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How the phrasing of climate change terminology impacts people's understanding and their intention to behave sustainably

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Abstract
A recent study by Bruine de Bruin, Clim Change 167, 2021 investigated how well laypeople understand eight key termini of climate change that are commonly used in IPCC reports (i.e. mitigation, carbon neutral, unprecedented transition, tipping point, sustainable development, carbon dioxide removal, adaptation, abrupt change). The results revealed systematic misinterpretations by participants. To improve laypeople's understanding of these termini, Bruine de Bruin et al. developed recommendations for alternative formulations but did not test whether these alternative formulations actually increase understanding and lead to changes of people's intentions to behave sustainably. To fill this gap, we carried out a preregistered online experiment ($N=285$) and compared the altered with the original formulations in terms of how well participants understand the termini subjectively and objectively. In addition, we measured participants' confidence in the correctness of their understanding and their intention to act sustainably. The results indicate that participants in the altered wording group (1) generally understood the termini better subjectively and objectively; (2) had more confidence in the correctness of their understanding, and (3) misinterpreted the termini less by relying on their mental models of non-climate contexts (where the termini often have different meanings). Interestingly, this overall pattern did not apply to all termini, indicating that altering the termini increased people's understanding for some concepts but not for others. Moreover, the altered wordings did not increase participants' intentions to act sustainably. Implications and further directions are discussed.

Keywords IPCC · Science communication · Climate change · Jargon · Public understanding · Intention to act

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Climate scientists are increasingly focused on sharing crucial knowledge with people who do not have an academic background in climate science. To attain this goal, the Intergovernmental Panel on Climate Change (IPCC)—created by the United Nations—regularly publishes reports on climate change that are openly accessible to the public. These reports usually receive broad media coverage and are cited frequently (O'Neill et al. 2015; Painter et al. 2023). At the same time, it has been shown that non-experts have difficulties to understand the content of these reports (Bruine de Bruin et al. 2021; Wege et al. (2024).

A reason for why non-experts experience difficulties in understanding these climate reports could lie in the way experts communicate. Indeed, when communicating to a broader audience, experts tend to lack good intuition about the knowledge of non-experts (e.g., Fischhoff et al. 1982) and overestimate how well people understand technical termini (e.g., Neuhauser and Paul 2011; Oppenheimer 2006; König et al. 2025). Based on theories postulating so-called mental models (e.g., Gentner and Stevens 1983; Meyer et al. 1985), Bruine de Bruin and Bostrom (2013) propose several steps that need to be followed before communicating with the public to ensure accurate understanding of technical termini. These steps involve, among others, designing appropriate communication content and testing its effectiveness in communicating with non-experts.

To increase understanding of the termini used in the IPCC reports, Bruine de Bruin et al. (2021) recently build up on such mental model theories (e.g., Bruine de Bruin and Bostrom 2013) to recommend alternative formulations. However, the last, and maybe most important step proposed by these models, has been neglected so far. That is, empirically testing whether the proposed alternative formulations actually facilitate laypeople's understanding. To fill this lacuna and to test whether the alternative formulations put forward by Bruine de Bruin et al. (2021) increase people's intention to behave sustainably, we carried out a preregistered experiment.

1 Challenges of climate change communication

Communication about climate change is rooted in various disciplinary traditions (Nerlich et al. 2010). Therefore, it is important that the used terminology and formulations are unambiguously and clearly communicated. In this respect, previous research has shown that experts overestimate how good laypeople understand technical termini (e.g., Neuhauser and Paul 2011; Oppenheimer 2006; König et al. 2025). A reason why non-experts have difficulties to understand technical terminology is put forward by mental model theories (e.g., Gentner and Stevens 1983; Meyer et al. 1985)—according to which non-experts have the tendency to interpret new information in terms of their pre-existing beliefs, which can lead to misinterpretations. To better communicate with non-experts, Bruine de Bruin and Bostrom (2013) argue that science communication needs to first understand people's relevant beliefs about the topic at hand and then to design new communication forms based on this acquired information. Specifically, the authors propose that communicators need to undergo four steps before communicating with non-experts. First, experts need to identify what people should need to know to make informed decisions. Second, it needs to be identified what non-experts already know. Third, communication content for a non-expert target audience has to be designed. Fourth, the effectiveness of the communication content has to be tested within an empirical study.

With regard to communicating climate reports to a non-expert audience, Bruine de Bruin et al. (2021) investigated together with the IPCC, how prevalent formulations that are commonly used are (mis)understood. The researchers selected eight termini which (1) were previously prominently used in IPCC communications; (2) are relevant for understanding science-based climate policy; and (3) presumably misunderstood by non-scientific audiences. The eight termini were: mitigation, carbon neutral, unprecedented transition, tipping point, sustainable development, carbon dioxide removal, adaptation, and abrupt change. In a qualitative study, the authors first interviewed 20 participants via telephone. Participants were presented with each of the termini and associated sentences (see Table 1). Afterwards, participants rated how understandable these termini are. At the end, participants had to interpret the termini, as well as provide feedback and suggestions for possible improvements when communicating the termini. The results of the study revealed a significant issue of misunderstanding for the presented termini. That is, many participants indicated that they either never heard the termini before or did not understand their meaning. Moreover, even if participants appeared (or reported) to understand a term, they relied on irrelevant mental models by connecting the term to topics other than climate change. Based on these findings, the authors generated recommendations for alternative ways to communicate the examined termini (see Table 1). In particular, the authors suggested to "[…] simplify wording, make links to climate change explicit, and describe underlying processes" (Bruine de Bruin et al. 2021, p. 2). As such, they followed steps 1 to 3 of the recommendations to design communications for non-experts as proposed by Bruine de Bruin and Bostrom (2013). However, they neglected taking into account the final step 4, which is the empirical test of whether the alternative way of communication actually improves people's understanding of the termini.

2 Understanding technical termini

In principle, researchers have different possibilities to measure how well people understand certain termini. On the one side, researchers could apply a subjective measure by merely asking people to indicate if they understand the termini. On the other hand, researchers could implement a more objective measure by letting participants define the termini. Afterwards, researchers can compare participants' reports with an objective criterion to assess how well participants understood the termini. These measures can be complemented by asking participants how confident they are that their understanding of the termini is correct. Interestingly, previous research has shown that objective and subjective understanding of a certain topic is not necessarily correlated and that people who are very confident that they understand the topic very well do not necessarily understand the topic that well objectively (e.g., Kruger and Dunning 1999; Mahmood 2016). Thus, to get a comprehensive assessment of how good people understand technical termini, researchers may apply different measures that tap into different facets of understanding—an approach we followed in the present research.

Irrespective of how understanding is measured, there is a debate in the literature about whether understanding climate change related issues relates to sustainable behavior. On the one side, it has been argued that effective communication about climate change can shape public perception, policy formulation, and collective action (Budescu et al. 2009; Kolenatý et al. 2022; Markowitz and Shariff 2012; McCaffrey and Buhr 2008). For example, research

Table 1 Original and altered wordings for the eight key termini

Term	Original wordings (from the IPCC-Reports)	Altered wordings (based on Bruine de Bruin et al. (2021))
Mitigation	Despite a growing number of mitigation policies, annual emissions continued to increase.	Despite a growing number of policies that reduce emissions to stop climate change from getting worse, annual emissions continued to increase.
Carbon neutral	To become carbon neutral around 2050, global carbon emissions would need to fall 45% by 2030.	To balance out the carbon dioxide we put into the air around 2050, global carbon dioxide emissions would need to fall 45% by 2030.
Unprecedented transition	Limiting global warming to 1.5C is not impossible but would require unprecedented transitions in all aspects of society.	Limiting global warming to 1.5C is not impossible, but would require unprecedented transitions, like making big changes together to stop climate change.
Tipping point	The precise levels of climate change sufficient to trigger tipping points remain uncertain.	The precise levels of climate change sufficient to trigger tipping points where it is too late to stop climate change remain uncertain.
Sustainable development	Natural hazards, climate change, and societal vulnerability can pose fundamental limits to sustainable development.	Natural hazards, climate change, and societal vulnerability can pose fundamental limits to sustainable development, like environmentally friendly growth in different aspects of life.
Carbon dioxide removal	Carbon dioxide removal can be used to compensate for unavoidable emissions.	Removing carbon dioxide from the air can be used to compensate for unavoidable emissions.
Adaptation	Without major investments in adaptation, island nations would be exposed to escalating flood risks.	Without major investments in adaptation, like adjusting to climate change, island nations would be exposed to escalating flood risks.
Abrupt change	A continued rise in global emissions increases the likelihood of abrupt changes in ocean circulation in the coming centuries.	A continued rise in global emissions increases the likelihood of abrupt and sudden, dramatic changes in ocean circulation in the coming centuries.

on the information deficit model (London Royal Society 1985; Wynne 1993, 2006) suggests that if the public was better informed, their attitudes, beliefs, and behaviors would change. In line with this model, Bruine de Bruin et al. (2021) argued that the alternative terminology they proposed could "improve public understanding and engagement as compared to the original wording" (p. 17). On the other side, research indicates that although understanding relevant climate change aspects contributes to people's sense of responsibility (Moser 2010), positive environmental attitudes not always and entirely predict people's behavior. For example, research on the knowledge-behavior gap (Colombo et al. 2023; Frick et al. 2021; Kollmuss and Agyeman 2002) shows that people's knowledge about climate change does not perfectly predict how sustainable they behave. Taken together, while some scholars put forward that mere knowledge changes behavior, other research finds that knowledge about climate change does not necessarily predict behavior. To shed further light onto the question of whether knowledge about climate change influences sustainable behavior, we tested if the altered wordings proposed by Bruine de Bruin et al. not only increase understanding but also the intention to behave sustainably.

3 Present research

Taken together, based on mental model theories (e.g., Bruine de Bruin and Bostrom 2013), it has been proposed that science communicators should not only design appropriate communication content, but also test whether the content is actually understood. With respect to the termini used in IPCC communications, Bruine de Bruin et al. (2021) proposed alternative wordings to increase non-experts' understanding. However, research so far remains open whether these altered wordings actually increase understanding. In the present research, we fill this gap by testing the hypothesis put forward by Bruine de Bruin et al. (2021) that the altered termini are understood better than the original termini. To this end, we presented half of our participants with the original IPCC items and the other half of participants with altered wordings that were proposed by Bruine de Bruin et al. (2021). For example, a phrase including the term "tipping point" was described as "The precise levels of climate change sufficient to trigger tipping points remain uncertain." in the original wording condition whereas it was described as "The precise levels of climate change sufficient to trigger tipping points where it is too late to stop climate change remain uncertain." in the altered wording condition (for a full list of used termini and wordings, see Table 1).

Since previous research showed that people often overestimate their abilities and lack metacognitive skills (e.g., Kruger and Dunning 1999; Mahmood 2016), we did not only ask participants whether they understand the termini, but also measured their actual objective understanding, as well as their confidence in understanding these termini. This allowed us to get a comprehensive estimate of how well climate termini are understood.

Moreover, to shed light onto the debate of whether mere knowledge about climate change influences sustainable behavior, we investigated whether the proposed terminology increases people's intention to act sustainably.

We preregistered the study on aspredicted.org (https://aspredicted.org/7tkv-2bnx.pd) and made the data with its analysis script, and experimental materials openly accessible on the Open Science Framework (OSF; https://osf.io/4mcew/).

4 Methods

4.1 Participants, power, and design

We contrasted the original IPCC climate formulations with the adapted formulations in a between-participants design with two groups. We aimed at detecting an effect size of at least $d=0.40$, as such an effect size corresponds approximately with the average size detected in preregistered (social) psychological experiments using between-subject designs (Richard et al. 2003; Schäfer and Schwarz 2019). A power analyses with G*Power (Version 3.1.9.6; Faul et al. 2007) revealed that for such an effect size, with a power of $1\text{-}\beta=90\%$, and an alpha probability of $\alpha=0.05$, 216 participants are needed. To compensate for possible dropouts, we aimed at recruiting at least 250 participants. With these calculations in mind, we recruited participants to take part in our survey voluntary via social media groups and *SurveyCircle*. We also advertised our study at our local university via *Sona-Systems.* Psychology students could receive course credit for taking part in the study. At the end, 300 participants followed our invitation to take part in the experiment and completed it.

In line with our preregistration, we excluded 15 participants (5%) who indicated that they did not participate conscientiously (no other attention checks were implemented in the survey). The final sample consisted of 285 participants (184 female, 85 male, 10 diverse, 6 preferred not to answer) with an age ranging from 17 to 70 ($M=26.35$; $SD=9.30$). A sensitivity power analysis indicated that with such a sample size, we were able to detect an effect size of $d=0.39$ with a power of $1\text{-}\beta=90\%$, and an alpha probability of $\alpha=0.05$ in a two-tailed *t*-test. The original terminology group consisted of 139 participants and the altered terminology group consisted of 146 participants. The sample included 219 participants from Germany and 66 from other countries. The sample was rather highly educated with a majority of participants being university students with at least a high school diploma or equivalent (for further details, see Supplementary materials 1).

4.2 Procedure and experimental manipulations

To make sure that a diverse sample of participants can take part in our experiment, the language of the survey was English. After clicking on the link to our survey, participants gave written and informed consent. They were informed that the goal of the study was to survey commonly used terminology in the area of climate change. We assigned participants randomly to one of the two between-participants conditions. In the original terminology condition, participants read the original wordings drawn from publicly available IPCC materials. In the altered terminology condition, participants read the altered terminology we developed based on Bruine de Bruine de Bruin et al.'s (2021) recommendations. Table 1 illustrates the original and altered wordings (for more details, see Supplementary materials 1). Participants were then presented with the wordings for the eight termini. For each term, participants first indicated subjective understanding. Afterwards, they had to define the term and to indicate how confident they are that their definition is correct. At the end, participants indicated their intention to act sustainably, reported basic demographics, indicated whether they took part in the study conscientiously and were then thanked and dismissed.

4.3 Dependent measures

Subjective Understanding To measure subjective understanding, participants indicated for each statement how easy it was to understand each of the termini on a 7-point rating scale (1 = *very easy*; 7 = *very difficult*). Cronbach's alpha across all termini was $\alpha = 0.78$.

Objective Understanding To assess objective understanding, participants had to define the termini in their own words. Afterwards, we coded participants' answers similarly as Bruine de Bruin et al. (2021) with some adjustments to improve quality of the coding. In particular, by following the recommendations proposed by Mayring (2015), we first developed a coding sheet that included the definitions of the termini based on the IPCC SR 15 Glossary (IPCC 2018). The coding sheet is made open accessible on our OSF project. Based on the definitions included in the coding sheet, the first author and an independent coder (both blind to conditions) then trained the coding by discussing answers from 10 randomly selected participants. Afterwards, the coders independently from each other coded the answers from all participants by allocating 0 (*wrong*), 0.5 (*partly correct*) or 1 (*correct*) points to each answer depending on its correctness. Overall, the two coders agreed in 87.30% of the cases. Cohen's (1960) Kappa was 0.81, which can be interpreted as almost perfect agreement (Landis and Koch 1977). Disagreements between the two coders were resolved through discussion between the two coders and the last author.

In addition, we coded whether participants'description of the termini's meaning were confused with other termini. After an initial training phase of discussing answers of 10 randomly selected participants, the first author and an independent coder (both blind to conditions) assessed for each participant whether each of the termini were confused with another term (1 = *yes*; 0 = *no*). The coding sheet involving the definitions of the termini is made open accessible on our OSF folder. Overall, the two coders agreed in 93.16% of the cases. Cohen's (1960) Kappa was 0.66, which can be interpreted as substantial agreement (Landis and Koch 1977). Disagreements between the two coders were resolved through discussion between the two coders and the last author.

Confidence To measure participants' confidence in the correctness of their answer, they indicated for each answer on a 7-point rating scale (1 = *not certain at all*; 7 = *completely certain*) how certain they are that their answer is correct. Cronbach's Alpha across all termini was $\alpha = 0.84$.

Intention to Act Sustainable Finally, we measured participants' intention to act sustainably by adapting items from established scales (Markle 2013; Silberer et al. 2020; Zhao et al. 2014). In particular, for 11 sustainable behaviors, participants indicated on a 7-point rating scale (1 = *very unlikely*; 7 = *very likely*) the likelihood that they will engage in these behaviors. Example behaviors are "use less disposable tableware," "buy energy efficient household devices," and "take public transportation instead of using the car (for longer distances)". See Supplementary materials 1 for the full list of items. Cronbach's alpha across all termini was $\alpha = 0.88$.

5 Results

5.1 Preregistered analyses

To test whether participants in the altered terminology condition would exhibit (1) better subjective understanding, (2) better objective understanding, (3) higher confidence in their comprehension, and (4) a stronger intention to act sustainably compared to the original terminology condition, we first averaged responses for each of these four categories of dependent variables for each participant. We then performed independent sample *t*-tests using the software IBM SPSS Statistics (Version 28.0.1.1). Before each *t*-test, we ran a Levene test for homogeneity of variance. If the Levene test indicated that the assumption of variance homogeneity was violated (i.e., $\alpha < 0.05$), we ran a Welch-test instead and corrected the degrees of freedom (Delacre et al. 2017).

Subjective understanding We first tested whether the alternative wording leads to better subjective understanding in participants. The *t*-test indicated that participants in the altered terminology group ($M = 5.17$, $SD = 0.92$) reported to subjectively understand the termini better than participants in the original terminology group ($M = 4.83$, $SD = 1.10$)[1], $t(283) = 2.82$, $p = 0.005$, $d = 0.33$, $CI_{95\%}$ [.10, 0.57].

Objective understanding We next investigated whether the alternative wordings leads to better objective understanding. Participants in the altered terminology group objectively understood the termini better as more of their answers were correct ($M = 0.66$, $SD = 0.22$) as compared to participants in the original terminology group ($M = 0.54$, $SD = 0.23$), $t(283) = 4.56$, $p < 0.001$, $d = 0.54$, $CI_{95\%}$ [.07, 0.17].

Confidence in understanding When investigating confidence in the correctness of participants' answers, the Levene's test showed that equal variances could not be assumed ($F = 4.97$, $p = 0.027$). To control for this, we used the Welch-test to interpret the results. The Welch-test showed that participants in the altered terminology group ($M = 4.84$, $SD = 1.01$) were more confident in the correctness of their answers than participants in the original terminology group ($M = 4.40$, $SD = 1.21$), $t(269.00) = 3.33$, $p < 0.001$, $d = 0.40$, $CI_{95\%}$ [.18, 0.70].

Intention to behave sustainably Finally, participants from the altered terminology group ($M = 5.33$, $SD = 1.03$) did not report significantly higher intentions to behave sustainably than participants from the original terminology group ($M = 5.18$, $SD = 1.15$), $t(283) = 1.10$, $p = 0.271$, $d = 0.13$, $CI_{95\%}$ [−0.11, 0.40]. To assess support for H0, we carried out a non-preregistered Bayesian *t*-test in *JASP software* (Version 0.16.4) with the default priors (i.e., $r = 0.707$). This analysis revealed a Bayes Factor of $BF_{01} = 2.51$, which can be interpreted as anecdotal evidence for the null hypothesis H_0 (there is no difference between the experimental groups in terms of the intention to behave sustainably).

[1] To ease the understanding, we reversed the scale for subjective understanding. Therefore, a high value indicates a better, and a low value indicates fewer understanding of the termini.

5.2 Non-preregistered robustness check

To investigate the robustness of the findings reported above, we ran separate *t*-tests to assess for which termini exactly the altered wordings increased understanding as compared with the original wordings. For each group of dependent variables, we applied Bonferroni adjustments to correct for multiple comparisons by dividing the desired *p*-value (i.e., $p = 0.05$) through the number of hypotheses *m* (i.e., $m = 8$). Consequently, we considered a result statistically significant when the *p*-value was $p < 0.006$.

For subjective understanding (see Fig. 1 for mean values), the *t*-tests revealed statistically significant differences in line with our predictions for the termini tipping point, $t(273.42) = 2.98$, $p = 0.003$, $d = 0.35$, $CI_{95\%}$ [.20, 0.97] carbon dioxide removal, $t(259.95) = 5.00$, $p < 0.001$, $d = 0.60$, $CI_{95\%}$ [.56, 1.28], and adaptation, $t(259.61) = 2.90$, $p = 0.004$, $d = 0.35$, $CI_{95\%}$ [.17, 0.88]. We did not find any significant differences for the termini abrupt change, mitigation, carbon neutral, unprecedented transition, and sustainable development, ($ts < 1.77$, $ps > 0.07$).

For objective understanding (see Fig. 2 for mean values), the *t*-test revealed significant differences for the termini tipping point, $t(283) = 2.82$, $p = 0.005$, $d = 0.33$, $CI_{95\%}$ [.05, 0.26] and carbon dioxide removal, $t(236.90) = 5.15$, $p < 0.001$, $d = 0.61$, $CI_{95\%}$ [.15, 0.33]. There was a trend for carbon neutral, $t(283) = 2.57$, $p = 0.011$, $d = 0.30$, $CI_{95\%}$ [.03, 0.25], unprecedented transition, $t(275.84) = 2.36$, $p = 0.019$, $d = 0.28$, $CI_{95\%}$ [.02, 0.23], and sustainable development, $t(283) = 2.19$, $p = 0.030$, $d = 0.26$, $CI_{95\%}$ [.01, 0.21]. We did not find any significant differences for mitigation, adaptation, and abrupt change ($ts < 1.57$, $ps > 0.11$).

Lastly, the analysis of confidence in the correctness of their understanding (see Fig. 3 for mean values) showed that participants were significantly more confident in the correctness of their definitions of the term carbon dioxide removal, $t(244.54) = 4.76$, $p < 0.001$, $d = 0.57$, $CI_{95\%}$ [.56, 1.34]. There was a trend for mitigation, $t(283) = 2.71$, $p = 0.007$, $d = 0.32$, $CI_{95\%}$ [.14, 0.91], tipping point, $t(274.78) = 2.79$, $p = 0.006$, $d = 0.33$, $CI_{95\%}$ [.16, 0.95], and abrupt change, $t(283) = 2.19$, $p = 0.029$, $d = 0.26$, $CI_{95\%}$ [.04, 0.76]. We did not find any significant

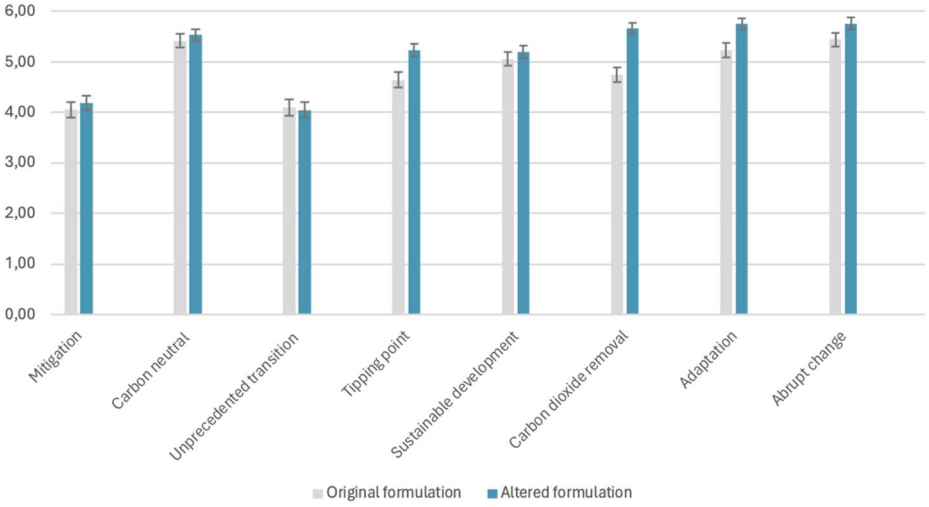

Fig. 1 Mean values for subjective understanding of each term. Note. Values on a reversed 7-point rating scale (1 = very difficult; 7 = very easy). Error bars indicate ±1 SEM

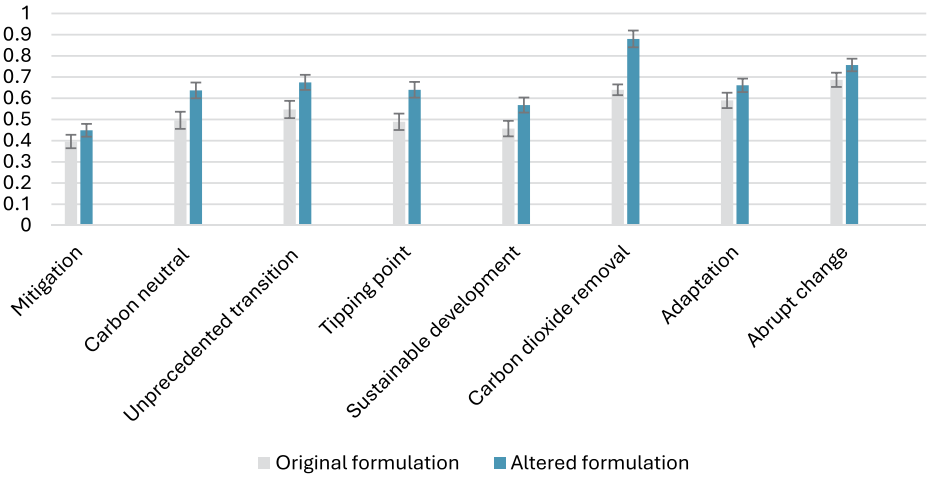

Fig. 2 Mean values for objective understanding of each term. Note. values on a scale from 0 (wrong), 0.5 (partly correct) to 1 (correct). Error bars indicate ±1 SEM

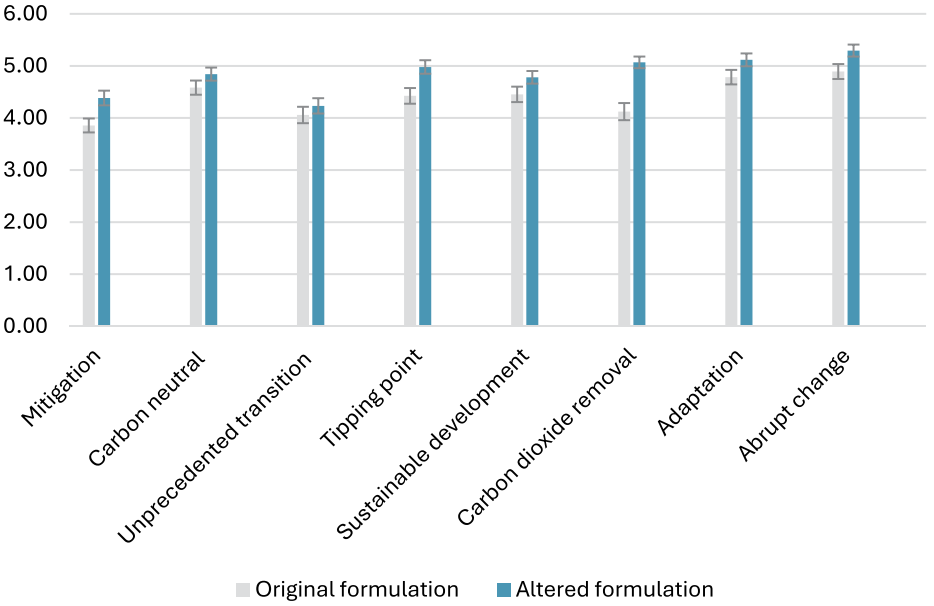

Fig. 3 Mean values for confidence in understanding of each term. Note. Values on a 7-point rating scale (1 = not certain at all; 7 = completely certain). Error bars indicate ±1 SEM

differences for the termini sustainable development, adaptation, carbon neutral, and unprecedented transition ($ts < 1.79$, $ps > 0.07$).

5.3 Non-preregistered exploratory analyses

In addition to the analyses above, we conducted a qualitative-exploratory analysis to better understand the pattern of results obtained and to link them to the findings of Bruine de Bruin et al. (2021). That is, we analyzed the explanations participants indicated for each of the termini. Here, we summarize the most interesting findings–a more detailed analysis is provided in the supplementary materials 1.

The qualitative text analysis revealed several similarities with Bruine de Bruin et al. (2021). For example, we found the term *mitigation* to be frequently confused with *mediation* or *negotiation*. However, the current study found this confusion in only 3% of participants, of which about 2% were presented with the original and only about 1% were presented with the alternative wordings, which is significantly less than the 35% reported by Bruine de Bruin et al. (2021).

Similarly, confusion about the meaning of *carbon neutral*—where participants equated it with *zero emissions*—was observed in 15% of participants, of which 10% belonged to the original and 5% belonged to the alternative wording condition. This is comparable with the 15% found by Bruine de Bruin et al. (2021). Going on step further than Bruine de Bruin et al., we found that participants confused *carbon neutral* also with *business practices* (e.g., reducing product carbon footprints) in 4% of the cases (3% in the original and 1% in the alternative wording condition).

For *unprecedented transition*, the current study found that 4% of participants, (2% in the original and 2% in alternative wording condition), confused the term with the termini *unplanned* or *unpredictable transition*. Bruine de Bruin et al. (2021) found that 40% held similar misconceptions.

11% of our participants confused the term *tipping point* with *turning point* (6% in the original and 5% in the alternative wording condition)—a confusion not observed by Bruine de Bruin et al. (2021).

Regarding *sustainable development*, we found that 6% of participants associating the term with *technological improvements* which splits into 5% misunderstandings in the control and 2% in the alternative wording condition. Bruine de Bruin et al. (2021) found that 65% of participants had similar confusions. Additionally, we found that 14% of our participants (8% in the original and 7% in the alternative wording condition) interpreted *sustainable development* in a *temporal context*, a confusion not reported by Bruine de Bruin et al. (2021).

6 Discussion

Based on theories postulating so-called mental models (e.g., Gentner and Stevens 1983; Meyer et al. 1985), Bruine de Bruin and Bostrom (2013) propose several steps before communicating scientific findings to the public. These steps involve, among others, designing appropriate communication content and testing its effectiveness in communicating with non-experts. To increase understanding of climate change related termini used in the

IPCC reports, Bruine de Bruin et al. (2021) build up on the mental model approach and recommended alternative formulations of eight commonly used climate change termini. However, the authors neglected empirically testing whether the proposed alternative formulations actually facilitate laypeople's understanding. To fill this gap, in the present research, we empirically tested whether the altered formulations put forward by Bruine de Bruin et al. (2021) increase people's understanding as well their intention to behave sustainably. We contrasted these altered formulations with the original wordings used by the IPCC. Although we found that overall the altered wordings, as compared to the original wordings, increased subjective understanding, objective understanding and confidence in the understanding, these effects were not driven equally by all termini. Moreover, reading the altered wordings did not increase participants' intention to behave sustainably. Despite some limitations, these results have several theoretical and practical implications.

7 Theoretical and practical implications

Previous research indicates that objectively and subjectively understanding certain topics is not necessarily related and that people who are very confident that they understand a topic may not perfectly understand it objectively (e.g., Kruger and Dunning 1999; Mahmood 2016). We find mixed support for this research. That is, we find that subjective and objective understanding are overlapping to a large degree. At the same time, these two measures do not perfectly match. For example, participants in the altered wording condition thought they understood the term *adaptation* better than those in the original wording condition, which was objectively not the case. Likewise, the results on confidence were largely overlapping with the findings on objective and subjective understanding. At the same time, for some termini (e.g., mitigation), participants in our sample were confident about understanding the meaning correctly although they actually did not understand it very well objectively.

This latter finding can be explained by taking into account the concept of mental models (e.g., Gentner and Stevens 1983; Meyer et al. 1985) according to which people interpret technical termini in line with their beliefs about a term, which can lead to misunderstandings although people are confident that they understood the term correctly. Indeed, similar to Bruine de Bruin et al. (2021), we detected some misconceptions that commonly arose in our participants based on the usage of mental models. That is, participants interpreted some termini based on their existing knowledge not related to climate change. For example, participants defined the term *mitigation* based on mental models in the field of business, politics, or law as they mixed it up with the term mediation. Similarly, some participants connected the term *adaptation* with other fields like technology or sociology and *sustainable development* with technological improvements. However, most of those and similar misconceptions arose in participants who read the original wordings, but not in participants who read the altered wordings. This indicates that the altered wordings can indeed counteract some misconceptions people might have. Interestingly, although we detected similar misconceptions as Bruine de Bruin et al., fewer participants in our sample relied on mental models than in the Bruine de Bruin et al. sample. A potential reason for this difference could be that our sample might have been somewhat better educated.

Another interesting finding, we detected, is that the alternative wordings put forward by Bruine de Bruin et al. (2021) increased understanding for some, but not all termini. To

further ease the understanding, Bruine de Bruin et al. recommended adding examples, but did not offer specific suggestions. As we wanted to directly test the effect of the alternative wordings itself, we have refrained from giving explicit examples in the present experiment. From a practical point of view, however, we recommend using examples to ease the understanding especially for the termini that participants did not understand better with the altered wordings. When selecting examples, we recommend examples that make linkages between the term and the topic of climate change more clearly for participants. This should lead people relying less on their mental models from other fields and consequently reduce misunderstandings. For the term mitigation, for instance, a fitting example could be the renaturation of moorlands to enhance carbon fixation.

Interestingly, the alternative wordings increased understanding especially for the term carbon dioxide removal. Here, the alternative wording defines where exactly CO2 is removed from. One may, thus, speculate that most participants in the original wording condition did not understand what exactly is being removed and that the alternative wording could provide clarity about this issue. This interpretation is supported by our qualitative analysis of the original wording suggesting that a common misunderstanding is that participants do not understand whether emissions or emitting factors are being removed. To increase the understanding of the other termini in a similar strong manner, future research should pay close attention to the confusions participants report feg to design interventions that deal with these confusions.

Research on the information deficit model (London Royal Society 1985; Wynne 1993, 2006) suggests that if the public was better informed, their attitudes, beliefs, and behaviors would change. In line with this theory, Bord et al. (2000) found that "knowing what causes climate change, and what does not is the most powerful predictor of both stated intention to take voluntary actions and to vote on hypothetical referenda to enact new government policies to reduce greenhouse emissions" (p. 205). However, more recent empirical research on the information deficit model (Kearnes et al. 2006; Marteau et al. 2008; Suldovsky 2014) showed that public communication of science is more complex than what the knowledge deficit model suggests (Simis et al. 2016). In line with this latter research, we did not find an effect of the wordings on participants' intention to behave sustainably even though participants on average understood the termini better in the altered wording condition as compared to the original wording condition. This indicates that merely furthering the understanding of factors about climate change does not inevitably change intended behaviors.

Several factors may explain this finding. First, literature on the knowledge-behavior-gap (Colombo et al. 2023; Frick et al. 2021; Kollmuss and Agyeman 2002) indicates that merely filling cognitive deficiencies and gaps in knowledge is not sufficient for people do make informed and rational decisions (Chess and Johnson 2011; Moser and Dilling 2011). A possible reason why increased knowledge about climate change did not change the intention to behave sustainably in our study might be that people lack the connection between sustainable actions and the complexities of the issue (Ereaut and Segnit 2007). That is, people seem to struggle to directly relate and connect actions such as taking the bus, saving water, or buying energy efficient devices with the wider picture of behaving in a climate-friendly way.

Second, an explanation for the gap between knowledge and action is offered by the theory of planned behavior (Ajzen 1991). This approach argues that even if people have the intention to act, this often does not translate into actual action because of the person's perception of whether they could successfully complete the behavior. It therefore involves the

perception of an individual's ability to perform a specific behavior, no matter whether this perception is accurate or not.

Third, previous research pointed out the role personal values have for sustainable behavior (e.g., Leiserowitz et al. 2006; Nordlund and Garvill 2002; Steg 2016). In particular, Corner et al. (2014) found that "there are certain clusters of values which are strongly predictive of positive engagement with climate change (in particular, self-transcendent/altruistic values), and others (self-enhancing values) that appear less congruent with sustained, long-term engagement" (p. 418). Besides altruistic and egoistic values, biospheric value orientation also predicts pro-environmental behavior (Dunlap et al. 2000). It might as well be that such personality traits influence sustainable behavior in such a strong way that other interventions such as facilitating the understanding of certain termini is not sufficient to affect the intention to behave sustainably.

Fourth, our experiment showed that the altered termini recommended by Bruine de Bruin et al. (2021) increase the understanding for some, but not all concepts. Thus, it might well be that participants did not understand relevant termini well enough to change their intended behavior. Taken together, different reasons explain the gap between knowledge and intended behavior we found in our experiment. In future research, these reasons may be tested in more detail. It is plausible to assume that by increasing the knowledge to a greater extent, by offering ways how to behave sustainably, and by relating the explained constructs with concrete behaviors, individuals would act more sustainably.

From a more practical point of view, our research also has important implications for the IPCC. The IPCC formulates that their role is "[…] to assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic information relevant to understanding the scientific basis of risk of human-induced climate change, its potential impacts and options for adaptation and mitigation […]" (IPCC 2013). Our findings indicate that for increasing public understanding as well as nudging people's sustainable behavior, climate change terminologies need to be explained in a much more comprehensible way.

8 Limitations and avenues for future research

Despite the implications discussed above, we need to acknowledge several limitations of our experiment. First, in comparison to the original wordings, the altered sentences were longer. Hence, it could have been that participants struggled to understand the altered sentences, which may have counteracted (and undermined) some of the beneficial effects. Indeed, previous research indicates that longer sentences reduce the ease of understanding (Lavarone et al. 2021; Mikk 2008). Thus, as a guide for future science communication, we suggest to formulate messages as simple as possible, and as complex as necessary (Blumer et al. 1987; Standish 2004).

Second, as the sample of our study consisted mostly of highly educated people, the question arises of whether the effect holds true for a more representative sample that includes also less educated people. Since we find that even highly educated people confuse termini proposed by Bruine de Bruin et al. (2021), it is reasonable to assume that the understanding of the termini would be even worse in a more representative sample that includes more people with a lower educational degree. Future research may thus develop additional ways to improve the understanding of termini related to climate change and evaluate its under-

standing in a representative sample. Since our sample did not include a balanced gender ratio, such a study should involve a similar number of female and male participants.

Third, although we were able to detect effect sizes larger than $d = 0.38$ with 90% power, it is important to note that some of our detected effects were smaller. Future research should thus assess even larger samples than we did to be able to reliably detect small effects.

Fourth, we did not randomize the order of the assessed dependent variables. In particular, we assessed subjective understanding before measuring objective understanding. One may argue that assessing subjective understanding first could have increased objective understanding because people may strive to act in line with their self-view and, as a consequence, could have engaged in a greater effort to understand what the termini really mean. To control for this issue, future research assessing the understanding of climate change related termini may randomize the order of the dependent variables.

9 Summary

The IPCC regularly informs the public about climate research. In a quantitative online experiment, we investigated the understanding of eight commonly used climate change termini. Specifically, we tested whether altered wordings proposed by Bruine de Bruin et al. (2021) increase understanding and intention to behave sustainably in comparison to the original IPCC wordings. The results show that participants understand the altered terminology of the termini on average better than when using the original wording used in IPCC reports. Participants also reported a higher confidence in understanding the presented termini and fewer misinterpretations based on mental models from other fields. However, the altered terminology did not increase participants' understanding for all termini. Moreover, we did not find that using altered formulations increases participants' intention to act sustainably. Further research could pick up our findings and try to increase understanding even further by adding explicit examples for the termini. In addition, future research is needed to investigate whether and how increased understanding fosters people's intention to act sustainably.

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Data availability The dataset generated during the current study with the analysis script is available at the Open Science Framework (OSF; https://osf.io/4mcew/).

Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose.

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