the risks associated with climate change, these changes are necessary, and the attitudes held by the public towards them are important. We conducted a survey on several predictors of acceptability and found that climate change knowledge did have a significant relationship with acceptability of both pathways, as did risk perception. No evidence was found of the relationship between knowledge and acceptability being affected by how much people perceived climate change as a risk. This study contributes to the essential and ongoing research into what makes people willing to accept the changes to lifestyle and energy systems necessary to tackle the threat of climate change.

Keywords: acceptability, climate change mitigation pathways, information deficit model, knowledge

The More You Know

Since pre-industrial times (1850 – 1900), the average global temperature has risen approximately 1℃. In the next 10 – 30 years, that figure is likely to rise to 1.5℃. In a world at that temperature, climate-related risks (extreme temperatures, cyclones, species extinctions, sea level rise, etc.) will be more extreme and happen more often. The severity of these future risks depends on the efforts made to mitigate and adapt to the changes we are making to the climate (Pörtner, et al., 2022). The IPCC (Intergovernmental Panel on Climate Change), a United Nations panel of experts, has proposed several ways to transition the lifestyle and energy systems we currently use into systems that address the changes that are sure to come. These pathways, if followed, could limit global warming to 1.5 degrees higher than pre-industrial levels. The extent to which the public is willing to accept large-scale changes to energy and lifestyle systems is essential to the success of those changes (Allen & Chatterton, 2013, Bertsch, et al., 2015; Bertsch, et al., 2016).

Public acceptability of climate change mitigation pathways is defined as an attitude towards the pathways – that is, an evaluative judgement (Albarracin & Johnson, 2018) of the extent to which they are found to be acceptable, good, and necessary. Previous research has been conducted on specific policies, energy technologies and behaviours related to climate change, and has found relations between public acceptability and age, climate change risk perception, gender, knowledge, personal values, perceived effectiveness, and perceived fairness of policy (Allum, et al., 2009, Bertsch, et al., 2016, Huijts, et al., 2012, van der Linden, 2014).

The pathways proposed by the IPCC are broader than any specific policy, technology, or behaviour. They cover a wide range of ways to mitigate and adapt to climate change (Pörtner, et al., 2022). Since these pathways are new, little research has been conducted on the acceptability of such broad scenarios. Understanding the variables that contribute to an

acceptability evaluation of such a pathway is the subject of this paper. This is important as one way or another, our current energy and lifestyle systems will take us down the path to 1.5℃ and it is crucial that a pathway is chosen and intentionally followed. In this paper, two pathways are focused on (pathways 2 and 4, proposed by Pörtner, et al., (2022)). They differ in a number of ways (see Appendix A). Those with the power to implement these changes are often elected, which stresses the need for an informed public.

The Information Deficit Model

Traditionally, the information deficit model has been used to interrogate the attitudes of the public through the lens of their lack of scientific knowledge (Gross, 1994). It posits that attitudes can simply be changed through education, and, accordingly, has been very appealing to policy makers. In this paper, the information deficit model will be applied, investigating the relationship between knowledge about climate change and public acceptability of climate change mitigation pathways. Additionally, climate change risk perception will be examined as a possible moderator for this relationship. First, the information deficit model will be critically reviewed, followed by literature on the role of risk perception and how it could be integrated into the model. Lastly, exploratory hypotheses on the roles of other variables (age, gender, personal values, perceived effectiveness, and perceived fairness of policy) will be discussed. Afterwards, an empirical study to test these theories will be presented.

The information deficit model is often criticised by social psychologists, as the relationship between knowledge and attitudes is often tenuous (Allum, et al., 2008). Moreover, different operationalisations of the variable “knowledge” may measure entirely different constructs and thereby have different relationships with public attitudes, which can confound the findings. Research often relies upon self-report measures of participants’ subjective knowledge (van der Linden, 2014). These studies find mixed results. For example, in the field of climate change risk perception, Brody, et al., (2008) found no evidence for a

relationship between risk perception and subjective knowledge, whereas Kellstedt, et al., (2008) found evidence for negative relationship, and other studies (Malka, et al., 2009, Menny, et al., 2011) found a significant positive relationship that varied across demographic groups. Moreover, these results, based on subjective measures, tend to be less reliable than studies that use objective measures, which test how accurate participants' knowledge of a given subject is (van der Linden, 2014). Critics of the information deficit model often propose that there are better explanatory variables for attitudes towards science and technology, (Allum et al., 2008), and that the information deficit model requires more variables to adequately explain public attitudes (Ellis, et al., 2009; Haggett, 2011; Wolsink, 2011). Knowledge certainly plays some role in attitude formation and the quality of attitudes (Bidwell, 2016), but not alone.

Climate Change Risk Perception

Studies have shown a significant, positive relationship between knowledge and climate change risk perception (van der Linden, 2014). Risk perception has separately shown a reliable relationship to attitudes and pro-environmental behaviours (Kothe, et al., 2019). The relationship between these three variables (objective knowledge, climate change risk perception and public acceptability) is the focus of this study, as while knowledge may only tenuously predict attitudes, risk perception - which has a firmer relationship - may be a moderating variable. This follows from the reasoning that people who perceive climate change as a risk are more likely to educate themselves on the topic (Egea & de Frutos, 2013, Kahlor, et al., 2006, Whitmarsh, 2008), thereby increasing their knowledge of climate change in comparison to those who do not perceive it as a risk, and consequently scoring higher on acceptability. Van der Linden (2014) found that knowledge explained 9.3% of variance in risk perception.

The primary hypothesis of this paper is that knowledge of climate change predicts the acceptability of two climate change mitigation pathways, with an additional moderation effect expected to be as follows: Objective knowledge is expected to have a positive correlation with acceptability of pathway 2, and this relationship is **stronger** if risk perception is higher, because it prioritises avoiding the most extreme climate-related risks (see Figure 1). Objective knowledge is also expected to have a positive correlation with acceptability of pathway 4**,** but this relationship is **weaker** if risk perception is higher, because it allows for more global warming and therefore more extreme climate-related risks (see Figure 2).

Explorative Hypotheses

As mentioned earlier, previous research on specific technologies, policies and behaviours has found relations between public acceptability and age, climate change risk

Figure 1

Proposed Moderation for Pathway 2

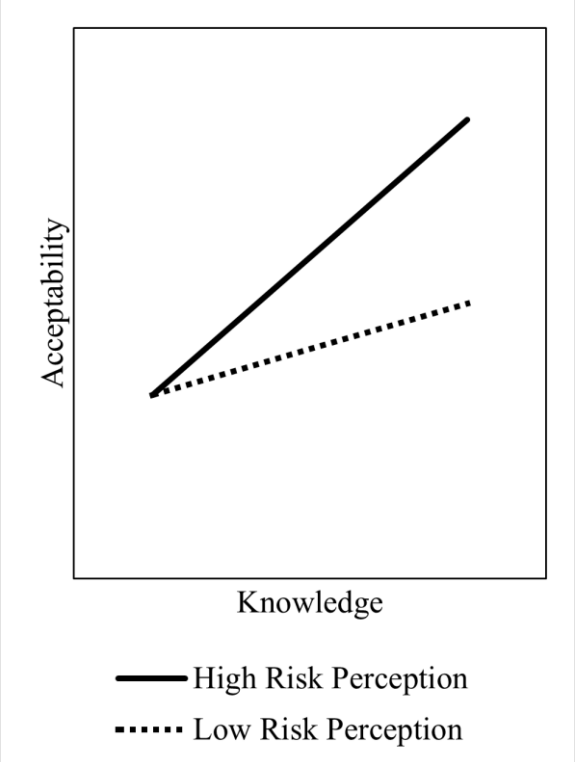
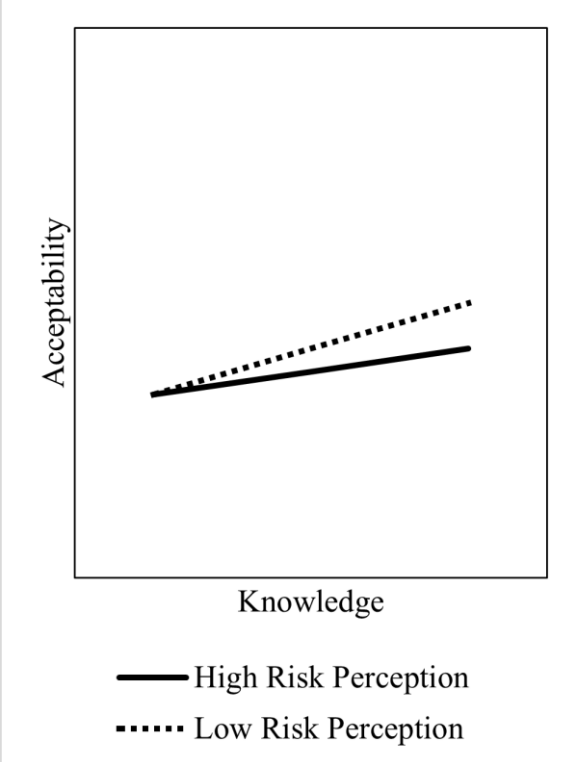


Figure 2

Proposed Moderation for Pathway 4



perception, gender, knowledge, personal values, perceived effectiveness, and perceived fairness of policy (Allum, et al., 2009, Bertsch, et al., 2016, Huijts, et al., 2012, van der Linden, 2014). In order to effectively integrate this new research into the existing body of research, these variables will be included in a secondary analysis as controls for the relationship of knowledge on acceptability, exploring the amount of variance uniquely explained by knowledge.

Additionally, the relationship between personal values and climate change knowledge will be explored – specifically biospheric, egoistic, and altruistic values. Personal values have been used in research on climate change risk perception (van der Linden, 2014) and social norms (Chen, 2014), and have been shown to predict pro-environmental behaviour. This is of particular interest, as a primary difference between the IPCC's pathways is large-scale behavioural change, particularly to diet and transportation (Pörtner, et al., 2022). Until now, no research has been done on the link between personal values and objective knowledge.

Current Study

In sum, the aim of this study is to find out if acceptability of two climate change mitigation pathways can be explained by objective knowledge about climate change, and if this relationship is moderated by perceiving climate change as a risk. By looking at current, real-world proposals that cover a broad range of lifestyle and energy changes, this research will have practical use in understanding public acceptability of climate change mitigation policies, in addition to theoretical use in discourse on the information deficit model.

Method

Participants

292 participants were recruited in total (96 male, 166 female, 5 other, 25 unknown, M_{age} = 24.11, SD = 9.13), using snowballing and the SONA system, an online platform for

managing research and recruiting participants. Snowballing was conducted primarily on social media, sharing a short description of the study (see Appendix B) and a link to the survey. The SONA system was used to recruit from students at the faculty of behavioural and social sciences of the University of Groningen, who were compensated with SONA credits. Due to the online nature of the snowballing, the sample was multinational.

Materials

A 75-item survey was constructed (see Appendix C. Note that in the survey Pathways 1 and 2 are referred to as Pathways A and B respectively.) and hosted using a survey webapp, Qualtrics (https://www.qualtrics.com). It included scales on objective knowledge, climate change risk perception, perceived effectiveness, costs and benefits, and distributional fairness of pathways, acceptability of pathways and a choice between two pathways. It also included a series of free-response questions.

Objective knowledge was evaluated using items from Leiserowitz, Smith, & Marlon (2010), using only questions for which there was an answer with a strong scientific consensus. Scores were based on how many items each participant answered correctly from a list of 5 multiple-choice items on climate change knowledge. Each answer was coded as correct or incorrect, so a participant could have a score of 1 – 5. Following van der Linden (2014), these were differentiated into items on the causes, impacts, and responses to climate change. Likely due to these differences in topic between items, Cronbach's alpha was found to be very low at .33. Alternative explanations could be a low number of items, and only three response options. There was no single item that could be removed to significantly improve Cronbach's alpha.

Acceptability was assessed on a 7-point scale with four items per pathway, measuring to what extent respondents find each pathway acceptable, good, and necessary. These items were adapted from Perlaviciute, et al. (2021), Cronbach's alpha = .86.

To measure climate change risk perception, we used six items adopted from Rainear & Christensen (2017). They can be divided into three items on threat vulnerability and three items on threat severity. These items used a seven-point Likert scale and were conceptualised in accordance with the protection motivation theory (PMT). Cronbach's alpha = .85.

Scales on perceived effectiveness were adapted from Wan, et al. (2014), and were found to have a Cronbach's alpha of .79. Items on costs and benefits were adapted from van Valkengoed, et al., 2021, but were not analysed in this thesis. Perceived distributional fairness was analysed using items taken from Larsson, et al. (2020), which had a Cronbach's alpha of .78. Finally, scales on biospheric, egoistic, and altruistic values were adapted from Bouman, et al. (2018), and were found to have a Cronbach's alpha of .724.

All data was interpreted using IBM SPSS Statistics 26.

Design and Procedure

The survey was presented exclusively online, with items presented in an order intended to decrease priming effects (for example, presenting questions on risk perception first, before items involving the consequences of climate change or participants personal values). Before any items were presented, each participant was presented with a brief description of the research design, gave their informed consent about their right to withdraw from participation, how their data would be treated and how they will receive no compensation (or, for the SONA pool, compensation in the form of SONA credits) for their time. At all stages, we followed the confidentiality guidelines based on the Netherlands code of conduct for research integrity.

The survey consisted of three sections. Firstly, questions on climate change risk perception and knowledge, as well as participants' values were asked. This was followed by a briefing on our two chosen IPCC pathways (pathways 2 and 4, referred to as pathways A and B in the survey). To progress beyond this briefing, participants had to respond correctly to questions about the two pathways. Once their understanding of the pathways was ensured,

participants were asked questions on how effective they understood each pathway to be in response to climate change, and the perceived costs, benefits, and distributional fairness of each pathway. Finally, the questionnaire closed with evaluations of how acceptable each pathway was, which pathway a participant would choose, and a series of free-response questions. In total, the survey consisted of 75 items and took a median of 14 minutes to complete.

Results

Primary Results

The average participant answered 3.72 (*s.d.* = 0.96) out of a possible 5 questions correct, which is their objective knowledge score. Perception of risk was found to average at 5.96 (*s.d.* = 0.88) on a scale of 0 – 7. Their acceptability of pathway 2 averaged at 6.72 (*s.d.* = 1.24) on a scale of 0 – 7. In comparison, their acceptability of pathway 4 averaged at 3.74 (*s.d.* = 1.70) on a scale of 0 – 7. Correlations of these primary variables (see Table 1) revealed that all variables had significant correlations with each other, and that acceptability of pathway 2 was positively correlated with knowledge and risk perception, whereas acceptability of pathway 4 was negatively correlated with them.

To test the hypothesis that, in accordance with the information deficit theory, knowledge correlates positively with acceptability, a linear regression analysis was conducted (see Tables 2 and 3). For pathway 2, a strong relationship ($R = .435$, $F(1,224) = 52.17$, $p < .001$) was found, which explained a moderate portion of the total variance in acceptability ($R^2 = .189$). For pathway 4, a weaker relationship ($R = .244$, $F(1,224) = 14.16$, $p < .001$) was found, which explained only a modest amount of the total variance in acceptability ($R^2 = .059$). Both models were found to be linear. No evidence was found that suggested the residuals were not independent and normally distributed, with constant variance.

To test whether risk perception moderates the relationship between knowledge and acceptability of pathways 2 and 4, two multiple regression analyses were conducted, with objective knowledge and climate change risk perception as predictors of acceptability for pathways 2 and 4 respectively (see Tables 4 and 5). An interaction variable was computed by multiplying the standardised variables of knowledge and risk perception but was not found to be significant in either analysis.

With the interaction variable excluded, the model was found to be significant when predicting acceptability of pathway 2, $R^2_{Adjusted} = .300$, $F(2, 223) = 49.32$, $p < .001$. As well as when predicting acceptability of pathway 4, $R^2_{Adjusted} = .100$, $F(2, 223) = 13.47$, $p < .001$. However, these results should be interpreted with caution as the residuals for climate change risk perception and acceptability of pathway 2 were left-skewed.

There was no evidence of multicollinearity between objective knowledge and climate change risk perception for both pathways. The model was found to be linear in both cases. The residuals were independent and normally distributed for both pathways, but the assumption of homoscedasticity was violated for pathway 2.

Exploratory Results

To extend on these findings, an exploratory hypothesis aimed to see how controlling for other variables affected the relationship between knowledge and acceptability (see Tables 6 and 7). This called for a hierarchical regression of objective knowledge onto each pathway, with control variables. When controlling for age, gender, climate change risk perception, perceived effectiveness, biospheric, egoistic, and altruistic values, and perceived distributional fairness, objective knowledge did only explain little additional variance over and above the variance explained by the control variables for pathway 2 ($\Delta R^2 = .018$, $p = .003$) and explained no significant change for pathway 4 ($\Delta R^2 = .001$, $p = .557$). No evidence was found for a violation of linearity for either pathway and in both cases, no evidence was found that

suggested the residuals were not independent and normally distributed, with constant variance. No evidence of multicollinearity was found.

A multiple regression analysis was conducted to explore which values correlate with objective knowledge of climate change (see Table 8). Biospheric values were found to have a weak positive relationship with objective knowledge ($R = .30$, $p = .005$), indicating that people with higher biospheric values had higher knowledge of climate change. A similar relationship was found for altruistic values ($R = .55$, $p < .001$), suggesting that participants with higher altruistic values also had higher knowledge of climate change. No significant relationship was found between egoistic values and objective knowledge of climate change, $p = .754$. There was no evidence for violations of linearity, or for the assumptions of constant residuals, normally distributed residuals, and independent residuals. No evidence for multicollinearity was found between knowledge and biospheric values.

Discussion

Supporting our primary hypothesis, participants with high objective knowledge of climate change were found to also score highly in acceptability of both pathways, and the correlation was stronger than past research has found (Egea & de Frutos, 2013, Simis, et al., 2016, van der Linden, 2014). No evidence was found in support of our hypothesis that risk perception affected the relationship between knowledge and acceptability. The proportion of variation in acceptability scores uniquely explained by knowledge was found to be very low in comparison to the variation explained by demographic variables (age, gender and personal values) and perceptions of climate change risk, pathway effectiveness and pathway fairness. This result aligns with common criticism of the information deficit model (Bidwell, 2016, Simis, et al., 2016) but does not detract from the link between knowledge and acceptability. Participants with high altruistic and biospheric values were also found to have high

knowledge of climate change, whereas no relationship was found between egoistic values and knowledge.

Strengths of Our Study

Our study focused on current, relevant climate mitigation policy, proposed this year by the IPCC, a world-renowned authority on the topic (Pörtner, et al., 2022). Moreover, the climate change mitigation pathways covered worldwide changes to lifestyle and energy systems, as opposed to a narrower perspective – for example, local attitudes towards the construction of wind farms in a particular place. The portion of participants recruited through snowballing were from all around the world, which may help the results of our study generalise more than those of a local study would.

Using an objective measure of knowledge as opposed to a subjective measure such as self-report questions has been shown to improve the reliability and validity of results (van der Linden, 2014). Additionally, basing the study on the well-established and traditional information deficit model (Gross, 1994) makes it far easier to incorporate into the existing body of research, and understand in the context provided by other studies on the same subject.

Limitations of Our Study

The low internal consistency of our questions on knowledge is not ideal and shows that they may not be evaluating the same general construct – knowing about the effects of deforestation, for example, does not mean that a given participant would know about the rate of change of glacial melting. With a longer question bank, a higher score of consistency would likely emerge, making it a better measure of objective climate change knowledge. If this study were to be replicated, a more internally consistent scale should be used.

The data on risk perception and acceptability of pathway 2 were both left-skewed, showing that participants reported higher values than a normal distribution would predict. This violated the assumption of normality, and statistical transformations were attempted to

make the data into a stronger fit. These did not make a noticeable difference, so they were not implemented, and data was left in its untransformed state, where it is easier to interpret.

While the benefits of an international sample have been discussed above, it assumes that people across the world will answer questions in roughly the same way. While our findings support this assumption, participants from different countries may still have been distinctly different. Since it was not relevant to any major hypotheses, we did not analyse data on participants' location, so whether certain respondents were members of distinct populations remains unknown.

Due to the inconsistency in previous research on the relationship between knowledge and acceptability (Allum, et al., 2008, Brody, et al., 2008, Kellstedt, et al., 2008), the strength of the relationship between knowledge and acceptability could not be estimated, and no statistical power analysis was conducted prior to the survey being published. With 292 participants (though a portion did not finish the survey), power was assumed to be sufficient to find a relationship, if there was one.

Theoretical Implications

This study provides compelling evidence in favour of the information deficit model, (Gross, 1994). It challenges the common criticism that the relationship between knowledge and attitudes is weak (Bidwell, 2016, Simis, et al., 2016). However, the lack of unique variance in acceptability explained by knowledge adds a layer of nuance to these findings, as it implies that people are influenced by knowledge of climate change in much the same way that they would be influenced by other variables, for example, how effective a participant perceives a climate change mitigation pathway to be.

The way that risk perception did not affect the relationship between knowledge and acceptability is not unprecedented, as Kahlor, et al. (2006), found that people who scored highly on knowledge and more fully understood climate change had more stable attitudes and

threat perceptions. Whitmarsh (2008), found the inverse – that participants who perceived climate change as a higher threat relied less on how much they knew about the topic when forming an attitude. That said, the lack of a moderation effect is contradictory to the findings of Egea & de Frutos (2013), who found that the relationship between environmental knowledge and positive attitudes varied largely across moderators, one of which was risk perception. In their study, perceiving climate change as a higher threat led to a stronger relationship between knowledge and positive attitudes towards climate change mitigation policies. They found no evidence of this moderation for the relationship between knowledge and negative attitudes towards climate change mitigation policies, however. Our findings contribute to this ongoing research by providing evidence against a moderation.

The exploration into which personal values – altruistic, biospheric or egoistic – correlate with knowledge of climate change opens the door for future research on the topic and is very relevant to discourse on which types of people understand climate change.

Practical Implications

The results of this study can be applied most practically in public communications. Understanding that both risk perception and knowledge vary with acceptability of climate change mitigation policy, but do not interact with each other may be helpful to those who wish to persuade the public one way or another. An approach to public communication that stresses climate-related risks that are in store for our planet, alongside promoting education, would be doubly effective, and one would not need to be concerned about one message affecting the other.

Which lines of thinking cause measurable changes in attitudes towards climate change mitigation policies are highlighted by the control variables that explained more unique variance in acceptability than knowledge. Demographic variables and perceptions of climate change risk, pathway effectiveness and pathway fairness all cover much of the same ground in

terms of explaining variations in pathway acceptability. So, depending on who the audience is, additional information may not add much to a call for support of a climate change mitigation policy. Certain people may actively avoid education about climate change because they prefer to hold an opinion opposed to the scientific consensus. These opinions are often spread through misinformation and scare tactics, changing perceptions of effectiveness and fairness, and diverting perceptions of risk. If providing the public with information does not affect the variability in their attitudes as much as other approaches, does this mean that more underhanded methods should be used? Does the end, a population largely in support of climate change mitigation policy, justify the means? The information deficit model may not be perfect, but it may be a more moral model than alternatives.

Conclusion

Our study aimed to find out if acceptability of two climate change mitigation pathways can be explained by objective knowledge about climate change, and if this relationship is moderated by perceiving climate change as a risk. The findings support the traditional information deficit model, while highlighting the role of potential other variables that contribute to an acceptability evaluation. Knowledge of climate change and climate change risk perception were shown to explain differences in acceptability of the pathways for future energy systems proposed by the IPCC. All in all, this study shows what questions a person asks when making such an evaluation. How dangerous is climate change, and how effective are the policies proposed by the scientific community or policymakers?

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Tables

Table 1

Correlations of Primary Variables

Variable	1	2	3	4
1. Knowledge	-			
2. Risk Perception	.384*	-		
3. Acceptability, Pathway 2	.437*	.485*	-	
4. Acceptability, Pathway 4	-.241*	-.296*	-.273*	-

n = 226

*$p < .001$

Table 2

Linear Regression: Knowledge on Acceptability for Pathway 2

Effect	Estimate	*SE*	95% CI	
			LL	*UL*
Constant	4.63*	.297*	4.053	5.22
Objective Knowledge	.557*	.077*	.406	.709

n = 223

*$p < .001$

Table 3

Linear Regression: Knowledge on Acceptability for Pathway 4

Effect	Estimate	*SE*	95% CI	
			LL	*UL*
Constant	5.33*	.441*	4.457	6.19
Knowledge	-.424*	-.241*	-.649	-.199

n = 223

*$p < .001$

Table 4

Moderator Analysis: Knowledge and Risk Perception on Acceptability for Pathway 2

Effect	Estimate	*SE*	95% CI	
			LL	*UL*
Constant	2.72*	.598*	1.53	3.90
Risk Perception	.470*	.094*	.285	.655
Knowledge	.329*	.081*	.169	.490
Interaction	-.082**	.050**	-.180	.015

n = 221

*$p < .001$

**$p = .097$

Table 5

Moderator Analysis: Knowledge and Risk Perception on Acceptability for Pathway 4

Effect	Estimate	*SE*	95% CI	
			LL	*UL*
Constant	8.43*	.937*	6.58	10.3
Risk Perception	-.569*	.147*	-.859	-.278
Knowledge	-.334*	.127*	-.585	-.082
Interaction	-.128**	.078**	-2.81	0.25

n = 221

*$p < .05$

**$p = .10$

Table 6

Hierarchical Regression Analysis: Knowledge and Controls on Acceptability of Pathway 2

Predictors	Acceptability of Pathway 2		
	B	R^2	ΔR^2
Step 1: Control Variables		.568*	
Step 2: Objective Knowledge	.165*	.586*	.018

n = 222

*$p < .005$

Control Variables: Age, gender, climate change risk perception, perceived effectiveness, biospheric, egoistic, and altruistic values, and perceived distributional fairness.

Table 7

Hierarchical Regression Analysis: Knowledge and Controls on Acceptability of Pathway 4

Predictors	Acceptability of Pathway 4		
	B	R^2	ΔR^2
Step 1: Control Variables		.544*	
Step 2: Objective Knowledge	-.033**	.545**	.001

n = 222

*$p < .005$

**$p = .557$

Control Variables: Age, gender, climate change risk perception, perceived effectiveness, biospheric, egoistic, and altruistic values, and perceived distributional fairness.

Table 8

Multiple Regression: Personal Values on Knowledge

Table 8

Effect	Estimate	*SE*	95% CI	
			LL	*UL*
Constant	1.35*	.547*	.273	2.43
Biospheric Values	.229*	.066*	.099	.358
Altruistic Values	.200*	.090*	.023	.377
Egoistic Values	-.040**	.058**	-.155	.075

n = 221

*$p < .05$

**$p = .496$

Appendix A

The pathways proposed by the IPCC can be broken down into pathways that "overshoot" the target of 1.5℃, then bring the temperature back down, and pathways with "no or limited overshoot." Significant warming beyond 1.5℃ may bring changes that we would not be able to reverse (Pörtner, et al., 2022), even if we can reverse the warming itself.

The two proposed pathways focused on in this paper – Pathways 2 and 4 – allow for different amounts of overshoot. Pathway 2 endeavours to limit overshoot to a maximum of 1.6°C, thereby cutting off global warming before the effects of climate change pass a "tipping point." Pathway 4 allows warming to go beyond 1.6°C, risking higher effects of climate change but planning to mitigate these effects as much as possible through use of future technologies. Both pathways aim to return to 1.5℃ by the end of the 21st century (Pörtner, et al., 2022).

The two pathways also differ in their approaches to reaching a stable temperature. Pathway 2 expects policy implementation and transitions to future energy production systems to be extremely fast. Pathway B expects these processes to be much slower, resulting in much more global warming. To bring the temperature back down, this pathway involves carbon capture, a process by which CO2 is removed from the atmosphere and stored in the ground. While the overshoot in temperature will be reversed, many effects of overshooting cannot be. Importantly, however, the economic growth and lifestyle we currently experience would be uninterrupted.

Appendix B

Me and my team are conducting a study for our bachelor thesis. It is about attitudes towards future energy systems and the related consequences.

Between 2030 and 2050, global warming is likely to rise to 1.5 degrees above pre-industrial levels. We are looking at different theoretical pathways towards this state, created by the IPCC.

All of your data and answers will be handled confidentially. We would appreciate it if you could take 10 minutes to fill it in :)

Appendix C

Acceptability of 1.5°C Pathways
"Your opinion about different climate change mitigation scenarios"

Why do I receive this information?
You are receiving this information because we would like to invite you to take part in this research to fill out a set of questionnaires. We will ask you about your opinion regarding certain scenarios that depict ways in which climate change could be limited to 1.5 degrees. This research will be conducted over the course of the second semester, starting in April and ending in June. The research plan has been evaluated by the ECP (ethical committee for psychology) The research is conducted by the Bachelor student group number 38: Katharina Gebhard, Stina Held, Nathan Mccabe, Maria Reinstrom, and Rebecca Schulz. They are supervised by Robert Görsch, in the name of the department of Environmental Psychology and the University of Groningen.

Do I have to participate in this research? Participation in the research is voluntary. However, your consent is needed. Therefore, please read this information carefully. Ask all the questions you might have, for example because you do not understand something. Only afterwards you decide if you want to participate. If you decide to not participate, you do not need to explain why, and there will be no negative consequences for you. You have this right at all times, including after you have consented to participate in the research.

Why this research?
The purpose of the present research is to see which future scenarios people prefer and why.

What do we ask of you during the research?
First, you will be asked for consent to participate. Next, you will be asked to fill out some questionnaires about your personal values, and your opinions on climate change. Subsequently, you will be asked to read short descriptions of two different climate change mitigation scenarios. Here, we would like to learn more about your perceptions of these technologies. The questionnaire is expected to take you roughly 15 minutes.

What are the consequences of participation?

Participation in this research has no direct benefits for you. However, you will be helping the psychology department with their research, which may give meaningful insights as to the stances of the general public on certain issues, as well as contributing to the scientific output of the university. The costs to you as a participant will be in the form of your time. There is the risk of inadvertent identification of you as an individual participant based on the data we are collecting. However, we will only collect very little personal data, and hence the risk is low.

How will we treat your data?
Your data will be treated confidentially. Your data, in aggregate, may be used for the purposes of scientific publication(s). The type of data that will be collected is questionnaire data, collected online through a Qualtrics survey. The data will be handled in confidence and be protected in accordance with university codes and the GDPR. Since we will not collect any data that makes you directly identifiable (e.g., IP address, Email address, or name), we cannot give you access, or means to rectify and/or erase your personal data after your participation. The pseudomized and de-identified data may be stored indefinitely on the secure university servers.

What else do you need to know?
You may always ask questions about the research: now, during the research, and after the end of the research. You can do so by emailing r.goersch@rug.nl. Do you have questions or concerns regarding your privacy, or regarding the handling of your personal data? For this you may also contact the Data Protection Officer of the University of Groningen: privacy@rug.nl. As a research participant you have the right to a copy of this research information. Do you have questions or concerns regarding your rights as a research participant? For this you may also contact the Ethics Committee of Psychology of the University of Groningen: ecp@rug.nl.

Q1 Informed consent
By answering “yes” to the following question, you are explicitly giving your informed consent to participate and agreeing to the following:

- I have read the information about the research.
- I understand what the research is about, what is being asked of me, what consequences participation can have, how my data will be handled, and what my rights are.
- I consent to the processing of my personal data.
- I understand that participation in the research is voluntary.
- I myself choose to participate.
- I can stop participating at any moment.
- If I stop, I do not need to explain why.
- Stopping will have no negative consequences for me.

I consent to participate in this study

- Yes (1)
- No (2)

Skip To: End of Survey If consent to participate in this study = No

Thank you for participating in this study!
Please read all questions carefully, there are no right or wrong answers. We are interested in your personal point of view. All responses to this questionnaire are confidential. Please answer all questions.

Q2 To begin with, we would like to ask you to provide some general information about yourself by answering the two questions below.

Q3 What is your gender?

- Male (1)
- Female (2)
- Other (3)
- Prefer not to say (4)

Q4 What is your age?

_____

In this first part of the survey, you will be asked to give answers to general matters in connection to climate change. Take your time with the answers and have fun!

Q5 To what extent do you agree with the following statements?

	Strongly disagree (1)	Disagree (2)	Somewhat disagree (3)	Neutral (4)	Somewhat agree (5)	Agree (6)	Strongly agree (7)
Climate change will have negative consequences (1)	•	•	•	•	•	•	•
The negative impact of climate change is severe (2)	•	•	•	•	•	•	•
The thought of climate change scares me (3)	•	•	•	•	•	•	•
Climate change can negatively affect me (4)	•	•	•	•	•	•	•

I will experience the negative effects of climate change in my lifetime (5)	•	•	•	•	•	•	•
I am vulnerable to the negative effects of climate change (6)	•	•	•	•	•	•	•

In this section, your knowledge of climate change will be tested.

Q6 How much does deforestation contribute to global warming?
- A lot (1)
- A little (2)
- No contribution (3)

Q7 How much does the hole in the ozone layer contribute to global warming?
- A lot (1)
- A little (2)
- No contribution (3)

Q8 Over the past 100 years, has the speed of glacier melting increased, decreased, or stayed the same?
- Increased (1)
- Stayed the same (2)
- Decreased (3)

Q9 How much do you think stopping eating beef would reduce global warming if it was done worldwide?
- A lot (1)
- A little (2)
- Not at all (3)

Q10 How much do you think switching from fossil fuels to renewable energy would reduce global warming if it was done worldwide?
- A lot (1)
- A little (2)
- Not at all (3)

Q11
Below you will find brief descriptions of values and their importance to you. Please read each

description carefully and indicate how much the statement reflects your own beliefs. Please try to distinguish as much as possible in your answering by using different scores. The value that is most important to you should thus receive the highest score. The value that is least important, the lowest.

	totally not like me (1)	somewhat not like me (2)	slightly not like me (3)	neutral (4)	slightly like me (5)	somewhat like me (6)	totally like me (7)
It is important to me to prevent environmental pollution. (1)	•	•	•	•	•	•	•
It is important to me that every person has equal opportunities. (2)	•	•	•	•	•	•	•
It is important to me to have control over others' actions. (3)	•	•	•	•	•	•	•
It is important to me to protect the environment. (4)	•	•	•	•	•	•	•
It is important to me to take care of those who are worse off. (5)	•	•	•	•	•	•	•
It is important to me that every person is treated justly. (6)	•	•	•	•	•	•	•
It is important to me to have authority over others. (7)	•	•	•	•	•	•	•
It is important to me to respect nature. (8)	•	•	•	•	•	•	•

It is important to me that there is no war or conflict. (9)	•	•	•	•	•	•	•
It is important to me to be influential. (10)	•	•	•	•	•	•	•
It is important to me to have money and possessions. (11)	•	•	•	•	•	•	•
It is important to me to be in unity with nature. (12)	•	•	•	•	•	•	•
It is important to me to be helpful to others. (13)	•	•	•	•	•	•	•
It is important to me to work hard and be ambitious. (14)	•	•	•	•	•	•	•

Pathway Descriptions

We are interested in people's stand toward changes suggested by the IPCC to limit the effects expected from global warming. To avoid an increase beyond 1.5°, the IPCC has suggested multiple pathways.

Implementation of these pathways requires changes to *industry* and *everyday behaviour on a global level*. They will affect our *lifestyles* and *economy*.
The two pathways we are focusing on differentiate in two main aspects: the overshoot they allow for, and the way they aim to reach a stable temperature.
Pathway A aims to limit the overshoot of 1.5°C to a maximum of 1.6°C, keeping the effect of climate change as low as possible.
Pathway B does not aim to limit the overshoot of 1.5°C, allowing it to go beyond 1.6°C, risking higher effects of climate change.

To limit the effects, both pathways aim to return to 1.5°C by the end of the 21st century.

Pathway A expects rapid transitions to future energy production systems and implementation

of industry and lifestyle policies. Pathway B expects slower transitions, resulting in overshoot, which is then reversed using carbon capture. There would be no need to change from the current CO2-emission-intensive lifestyle.

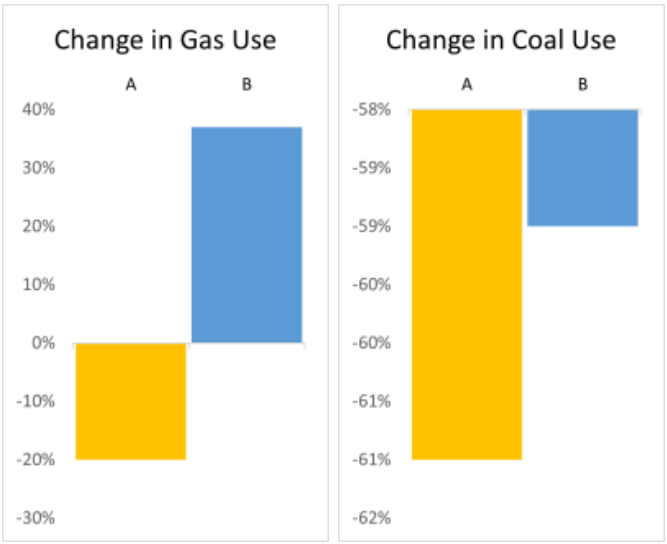
Details of the proposed energy transitions can be seen below:

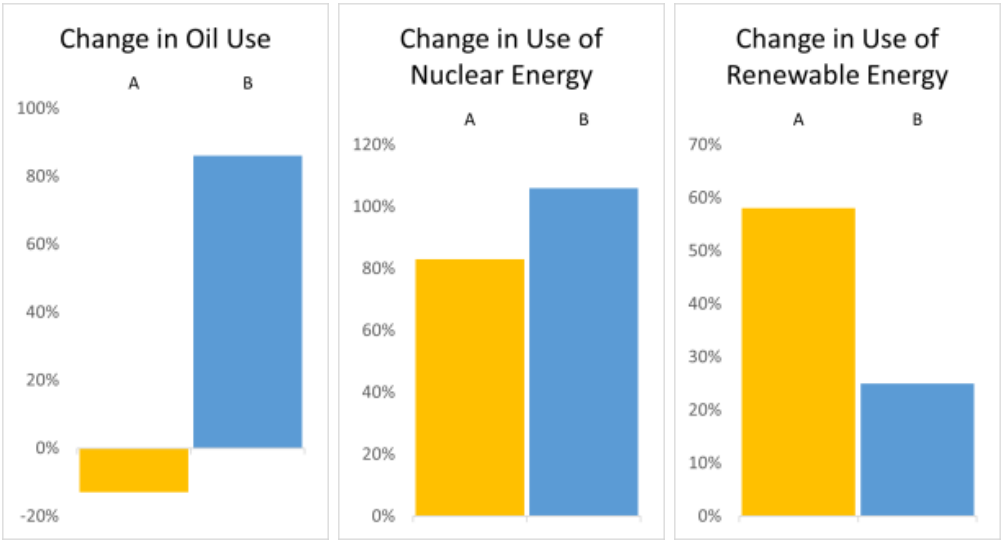
Pathway A reduces energy demand by 5% by 2030

- Eating local and seasonal foods
- Reducing meat and dairy consumption
- Reducing waste in water, food, and transportation industries
- Using resources more efficiently (insulation etc.)
- Low emission innovations
- Energy-saving behaviour (walking, cycling, mass transit, lower heating)
- Organisational change (replacing business travel by video call)
- Flood protective behaviour
- Heat protective behaviour (green roofs)
- Efficient water use (rationing)

Pathway B increases energy demand by 39% by 2030

- Increased economic growth and globalisation
- Increased meat and dairy consumption
- Increased demand for fuel
- Increased worldwide shipping
- Electrification
- Building desalination plants to convert seawater into freshwater





Q12 Before you'll be able to fill out the rest of the survey, we will test your knowledge about the pathways that were just described. You can take your time with this and answer the questions carefully. If you need to refresh your mind about some bits of information about the pathways, you'll find the most important information summarized on the bottom of the page (you'll be able to see this information through-out the whole survey). You also have the option to go back and forth between questions and the description throughout the survey.

Q13 Which one of the two pathways proposes more profound behavioural changes?

- Pathway A (1)
- Pathway B (2)

Q14 Removing carbon dioxide from the atmosphere is proposed as one of the main solutions to mitigate global warming by which one of the pathways?

- Pathway B (1)
- Pathway A (2)

Q15 Which statement is true regarding the overshoot that pathway B allows?

- global warming will not exceed 1.5°C at any point during the 21st century in pathway B (1)
- global warming will maximally reach 1.6°C but will return to 1.5°C by the end of the century in pathway B (2)
- global warming will exceed 1.6°C but is predicted to return to 1.5°C by the end of the century in pathway B (3)

Q16 The energy supply by renewable energy resources will increase by approximately 60% in pathway ... and by approximately 25% in pathway ...

- pathway B, pathway A (1)
- pathway A, pathway B (2)

Pathway A:	Pathway B:
- **no or limited** exceeding of 1.5°C of global warming to a maximum of 1.6°C - Far reaching **lifestyle** changes (e.g. less meat consumption, reduced heating, using mass transit instead of cars) - Very limited use of carbon dioxide removal techniques, great reliance on **renewable** energy sources, decrease in fossil fuel energy sources	- Will **exceed** 1.6°C of global warming - **Maintenance** of current CO2-emission-intensive-**lifestyle** - Heavy reliance on **carbon dioxide removal** techniques, less use of renewable energy, increased use of **fossil fuel** energy resources (oil)

In the following, you will be asked to evaluate the pathways according to some aspects. Should you feel that you need to refresh your mind about the content of the pathways, feel free to go back and forth between questions or to look at the summary at the bottom of each page.

Q17 In regards to pathway **A** (for more information about the pathways, look at the summary at the bottom of the page), to what extent do you agree with the following items?

	Strongly disagree (1)	Disagree (2)	Somewhat disagree (3)	Neither agree nor disagree (4)	Somewhat agree (5)	Agree (6)	Strongly agree (7)
The pathway provides a sufficient mean to limit global warming to 1.5°C by the end of the 21st century (1)	•	•	•	•	•	•	•
The pathway provides a clear mean for reducing the consequences of climate change (2)	•	•	•	•	•	•	•

The pathway facilitates limiting the effects of climate change (3)	•	•	•	•	•	•	•
By following this pathway, global warming would be limited to 1.5°C by the end of the 21st century (4)	•	•	•	•	•	•	•

Q18 In regard to <u>pathway **B**</u> (for more information about the pathways, look at the summary at the bottom of the page), to what extent do you agree with the following items?

	Strongly disagree (1)	Disagree (2)	Somewhat disagree (3)	Neither agree nor disagree (4)	Somewhat agree (5)	Agree (6)	Strongly agree (7)
The pathway provides a sufficient mean to limit global warming to 1.5°C by the end of the 21st century (1)	•	•	•	•	•	•	•
The pathway provides a clear mean for reducing the consequence	•	•	•	•	•	•	•

s of climate change (2)							
The pathway facilitates limiting the effects of climate change (3)	•	•	•	•	•	•	•
By following this pathway, global warming would be limited to 1.5°C by the end of the 21st century (4)	•	•	•	•	•	•	•

Q19 To what extent do you agree or disagree with the following statements if pathway A was implemented?

The implementation of pathway A….

	Strongly Disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly Agree (5)
would positively affect my personal life (1)	•	•	•	•	•
would positively impact my quality of life (6)	•	•	•	•	•
would bring life closer to my ideal way of living (7)	•	•	•	•	•
would positively affect the lives of others (8)	•	•	•	•	•
would positively impact the quality of life for others (10)	•	•	•	•	•

would positively impact the well-being of others (11)	•	•	•	•	•

Q20 To what extent do you agree or disagree with the following statements if pathway B was implemented?

The implementation of pathway B….

	Strongly Disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly Agree (5)
would positively affect my personal life (1)	•	•	•	•	•
would positively impact my quality of life (6)	•	•	•	•	•
would bring life closer to my ideal way of living (7)	•	•	•	•	•
would positively affect the lives of others (8)	•	•	•	•	•
would positively impact the quality of life for others (10)	•	•	•	•	•
would positively impact the well-being of others (11)	•	•	•	•	•

In this part of the survey, you will be asked to indicate how fair you think the measures are towards yourself and others. At the end of the page you can, as always, find the overview of the two pathways.

Q21 Both pathways' overall: Please rate the following statements regarding fairness from strongly disagree to strongly agree.

	strongly disagree (1)	disagree (2)	slightly disagree (3)	neither agree nor disagree (4)	slightly agree (5)	strongly agree (6)

The proposed measures of both pathways are overall fair for me. (1)	•	•	•	•	•	•	
The proposed measures of both pathways are overall fair for others. (2)	•	•	•	•	•	•	
Others and I will be equally affected by the implications of both pathways. (3)	•	•	•	•	•	•	
Both pathways energy demands are equally fair for me and others. (4)	•	•	•	•	•	•	

Q22 Pathway A: Please rate the following statements regarding fairness from strongly disagree to strongly agree.

	strongly disagree (1)	disagree (2)	slightly disagree (3)	neither agree nor disagree (4)	slightly agree (5)	agree (6)	strongly agree (7)
The proposed measures of pathway A are overall fair for me. (1)	•	•	•	•	•	•	•
The proposed measures of pathway A are overall fair for others. (3)	•	•	•	•	•	•	•
Others and I will be equally affected by the implications of pathway A. (4)	•	•	•	•	•	•	•
The energy demands of pathway A are	•	•	•	•	•	•	•

equally fair for me and others. (5)	

Q23 Pathway B: Please rate the following statements regarding fairness from strongly disagree to strongly agree.

	strongly disagree (1)	disagree (2)	slightly disagree (8)	neither agree nor disagree (3)	slightly agree (4)	agree (7)	strongly agree (5)
The proposed measures of pathway B are overall fair for me. (1)	•	•	•	•	•	•	•
The proposed measures of pathway B are overall fair for others. (2)	•	•	•	•	•	•	•
Others and I will be equally affected by the implications of pathway B. (3)	•	•	•	•	•	•	•
The energy demands of pathway B are equally fair for me and others. (4)	•	•	•	•	•	•	•

Q24 In the last part of our survey, we would like to ask you to give your opinion on the pathways by filling out the following questions.

Q25 To what extent do you think pathway A is acceptable?

	not at all acceptable (1)	unacceptable (2)	slightly unacceptable (3)	neutral (4)	slightly acceptable (5)	acceptable (6)	very acceptable (7)
I think pathway A is... (1)	•	•	•	•	•	•	•

Q26 To what extent do you think pathway B is acceptable?

	not at all acceptable (1)	unacceptable (2)	slightly unacceptable (3)	neutral (4)	slightly acceptable (5)	acceptable (6)	very acceptable (7)
I think pathway B is... (1)	•	•	•	•	•	•	•

Q27 To what extent do you think pathway A is good/bad?

	very bad (1)	bad (3)	slightly bad (4)	neutral (7)	slightly good (8)	good (9)	very good (10)
I think pathway A is... (1)	•	•	•	•	•	•	•

Q28 To what extent do you think pathway B is good/bad?

	very bad (1)	bad (3)	slightly bad (4)	neutral (7)	slightly good (8)	good (9)	very good (10)
I think pathway B is... (1)	•	•	•	•	•	•	•

Q29 To what extent do you think pathway A is necessary?

	not at all necessary (2)	not necessary (3)	slightly not necessary (4)	neutral (5)	slightly necessary (6)	necessary (7)	very necessary (8)
I think pathway A is... (1)	•	•	•	•	•	•	•

Q30 To what extent do you think pathway B is necessary?

	not at all necessary (2)	not necessary (3)	slightly not necessary (4)	neutral (5)	slightly necessary (6)	necessary (7)	very necessary (8)
I think pathway B is... (1)	•	•	•	•	•	•	•

Q31 Which pathway do you prefer?

- Pathway A (1)

- Pathway B (2)

Q32 Now we would like to know if you think one or both of these scenarios will actually come true in the future. How realistic do you consider each of the two pathways?

	Very unrealistic (1)	Somewhat unrealistic (2)	Neutral (3)	Somewhat realistic (4)	Very realistic (5)
Pathway A (1)	•	•	•	•	•
Pathway B (2)	•	•	•	•	•

Q33 If you were a policy maker, which pathway would you choose? And why?

_____

Q34 What would you like to change about the pathways?

_____

Q35 We hope that you had fun filling out our survey! If you have any comments or suggestions, please feel free to put them in the box below.

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