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Experiencing Climate Change Virtually: The Effects of Virtual Reality on Climate Change Related Cognitions, Emotions, and Behavior

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ABSTRACT

We conducted a pre-registered, between-subjects experiment to investigate whether experiencing climate change consequences virtually can influence cognitions, emotions, and pro-environmental intentions and behaviors. Participants ($N = 277$) experienced a wildfire through different media that varied in their degree of technological immersiveness (virtual reality vs. regular video vs. magazine articles only). Participants in the virtual reality condition reported higher spatial presence, stronger emotional responses, stronger bodily responses, and reported that the experience felt more life-like. Increased spatial presence was associated with increased risk perceptions and negative emotions. Risk perceptions and negative emotions were subsequently associated with reduced intentions to consume dairy and meat, but not associated with actual plant-based food choices (vegan vs. non-vegan chocolate bar). Actual donations to ENGOs were only influenced by risk perceptions, not emotions. The role of psychological distance was explored, which led to different conclusions for quantitative (no effect of virtual reality) and qualitative measures (virtual reality can reduce psychological distance).

Anthropogenic climate change poses a significant threat to nature, animals, and humanity. To notably reduce the impact of humans on the climate, many changes are necessary in economics and governance, but also in individual behaviors (Nielsen et al., 2020). Despite being generally concerned about climate change, people are often reluctant to engage in pro-environmental behavior. This concern-behavior gap can be explained by, among other factors, the tendency to think about climate change as something distant that will not impact the self (Lorenzoni et al., 2007). This is not surprising – although climate change is currently affecting the lives of millions, the process is unfolding slowly, and it is not visible to the naked eye. Correspondingly, previous research shows that once people do experience the consequences of climate change (e.g. heatwaves), they

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are more likely to perceive climate change as a risk which is associated with more pro-environmental behavioral intentions (Bradley & Reser, 2016; Spence et al., 2011; Van der Linden, 2015).

We posit that an innovative manner to enable people to experience climate change consequences is by simulating these consequences with immersive media like virtual reality. Virtual reality (VR) has been suggested as a promising tool to improve awareness of climate change because it makes "the invisible visible" (Fauville et al., 2020). Virtual reality can provide people with an immersive experience resembling real-life experiences (Markowitz et al., 2018). This way, people can experience the consequences of climate change (e.g. wildfire) safely.

This study adds to the literature in multiple ways. First, we study whether experiences of climate change consequences in virtual reality can produce effects on pro-environmental behavior similar to real-life experiences. Second, most studies on virtual reality in the environmental domain study environmental concerns and beliefs, and only a handful study actual behavior change (e.g. Ahn et al., 2014; Meijers et al., 2022). We will enrich the existing research on virtual reality effects by testing whether a climate change experience in virtual reality can change pro-environmental intentions and whether it translates into actual behaviors. Regarding behaviors, we focus on switching to a largely plant-based diet as consuming less dairy and meat can significantly reduce an individual's carbon footprint (Poore & Nemecek, 2018). Furthermore, individuals can help mitigate climate change by donating money to an environmental non-governmental organization (ENGO). Therefore, we study dairy and meat consumption intentions, use a choice task to assess actual dairy consumption behavior and investigate actual donation behavior to an ENGO.

Third, we aim to uncover what underlying processes explain the hypothesized effect of a virtual reality climate change (i.e. wildfire) experience on pro-environmental behavior. Virtual reality has been shown to evoke spatial presence (i.e. the feeling of being there; Heeter, 1992), which can create the illusion of a direct experience (Schöne et al., 2019). We study how this perceived spatial presence might influence cognitions and emotions. Specifically, we focus on both cognitive risk perceptions (i.e. perceived severity and susceptibility of the threat) and negative emotional responses (e.g. worry, concern, fear). So far, there have been only a few studies examining the role of both cognitive and emotional responses as mediators of persuasive messages in the context of climate change (e.g. Hartmann et al., 2014; Kim et al., 2021), and none using virtual reality. Lastly, we exploratively test the role of psychological distance – a concept that is often posited as one of the reasons for virtual reality to be effective, but so far has only been scarcely and impartially investigated. The current study uses both quantitative (e.g. scales, choices) and qualitative measures (e.g. thought listing) to paint a completer picture.

1.1. Experiencing climate change

Climate change cannot be directly observed and is so large-scale and long-term that it can be difficult to fully comprehend. But climate change does not only manifest as a statistical trend over long periods, it also has concrete consequences. For instance, it increases the likelihood and severity of extreme weather events (Vautard et al., 2020), which can be experienced first-hand. Such personal experiences have been suggested as an important factor in threat assessment, as both cognitive and emotional responses often depend on how vividly negative outcomes can be imagined (Slovic et al., 2004).

Experiences of extreme weather events have been found to correlate with increased climate concern (Bradley & Reser, 2016; Spence et al., 2011), higher risk perceptions (Bradley & Reser, 2016; Van der Linden, 2015), and negative emotions (Bergquist et al., 2019; Demski et al., 2017). Risk perceptions stemming from experiences of climate change have also been found to motivate pro-environmental intentions and behaviors (Bradley & Reser, 2016; Demski et al., 2017; Spence et al., 2011). Yet, willfully exposing people to climate change consequences to enhance climate change concern and stimulate behavior change would be unethical. Therefore, our first aim is to test whether the effects of experiencing climate change on cognitions, emotions, and behaviors can also be triggered by experiencing climate change consequences (i.e. a wildfire) in virtual reality.

1.2. Virtual reality experiences

In the last two decades, there have been great advances in research using virtual reality as a tool for changing beliefs, attitudes, and to a lesser extent, behavior (Slater & Sanchez-Vives, 2016). Virtual reality has also, although rather sparsely, been applied to the field of environmental impact (e.g. Ahn et al., 2014; Breves & Heber, 2020; Meijers et al., 2022; Raja & Carrico, 2021; Smit et al., 2021). For example, in a recent interview study on reactions to ocean acidification in virtual reality, most participants reported that the experience made the problem feel psychologically closer and induced negative emotions (Raja & Carrico, 2021). Another quasi-experimental study showed that both real-life and virtual reality experiences of snorkeling in the Great Barrier Reef had a substantial effect on intentions to take action to conserve nature (Hofman et al., 2021). These promising findings show that virtual reality depictions of climate consequences, which not many people are likely to experience first-hand, might be a good proxy for impactful real-life experiences.

To be able to talk about experiencing something virtually, the immersive quality of the medium and the subsequent illusion of spatial presence ("being there") in the virtual surroundings are important (Markowitz et al., 2018). Research shows that virtual reality is better suited to elicit a sense of spatial presence compared to regular videos (Breves & Heber, 2020; Fonseca & Kraus, 2016). Virtual reality may thus provide people with a seemingly real, unmediated experience. We expect that the more technologically immersive a medium is, the more spatial presence it will elicit, and the larger the behavior change. To test this, we will make use of three conditions to gauge the effects of technological immersiveness on behavior change: no technological immersiveness (articles-only condition: reading one magazine article with tips for behavior change to mitigate climate change, and a second article about the link between climate change and wildfires); medium technological immersiveness (regular video condition: reading the two articles and watching a regular video of climate change consequences), and high technological immersiveness (virtual reality condition: reading the two articles and having a virtual reality experience of climate change consequences). We hypothesize that:

> H1. A virtual reality experience of climate change consequences results in more pro-environmental a) intentions (i.e. dairy and meat consumption intentions) and b) behavior (i.e. donation and food choices) compared to reading articles only or viewing a regular video, H2: these effects are mediated by perceived spatial presence.

1.3. Mechanisms of behavior change

While studies suggest that virtual reality can be a helpful tool to provide climate change experiences and trigger behavior change, the underlying process of this effect has not been studied thoroughly. In the current study, participants will be exposed to a message, a so-called fear appeal, depicting climate change consequences in the form of a wildfire (in different degrees of technological immersiveness) which constitutes a significant threat. Relying on behavior change theories such as the Extended Parallel Processing Model, Protection Motivation Theory, and the Health Belief Model[1] (Maddux & Rogers, 1983; Strecher & Rosenstock, 1997; Witte, 1994), we expect the virtual reality experience to evoke both an increase in cognitive risk perceptions and negative emotions concerning climate change (Hartmann et al., 2014; Tannenbaum et al., 2015). The intensity of the evoked cognitive and emotional responses is expected to be contingent on the technological immersiveness of the medium, with virtual reality leading to more intense responses than viewing a regular video or reading magazine articles only. Furthermore, we expect that the roles of risk perception and negative emotions in behavior change might differ, as we detail below.

1.3.1. Risk perceptions

Previous studies show that risk perceptions and pro-environmental behavior are associated (Spence et al., 2011; Spence et al., 2012). Furthermore, studies on using fear appeals to motivate pro-environmental intentions and behaviors show that risk perceptions play an important role in behavior change (Hartmann et al., 2014; Hunter & Röös, 2016). Based on previous theory and

empirical findings, we hypothesize that experiencing climate change consequences in virtual reality will make climate change risks seem more acute due to the heightened spatial presence (as people will be more likely to feel they are experiencing the climate change consequences). Subsequently, we expect that this increased risk perception stimulates behavior change. In sum, we expect a sequential mediation where due to the increased spatial presence in the virtual reality condition the risk perception increases, which stimulates behavior change:

> H3. A virtual reality climate change experience results in more pro-environmental a) intentions and b) behavior compared to reading articles only or viewing a regular video, this effect is mediated by perceived spatial presence and perceived risk, respectively.

1.3.2. Emotional responses

Even though fear appeals are widely used as a tactic to increase climate change engagement and motivate action, emotions are sometimes overlooked or assumed to have only a secondary role compared to processing messages rationally (see Hartmann et al., 2014). A comprehensive meta-analysis of the effects of fear appeals in diverse fields has found it to be an effective way to influence action, intentions, and attitude change (Tannenbaum et al., 2015). It is thus not surprising that communicators frequently try to evoke negative emotions about climate change (Chapman et al., 2017). Hartmann et al. (2014) found emotional responses to fear appeals to be important to motivate behavior, with an even stronger effect than cognitive risk perceptions. Negative emotions such as fear may however also lead to maladaptive responses, such as counterarguing, aimed at reducing the fear rather than reducing the threat (Witte, 1994). In such an instance a fear appeal might backfire and will not lead to the adaptive response of behavior change. While emotional responses might have similar effects on behavior change as risk perceptions, research does not agree about this. Thus, we pose a research question on the underlying mechanism of negative emotions. We expect that higher technological immersiveness leads to an increase in people's perception of spatial presence and that this translates into stronger negative emotions. Subsequently, the question is whether these negative emotions translate into behavior change:

> RQ1. To what extent is the positive effect of a virtual reality climate change experience on pro-environmental a) intentions and b) behavior compared to reading articles only or viewing a regular video, mediated by perceived spatial presence and emotional responses, respectively?

1.4. Psychological distance

Research suggests that perceived psychological distance (i.e. spatial, social, temporal, hypothetical distance) plays an important role in behavior change in the environmental domain (e.g. Jones et al., 2017; Loy & Spence, 2020). The large psychological distance to climate change is often seen as one of the main culprits for climate inaction. The larger the social (it happens to others, not me), temporal (it happens later, not now), spatial (it happens somewhere else, not here), and hypothetical psychological distance (the effects are uncertain, not certain), the lower the likelihood of action. Virtual reality has been proposed to be able to decrease the perceived psychological distance as it can make abstract concepts more concrete and present them more vividly. Empirical findings, however, are limited and mixed. For example, Raja and Carrico (2021) have shown in a qualitative study that some psychological distance dimensions (i.e. spatial closeness) are more frequently mentioned after watching 360° videos than others. Ahn et al. (2016) found that the use of virtual reality can decrease the perceived temporal psychological distance. Breves and Schramm (2021) tested three dimensions (i.e. temporal, spatial, hypothetical) and found only temporal distance to be affected by virtual reality. To fill this gap in the literature and to test the assumption that virtual reality can decrease psychological distance, we exploratively investigate the role of all four different types of psychological distance dimensions in stimulating behavior change:

RQ2. To what extent does a virtual reality climate change experience affect the four psychological distance dimensions (i.e. spatial, social, temporal, hypothetical) compared to reading articles only or viewing a regular video?

2. Method

2.1. Participants and design

Participants were recruited via the subject pool of the university and were randomly assigned to one of the conditions (articles-only, regular video, virtual reality) in a between-subjects experimental design. A Monte Carlo power analysis for indirect effects was conducted using a free online application (Schoemann et al., 2017). For a model with two parallel mediators, a target power of 80%, 1,000 replications, 20,000 Monte Carlo draws per replication, a confidence level of 95%, and effect sizes based on previous research, 238 participants were needed. We assumed a weak to moderate correlation between technological immersiveness and behavior ($r = .30$; Ahn et al., 2014), moderate correlations between technological immersiveness and mediators ($r = .40$; Breves & Heber, 2020), moderate to strong correlations between mediators and behavioral intention variables ($r = .50$; Hartmann et al., 2014) and a strong correlation between risk perceptions and emotional responses ($r = .80$; Hartmann et al., 2014).

In total, 278 participants participated in the study in exchange for either course credits or monetary compensation. Participants provided informed consent and the study was approved by the university's Ethical Review Board (PC-11550). One participant provided nonsensical answers to the open-ended questions, leaving a total of 277 participants ($M_{age} = 20.67$, $SD_{age} = 3.81$; 77.3% identifying as female, 21.3% as male, and 1.4% as non-binary; coming from 55 different countries, 24.5% being Dutch; $M_{political\ orientation} = 3.52$, $SD_{political\ orientation} = 2.14$ on a left-right 11-point scale – 23 preferred not to say). All participants but one indicated to believe the world's climate is changing and 274 thought this is (at least partially) caused by human activity (1 missing, 2 believed it is mainly caused by natural processes). In general, their dispositional (response) efficacy beliefs were rather high ($M = 5.17$, $SD = 0.71$). The study was conducted in English given the large number of international students at the university and the generally high level of English proficiency in the Netherlands. The study was pre-registered and the pre-registration, all materials, measures, and the data are available at OSF.

2.2. Procedure

Participants came to the university lab, were welcomed by the experimenter, and were randomly assigned to one of the conditions. Participants were then led into one of three small, closed-off rooms where they read the factsheet and provided informed consent. Hereafter, participants answered questions concerning climate change beliefs (Poortinga et al., 2011) and efficacy beliefs (Meijers et al., 2023) which we included for sample description (see OSF for the full survey). Then, all participants were asked to read two magazine articles presented printed, and laminated.

2.2.1. Magazine articles

The first article aimed to increase (response) efficacy beliefs by providing participants with information on how they can act to counter climate change (see Figure A1). Messages evoking risk perceptions and negative emotions have considerably stronger effects on persuasive outcomes when **efficacy appeals** are included (Tannenbaum et al., 2015). The article encouraged three impactful pro-environmental behaviors: reducing dairy and meat consumption and donating to an ENGO. In this way, we ensured that people were aware that decreasing meat and dairy consumption as well as donating to an ENGO, would help in alleviating climate change and wildfires. Participants were asked to write down what they learned to ensure they understood the link between the behaviors and climate change mitigation. Their responses confirmed they understood the link.

The second article was the **fear appeal** and explained the link between climate change and wildfires. Furthermore, the articles emphasized that wildfires are increasingly destructive not only in far-

away countries but also nearby – in the Netherlands (see Figure A2). After reading this article, participants were asked to jot down in their own words what they read in the article to ensure that the link between wildfires and climate change was salient. Once more, their responses confirmed they understood the link. The efficacy appeal was shown first, as this order has been found to reduce avoidance of the threat message and has more persuasive effects (Brown & West, 2015).

2.2.2. Manipulation

After reading the articles, the participants in the articles-only condition continued with the questionnaire. Participants in regular video and virtual reality conditions were shown a four-and-a-half-minute snippet of a forest fire video that was captured during a scheduled burn of a pine tree forest in New Jersey in 2019. The video initially showed a calm forest, but soon fire appeared in the distance, spreading increasingly closer, finally surrounding the viewer, and in the end, only embers remained in the scorched forest. Participants in the virtual reality condition were shown the video in an immersive 360° virtual reality format via a head-mounted display (i.e. HTC Vive). The participants in the regular video condition saw the exact same video but unidirectional via a regular computer screen. Participants in both video conditions were given a headset to listen to the sound that accompanied the video, the crackling fire.

2.2.3. Questionnaire

Following this, participants continued answering the questionnaire, which measured perceived spatial presence, emotional responses, risk perceptions, and psychological distance respectively. Hereafter, participants' intentions to reduce meat and dairy consumption and their actual donation behavior were measured. Then, we captured participants' thoughts and feelings when reading the article and (if applicable) watching the video with an open-ended question, to also generate qualitative insights. Hereafter, we asked participants in the video conditions whether they watched the whole video and if they did not, why (we emphasized at the beginning of the experiment that if participants thought the experience was too uncomfortable, they could stop whenever they wanted). Then, participants filled out questions regarding their demographics (i.e. age, gender, country of origin, political orientation), eating habits (ranging from omnivore to vegan), and allergies. Lastly, participants were thanked for their participation and were told in passing that some chocolate bars were left from another experiment, and they could take one if they wanted, this was our food choice measure.

2.3. Measurement instruments

2.3.1. Mediators

Spatial presence was measured with four items on a 7-point Likert scale (*strongly disagree* to *strongly agree*), like *I felt like I was actually there in the forest*, and *It seemed as though I was actually surrounded by fire* (Tussyadiah et al., 2018; Cronbach's α = .96). **Risk perceptions** of climate change were measured as vulnerability and severity of climate change consequences for the respondent *personally* and for others (*coming generations, society, people in poor countries, plants and animals*) with a total of ten items on 7-point Likert scales, ranging from *impossible* to *extremely likely* and from *no effect* to *extremely serious* (Hunter & Röös, 2016; Cronbach's α = .88). **Emotional responses** were measured with five items asking whether they felt *afraid, scared, fearful, concerned,* and *worried* on a 7-point scale ranging from *not at all* to *extremely* (Hartmann et al., 2014; Cronbach's α = .94).

2.3.2. Behavioral intentions and behavior

Participants were asked about their **intention to reduce meat consumption** with four items like *I am planning to reduce my meat intake in the near future,* and *I am willing to eat meat less often per week* on a 7-point scale (*strongly disagree – strongly agree*; Cronbach's α = .92; De Groeve et al., 2019). Participants reported their **intention to reduce dairy consumption** with the same four items adapted for dairy consumption e.g. *I am willing to consume dairy products less often per week* (Cronbach's α = .92).

Next, we measured ***donations***. Participants read that as a token of appreciation for their participation in the study, two randomly chosen students would receive a €30 voucher. In case they were chosen, they had the option to keep the money for themselves or donate it to one of the ENGOs they read about in the article (350.org and WeForest). Then they were asked to indicate their preference on a 7-point scale ranging from *Keep the €30* to *Give €30 to charity* in steps of €5 (e.g. 2 = *Keep €25 and give €5 to charity*; 5 = *Keep €10 and give €20 to charity*). The second behavioral measure was a ***food choice measure***. Participants were told in passing that some bars were left from another experiment, and they could take one if they wanted. A choice of two vegan and two non-vegan chocolate bars of comparable taste was presented for this purpose. The vegan option was clearly labeled so that it could be easily recognized as such by the participants.

2.3.3. Explorative variables

Each dimension of ***psychological distance*** was measured on a 7-point scale (*strongly disagree – strongly agree*) with items like *Climate change mostly affects other parts of the world* (spatial distance, four items; Cronbach's α = .84), *Climate change mostly affects people I do not know* (social distance, three items; Cronbach's α = .87), *Climate change effects will mostly occur in the future* (temporal distance, three items; Cronbach's α = .72), and *I am uncertain what the effects of climate change are* (hypothetical distance, three items; Cronbach's α = .78; Loy & Spence, 2020). See OSF for all items used.

2.4. Data analyses

For data analyses of the closed-ended, quantitative questions (e.g. 1-7 Likert scale), we followed our pre-registration.[2] For example, we did not include vegans for the behavioral intentions or the food choice (but we did include them for the donation DV). Vegetarians were only excluded from the meat-eating behavioral intentions measure. For the open-ended, qualitative questions, we took an inductive approach, in which the researchers first familiarized themselves with the data and then created a codebook (see OSF) in an iterative process (DeCuir-Gunby et al., 2011). The researchers and two student assistants coded independently a subset of comments, after which any inconsistencies were discussed and resolved, and the codebook was further developed. When the codebook was finalized, the student assistants double coded all comments. The remaining inconsistencies were discussed and resolved. Next to analyzing the comments qualitatively, we also analyzed them quantitatively. We used crosstabs for the analyses, making use of the Mantel-Hanzel Chi-square for ordinal data (i.e. less to more technological immersiveness: articles-only, regular video, virtual reality).

3. Results

3.1. Randomization check

Participants did not differ across conditions in age, $F(2, 273) = 0.36$, $p = .699$, gender, $\chi^2 (4) = 6.38$, $p = .173$, or eating habits, $\chi^2 (12) = 10.41$, $p = .580$. Also, Bonferroni post-hoc tests showed that participants in the articles-only and regular video condition had a similar political ideology ($p = .057$), so did participants in the articles-only and virtual reality conditions ($p > .999$), as well as participants in the regular video and virtual reality conditions ($p = .114$).[3] Therefore, no covariates were considered for hypotheses testing.

3.2. Main effects

3.2.1. Spatial presence

To test whether people felt like they were actually experiencing a wildfire, we used an ANOVA. The ANOVA showed that perceived spatial presence differed in the three conditions, $F(2, 274) = 118.80$, $p < .001$, $\eta_p^2 = .46$. As expected, the ANOVA with Bonferroni post-hoc tests showed that participants

in the virtual reality condition reported higher levels of spatial presence (M = 5.05, SD = 1.24) than those in the regular video condition (M = 4.48, SD = 1.55), p = .011 and than those in the articles-only condition (M = 2.22, SD = 1.12), p < .001 (participants in the articles-only condition also significantly differed from the participants in the regular video condition p < .001, please see Table 1).

In line with the quantitative measures, the qualitative measures confirmed that virtual reality can provide a more life-like experience than reading articles only or watching a regular video. Participants in the virtual reality condition were more likely to indicate that the wildfire felt life-like (54.5%) than participants in the articles-only or regular video condition (1.6% and 35.4% respectively), χ^2 (1) = 34.71, p < .001.

"*I felt like I was really in the forest and experiencing the fire.*" Female (21, France), virtual reality condition

Participants in the regular video condition were also more likely to indicate that the wildfire felt more life-like than participants in the articles-only condition, but less often than in the virtual reality condition.

"*The video was a much more real and visceral way to experience the issue of wildfires compared to simply reading the pamphlet.*" Male (22, USA) regular video condition

Similarly, participants in the articles-only condition merely mentioned bodily experiences in 1.6% of the cases, participants in the regular video condition in 12.3% of the cases, and participants in the virtual reality condition in 31.8% of the cases, χ^2 (1) = 21.54, p < .001.

"*For the video I have never seen a wildfire this close and gave me goosebumps. I could see how the fire was so far away and small at first, grow to be huge and wiping out all livings.*" Female (23, South Korea) regular video condition

"*My hands where sweating and I felt my heart race [...], I really wanted the video to be over because it was really scary and I tried to convince myself that it was not real.*" Female (20, Peru) virtual reality condition

3.2.2. Risk perceptions

When it came to the effects of the conditions on risk perceptions, the results showed that participants rated the risk equally high in all three conditions (F(2, 274) = 0.67, p = .513), and all consistently high (all M > 6.25 on a 7-point scale, see Table 1). The same picture became apparent from the qualitative measures. Participants in all three conditions mentioned to a similar extent that climate change and environmental problems are a threat (about 50% in all conditions, χ^2 (1) < 0.01, p = .949), often referring to the fact that they already knew this or stating this as a given.

"*I think that the issue of wildfires associated with extreme weather conditions (such as very high temperatures and increasing droughts) caused by climate change is a very pressing and very concerning problem.*" Female (21, Italy) articles-only condition

"*When thinking back to the pamphlet and videos the seriousness of climate change was made clear. I now realize more than ever how bad it is and how much needs to change.*" Female (18, Germany) regular video condition

Table 1. Means and SDs for the (potential) mediators and dependent variables.

	Articles-only	Regular video	Virtual reality
Spatial presence	2.22(1.12)[a]	4.48(1.55)[b]	5.05(1.24)[c]
Risk perceptions	6.26(0.67)[a]	6.35(0.55)[a]	6.35(0.58)[a]
Emotional responses	4.31(1.36)[a]	4.84(1.41)[b]	5.15(1.35)[b]
Meat consumption	5.07(1.58)[a]	5.39(1.43)[a]	5.47(1.32)[a]
Dairy consumption	4.90(1.60)[a]	4.97(1.44)[a]	5.18(1.42)[a]
Donation	€19.78(€11.09)[a]	€19.44(€10.40)[a]	€21.75(€9.90)[a]
Food choice	46.3%[a]	55.8%[a]	60.2%[a]

Note. All variables are measured on a 1-7 scale except for food choice where participants could choose either a chocolate bar containing dairy or a vegan option, the donation variable was converted to Euro. The percentages reported are the percentages of vegan chocolate bars chosen. Different subscripts indicated significant differences p < .050 with Bonferroni post-hoc tests.

"*I feel as climate change is a very serious issue and the wildfire example is just another one of the terrifying realities that are occurring now thanks to climate change.*" Male (19, Indonesia), virtual reality condition

When combining the results of the quantitative and qualitative approaches regarding the effects of the conditions on risk perceptions, it seems that the level of technological immersiveness of the medium does not affect risk perceptions differently.

3.2.3. Emotional responses

When it came to the effects of condition on emotional responses, the results showed that participants differed in the extent to which they experienced emotions depending on the technological immersiveness of the medium they were exposed to ($F(2, 274) = 8.82$, $p < .001$, $\eta_p^2 = 0.06$). That is, participants in the virtual reality condition ($M = 5.15$, $SD = 1.35$) and the regular video condition ($M = 4.84$, $SD = 1.41$) reported more negative emotions than participants in the control condition ($M = 4.31$, $SD = 1.36$; $p < .001$ and $p < .029$ respectively). The qualitative findings show a similar pattern. In the open-ended question, participants in all three conditions made references to their negative emotions concerning climate change and/or environmental problems in general (about 70% of the participants in all conditions, $\chi^2 (1) = 0.02$, $p = .889$). Importantly, however, the intensity of these emotions differed between conditions, $\chi^2 (1) = 8.52$, $p = .004$, with participants in the more immersive conditions experiencing more *intensive* emotions. Participants in the articles-only condition mostly mentioned one (diminutive) negative emotion (59.7%).

"*When I look back at the pamphlet I feel a little concerned of the effects of climate change and wildfires, because the pictures are very real (to me). I recognize a lot of information from what I've heard before (on the news, on television, on social media) but it is still a little confronting.*" Female (18, the Netherlands) articles-only condition

Participants in the regular video condition mentioned several (strong) negative emotions (56.9%).

"*I felt somewhat concerned while reading the article but I felt actually a tinge of real fear when I was watching the video. I thought about what it might be like to see my own living area be destroyed like this and I felt an even stronger need to take action to prevent it.*" Female (19, the Netherlands) regular video condition

And participants in the virtual reality condition mentioned the most (strong) negative emotions (65.1%).

"*I feel very shocked, especially after seeing the video and being somewhat exposed to this horrible situation that resembles the one that victims of wildfires are exposed to. The pamphlet did not provide more information than I already knew, it really was the video that made a shocking difference in the way that I now feel and think about wildfires, as the scaring effect is very effective. I felt like I was in the fire, started to sweat and get nervous, thinking I had no way to run. It was very scary and definitely shocking moment that I won't forget so easily and that will stick with me for a while.*" Female (20, Brazil) virtual reality condition

When combining the results of the quantitative and qualitative approaches regarding the effects of condition on emotional responses, it seems that more immersive media are better suited for eliciting emotional responses than less immersive media.

3.2.4. Behavior change

To test whether a virtual experience (vs. regular video vs. articles-only) would lead to more pro-environmental intentions and behaviors (H1), we ran ANOVAs. Please note that for the food-related dependent variables, we took eating habits into account (e.g. for dairy consumption intentions, vegans were excluded from the analyses, see section "2.4. Data analyses" for more details). The results of the ANOVAs unexpectedly showed that participants reported similar meat consumption ($F(2, 228) = 1.60$, $p = .204$) and dairy consumption intentions ($F(2, 249) = 0.806$, $p = .448$) regardless of the condition (for Means and SDs see Table 1). Furthermore, the amount donated did not differ per condition, $F(2, 274) = 1.34$, $p = .262$. Lastly, we ran crosstabs to test the effect of condition on the type of chocolate bar participants chose. There were no significant differences

per condition χ^2 (1) = 3.19, p = .074 (see Figure 1). When looking at the qualitative measure, a similar pattern arose. In all three conditions, the participants spontaneously commented on the need to act about 37% of the time, but in all three conditions to the same extent (χ^2 (1) = 0.45, p = .833).

"*When I see or hear these stories, I want to make a difference in the world to prevent these natural disaster. On the other hand, I think that everyone has to contribute to combat climate changes, not just only a couple of individuals. I think that everyone on this planet needs to change in order to fight against all of these natural disasters.*" Female (19, the Netherlands) articles-only condition

"*[…] I realized that it is not that difficult to change something in order to slow climate change, for example just stop eating diary and meat.*" Female (18, Germany) regular video condition

Participants also regularly referred to other actors such as governments, companies, and organizations, and in some instances referred to a general sense of hopelessness.

"*I strongly believe that the largest part of combating climate change is to be done by putting strict rules on big industry and big corporations, since they represent a much bigger part of the problem. […] I also recognize that we as consumers should also do our part. I would love to go towards a diet where meat is eaten less often and with higher standards in terms of ecological and biological values.*" Male (23, the Netherlands) articles-only condition

"*Most of all, I feel hopeless, I'm already trying my best not buying meat, using plant-based dairy, not use so much of plastic materials, but it just doesn't seem like enough. does it.*" Female (20, Czechia) regular video condition

"*I also thought that I am already vegetarian and that there is a limit to what can be done at the individual level, governments should be more proactive in defending the environment but I don't think they will.*" Female (20, Italy) virtual reality condition

In sum, based on the closed-ended and open-ended questions, H1 has to be rejected. That is, virtual reality does not directly lead to more pro-environmental intentions and behaviors than watching a regular video or reading articles only.

3.3. Underlying mechanisms

3.3.1. The underlying role of spatial presence
When looking into the mediating role of spatial presence, the results using PROCESS v3.4 Model 4 and Model 81 (5,000 bootstraps, Hayes, 2017) showed that this heightened sense of spatial presence in the virtual reality and regular video condition did not directly translate in more behavior change, thereby rejecting H2 (see Figures 2 and 3, and Table A1).

3.3.2. The underlying role of risk perceptions and emotional responses
Hereafter, we looked into the role of spatial presence and subsequently perceived risk and emotional responses in parallel as underlying mechanisms. To this end, we used PROCESS v3.4 Model 81 (5,000 bootstraps, Hayes, 2017) for each of the dependent variables. For **behavioral intentions**, the results showed that the increased spatial presence after the virtual reality experience and after watching the regular video was associated with higher risk perceptions and emotional responses, which subsequently influenced both meat and dairy consumption intentions, see Figure 2. The relative indirect effects (see Table A2) also confirmed these two parallel pathways for intentions.

The results for **behavior**, that is donations and food choice, showed a different pattern, see Figure 3. Again, the increased spatial presence after the virtual reality experience (and watching the regular video), was associated with higher risk perceptions and emotional responses. However, risk perceptions were associated with donating more money but not with food choices. Furthermore, emotional responses were not associated with donations or food choices (see Table A2 for the relative indirect effects). In sum, based on the findings, H3 can be tentatively accepted. There is evidence for an indirect effect of the virtual reality and the regular video vs. the articles-only
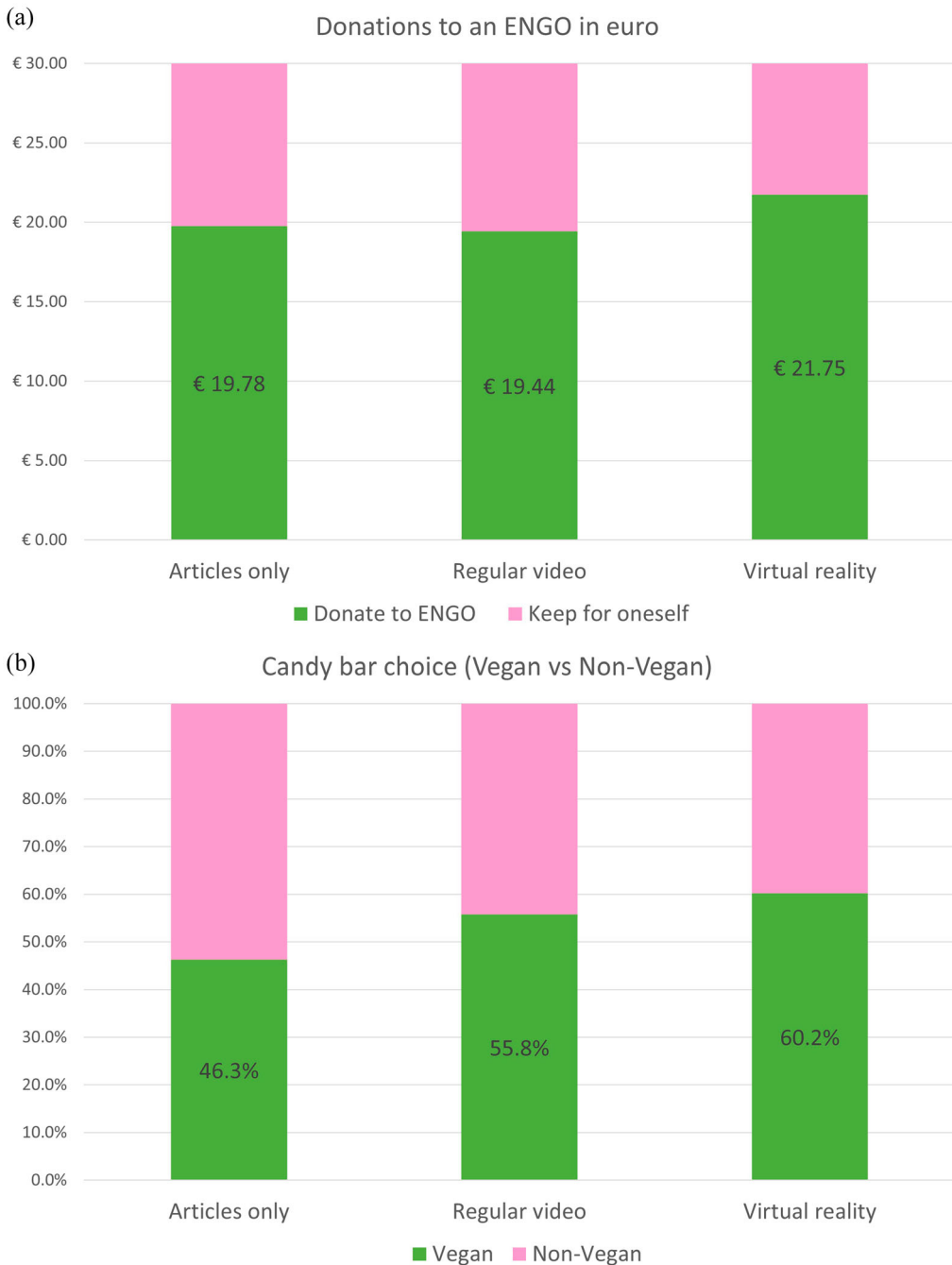
(a)

(b)

Figure 1. Effects of condition (low, medium, high technological immersiveness) on behavior. Note Figure 1a. Donations to ENGO or amount kept for oneself. There were no statistical differences between the conditions $F(2, 274) = 1.34$, $p = .262$. Note Figure 1b. Choices for a vegan vs non-vegan chocolate bar. There were no statistical differences between the conditions $\chi^2 (1) = 3.19$, $p = .074$.

condition on behavioral intentions (meat and dairy consumption; H3a) and behavior (donating; H3b) via increased spatial presence and risk perceptions, but not for actual food choices. In answer to RQ1, the results show that for behavioral intentions there is evidence for an indirect effect of
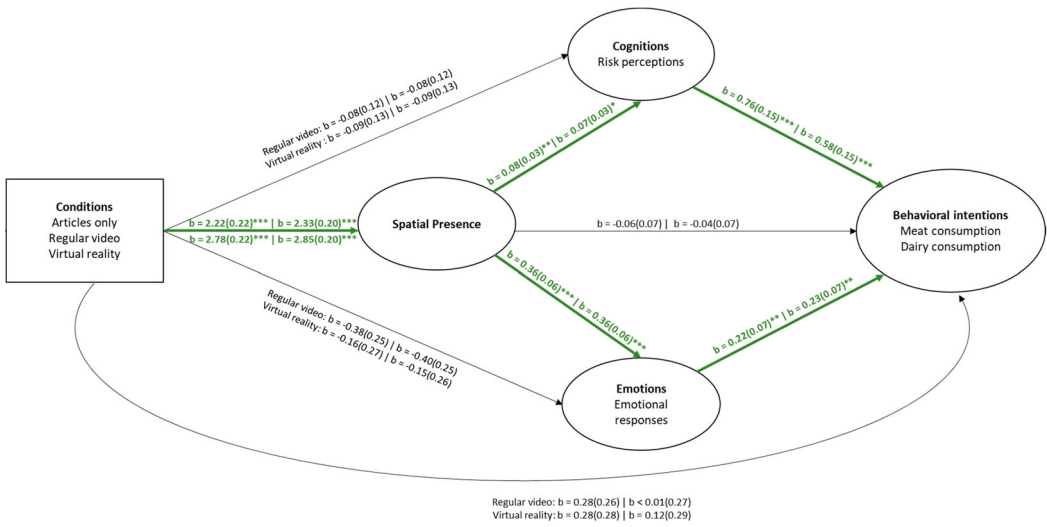
Figure 2. Underlying mechanisms for behavioral intentions (meat and dairy consumption). Note. The coefficients (standard errors) and their significance level (* $p < .050$, ** $p < .010$, *** $p < .001$) for the pathways, using Model 81 of PROCCESS with a multi-categorical predictor. When two lines are included, the top line represents the comparison between the articles-only and the regular video condition, the bottom line represents the comparison between the articles-only and the virtual reality condition. The numbers before the pipe (|) represent the statistics regarding meat consumption intentions, and the numbers after the pipe (|) represent the statistics regarding dairy consumption intentions.
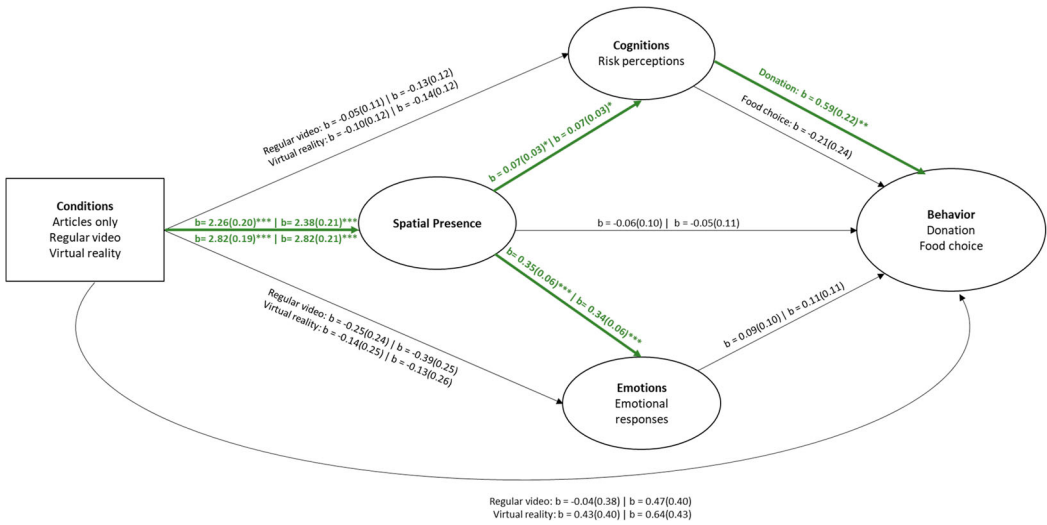
Figure 3. Underlying mechanisms for behaviors (donation and food choice). Note. The coefficients (standard errors) and their significance level (* $p < .050$, ** $p < .010$, *** $p < .001$) for the pathways, using Model 81 of PROCCESS with a multi-categorical predictor. When two lines are included, the top line represents the comparison between the articles-only and the regular video condition, the bottom line represents the comparison between the articles-only and the virtual reality condition. The numbers before the pipe (|) represent the statistics regarding donations, and the numbers after the pipe (|) represent the statistics regarding food choices (choosing a vegan chocolate bar).

virtual reality and regular video vs. articles-only on behavioral intentions (meat and dairy consumption; RQ1a) via increased spatial presence and emotional responses. However, the results did not show such an indirect pathway for behavior. Emotional responses did not seem to be associated with actual behavior (RQ1b).

3.4. Explorative analyses

3.4.1. Psychological distance

As research often suggests that virtual reality might be effective for behavior change because it can decrease the psychological distance (in this case regarding climate change), we exploratively tested whether perceived psychological distance to climate change was smaller for participants in the virtual reality than the regular video and articles-only conditions. We only found a small significant effect for temporal distance $F(2, 274) = 3.99$, $p = .020$, $\eta_p^2 = .03$, and in the opposite direction. That is, participants in the virtual reality condition perceived a larger temporal distance ($M = 5.01$, $SD = 1.28$) than participants in the articles-only condition ($M = 4.51$, $SD = 1.36$), $p = .023$. Participants in the regular video condition did not differ in perceived temporal distance from the virtual reality and articles-only conditions ($M = 4.92$, $SD = 1.20$; both p-values > .100). Furthermore, risk perceptions were negatively associated with all four dimensions of psychological distance; thus, higher risk perception was associated with less psychological distance. For the emotional responses the associations differed per dimension, see Table A3.

In contrast to the quantitative measures, the qualitative statements of participants did show a difference in how concrete (psychologically closer, more tangible) vs abstract (psychologically distant, hard to grasp) participants construed climate change and wildfires. Participants in the articles-only condition were more likely to comment on climate change and wildfires as something psychologically distant (11.1%) than participants in the regular video (4.5%) and participants in the virtual reality condition (4.1%).

> "*Since wildfires have yet to have a direct effect on my life, the issue feels more distant and less relevant to me as someone who has been directly affected by it or witnessed it first-hand. As a result, I am naturally less worried about it.*" Male (20, Malaysia) articles-only condition

In contrast, participants in the virtual reality condition were more likely to comment on the psychological closeness (54.6%), than participants in the regular video (40.4%) and articles-only conditions (36.7%), $\chi^2 (1) = 7.97$, $p = .005$.

> "*Global warming is a serious problem, but a lot of people don't really see that because the wildfires or other natural disasters are far away most of the time. After the video I really started thinking about all the consequences of global warming and the need to do something about it before it is too late.*" Female (21 years, the Netherlands) virtual reality condition

> "*Before I felt less concerned about climate change and global warming, because it all seemed like something that is far away from my daily life and there was few that I could do. But after reading the pamphlet and experienced the 4D video, it's now clearer for me about what I can actually do and how severe the consequence can be.*" Female (24, China) virtual reality condition

Sometimes participants also made spontaneous explicit comparisons between the different media types:

> "*The pamphlets gives a feeling of distance with the problems at hand. When reading the pamphlet I don't feel a need to change my behaviour, I feel more informed. The video is more touching, I feel as if the video get me closer to the problem, making me feel more anxious and afraid of my future rather than when reading the pamphlet.*" Male (18, France) regular video condition

> "*Reading the pamphlet and seeing the video concerned me even more about the climate change. Because there are not that many wildfires in the Netherlands, seeing one in VR makes it more tangible for me to understand. Also experiencing a wildfire makes you more conscious about what a wildfire can do to a place. With reading the pamphlet you reading the facts, and it clearly explains why, but with a video in VR the impact is much heavier.*" Male (21, The Netherlands) virtual reality condition

When taking the insights from the quantitative and qualitative measures, RQ2 cannot be answered unequivocally. That is, the closed-ended, quantitative questions provide no evidence for high technological immersive media being better able to decrease psychological distance than less immersive media. However, the open-ended, qualitative questions paint a different picture. This disparity in findings might be a measurement issue, something we reflect on in the discussion.

4. Conclusion and discussion

4.1. Spatial presence

We used a virtual reality experience showing a wildfire to provide people with an immersive mediated personal experience of climate change consequences. We hypothesized that such a 'life-like' experience would increase people's risk perceptions and negative emotional responses in comparison to just reading articles about climate change or watching the same footage in a regular video format. The results showed that participants in the virtual reality condition were more likely to feel that they were actually experiencing a wildfire than participants in the regular video and the articles-only condition. That is, they were more likely to report a feeling of spatial presence, to report that the wildfire experience seemed life-like, and to report bodily experiences (e.g. sweating hands, heart racing). As such, virtual reality experiences of climate change consequences may add something on top of regular news or magazine articles as it can provide people with a more life-like experience – as a participant put it: virtual reality "*may be more of an "eye-opener" to people.*"

4.2. Cognitions and emotions

Next, we tested whether the enhanced feeling of spatial presence influenced risk perceptions and negative emotional responses. The results regarding risk perceptions showed that participants in all three conditions saw climate change as very severe ($M > 6.25$ on a 7-point scale in all conditions), there was no difference between conditions, possibly due to a ceiling effect. For emotional responses, participants in the virtual reality and regular video conditions reported stronger negative emotions regarding climate change than those in the articles-only condition. Thus, adding video footage of climate change consequences seems to be a promising manner to increase people's climate change concerns. It is important to note though that participants in the regular video condition saw the video on a large computer screen and, just like participants in the virtual reality condition, were wearing headphones that were playing the sound of the wildfire. For future research, it might therefore be important to test exactly how immersive a regular video should be to produce emotional responses. While doing so, it could be interesting to also test 360° videos seen on a computer screen (in contrast to the unidirectional video we used on the computer screen) versus via a virtual reality headset, as recent research shows that watching 360° videos seen on a computer screen might be less likely to arouse emotional fear responses than a regular video (Oh et al., 2021).

4.3. Behavior

We hereafter tested whether the changes in spatial presence, risk perceptions, and emotional responses could instigate behavior change. The indirect-only effects demonstrated that a feeling of spatial presence is vital for further effects to arise; only when people feel they are present in the environment, this might influence downstream effects like risk perceptions, emotions, and behavior change. This concurs with previous studies showing the importance of spatial presence (e.g. Breves, 2020). Spatial presence could be further enhanced in future studies by for example adding interactive virtual reality features as well as haptic feedback (Gibbs et al., 2022).

Furthermore, different indirect-only paths arose for behavioral intentions and actual behavior. The increase in spatial presence in both the virtual reality and regular video condition, in comparison to the articles-only condition, was associated with higher risk perceptions and emotional responses and subsequently intentions to reduce both meat and dairy consumption. For behavior, however, the effects were different. Food choice (i.e. choosing a vegan or dairy-based chocolate bar) was not associated with either risk perceptions or emotional responses. For donating to an ENGO there was an indirect-only path via spatial presence and risk perceptions, but not via emotional

responses. This is rather unexpected, as a recent review shows the importance of emotions and affect when it comes to climate change behaviors (Brosch, 2021). Future research could test whether this difference in paths via risk perceptions and emotional responses on intentions and behavior replicates while testing also different types of intentions and behaviors. Since quite some participants mentioned the collective nature of climate change (where changes are necessary on a micro, meso, and macro level), it might be interesting to look into more macro-level dependent variables such as policy support.

4.4. Psychological distance

We exploratively investigated the role of psychological distance. When looking at the quantitative measures, we did not find any evidence for virtual reality being able to decrease the psychological distance. There were no significant findings for spatial, social, or hypothetical distance. Furthermore, participants in the virtual reality condition perceived a *larger* temporal distance than participants in the articles-only condition (the regular video condition did not differ from the other conditions). We can only speculate why this unexpected, opposite effect arose. On the one hand, it could be a chance finding, on the other hand, it could be due to motivated reasoning. That is, people might feel helpless and to cope with the threat they might construe the threat as more temporally distant and therefore less threatening. This is something future research could investigate.

The qualitative measures paint a different picture, however. Participants reported a difference in how concrete (psychologically closer, more tangible) vs abstract (psychologically distant, hard to grasp) they construed climate change and wildfires. Whereas in the articles-only condition, participants were more often commenting on the psychological distance and abstractness of climate change and wildfires, participants in the virtual reality condition were more likely to comment on the psychological closeness and concreteness.

One potential reason for the disparity could be the measurement we used for psychological distance. Recent research indicates differences between egocentric and non-egocentric psychological distance (Duan et al., 2022). In two studies, the researchers showed that climate change communication affected egocentric psychological distance (i.e. distance from the self), but not non-egocentric psychological distance (i.e. distance from others; Duan et al., 2022). The measurement we used (by Loy & Spence, 2020), makes use of non-egocentric statements (e.g. climate change is a significant problem mainly for others), which is potentially less suitable for studying the effects of climate change communication according to the findings by Duan et al. (2022) and thus a limitation of the current study. For future virtual reality research, it would therefore be interesting to test the effects of psychological distance systematically with different measures.

4.5. Conclusions

With climate change being one of the most pressing problems of our time and with a limited window of time to act, it is important to figure out ways to stimulate people to behave in a more climate-friendly way. Whereas no single solution is going to solve the complex problem of climate change, creating immersive content may be a cog in the machine by awakening climate change cognitions, emotions, and down-the-line behavioral intentions and behavior. More and more news outlets use immersive content, such as *the Guardian* which created virtual reality content on bird extinction and nature conversation. With affordable virtual reality devices and tools (e.g. virtual reality glasses, Google cardboard), the possibilities are increasing. The current study suggests that making use of these possibilities is important, as having people experience climate change consequences virtually via immersive media might highlight the problem for people and kick-start action.

Notes

1. Please note that strong efficacy and response efficacy beliefs are vital for behavior change when messages are used that enhance risk perceptions and induce fear. We reflect on this in section 2.2. Procedure.
2. Please note that we used Bonferroni post-hoc tests instead of Tukey post-hoc tests as specified in the pre-registration. Given that we have quite some comparisons we chose for Bonferroni post-hoc tests instead of Tukey post-hoc tests to decrease the chance of a Type I error.
   Also, please note that for the hypotheses we proposed PROCESS models for sub-parts of the model in addition to a PROCESS model for the total model. The results of the total model are presented for conciseness reasons as the results of the sub-models are very similar making these redundant.
3. Please note that the overall effect of the ANOVA for political ideology showed that there were differences in reported political ideology across the three conditions, $F(2, 251) = 3.32$, $p = .038$. The follow-up post-hoc tests however showed no differences between the conditions. Although this might feel counterintuitive, this sometimes happens.
4. Please note that there are some slight differences between the pictures in the articles used in the study and the pictures presented here due to copyright issues.

Author contribution statement

Marijn Meijers: Conceptualization; Data curation; Formal analysis; Funding acquisition; Methodology; Supervision; Visualization; Project administration; Writing – original draft; Writing – review & editing.

Ragnheiður "Heather" Torfadóttir: Conceptualization; Funding acquisition; Supervision of Investigation; Methodology; Project administration; Writing – original draft; Writing – review and editing.

Anke Wonneberger: Conceptualization; Funding acquisition; Methodology; Writing – review & editing.

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References

Ahn, S. J., Bailenson, J. N., & Park, D. (2014). Short- and long-term effects of embodied experiences in immersive virtual environments on environmental locus of control and behavior. *Computers in Human Behavior*, *39*, 235–245. https://doi.org/10.1016/j.chb.2014.07.025

Ahn, S. J., Bostick, J., Ogle, E., Nowak, K. L., McGillicuddy, K. T., & Bailenson, J. N. (2016). Experiencing nature: Embodying animals in immersive virtual environments increases inclusion of nature in self and involvement with nature. *Journal of Computer-Mediated Communication*, *21*(6), 399–419. https://doi.org/10.1111/jcc4.12173

Bergquist, M., Nilsson, A., & Wesley Schultz, P. (2019). Experiencing a severe weather event increases concern about climate change. *Frontiers in Psychology*, *10*(FEB), 1–6.

Bradley, G. L., & Reser, J. P. (2016). Adaptation processes in the context of climate change: A social and environmental psychology perspective. *Journal of Bioeconomics*, *19*(1), 29–51. https://doi.org/10.1007/s10818-016-9231-x

Breves, P. (2020). Bringing people closer: The prosocial effects of immersive media on users' attitudes and behavior. *Nonprofit and Voluntary Sector Quarterly*, *49*(5), 1015–1034. https://doi.org/10.1177/0899764020903101

Breves, P., & Heber, V. (2020). Into the wild: The effects of 360 immersive nature videos on feelings of commitment to the environment. *Environmental Communication*, *14*(3), 332–346. https://doi.org/10.1080/17524032.2019.1665566

Breves, P., & Schramm, H. (2021). Bridging psychological distance: The impact of immersive media on distant and proximal environmental issues. *Computers in Human Behavior*, *115*, 106606. https://doi.org/10.1016/j.chb.2020.106606

Brosch, T. (2021). Affect and emotions as drivers of climate change perception and action: A review. *Current Opinion in Behavioral Sciences*, *42*, 15–21. https://doi.org/10.1016/j.cobeha.2021.02.001

Brown, S. L., & West, C. (2015). Sequencing the threat and recommendation components of persuasive messages differentially improves the effectiveness of high- and low-distressing imagery in an anti-alcohol message in students. *British Journal of Health Psychology*, *20*(2), 324–340. https://doi.org/10.1111/bjhp.12103

Chapman, D. A., Lickel, B., & Markowitz, E. M. (2017). Reassessing emotion in climate change communication. *Nature Climate Change*, *7*(12), 850–852. https://doi.org/10.1038/s41558-017-0021-9

DeCuir-Gunby, J. T., Marshall, P. L., & McCulloch, A. W. (2011). Developing and using a codebook for the analysis of interview data: An example from a professional development research project. *Field Methods*, *23*(2), 136–155. https://doi.org/10.1177/1525822X10388468

De Groeve, B., Bleys, B., & Hudders, L. (2019). Okay to promote eating less meat, but don't be a cheat–The role of dietary identity, perceived inconsistency and inclusive language of an advocate in legitimizing meat reduction. *Appetite*, *138*, 269–279. https://doi.org/10.1016/j.appet.2019.03.031

Demski, C., Capstick, S., Pidgeon, N., Sposato, R. G., & Spence, A. (2017). Experience of extreme weather affects climate change mitigation and adaptation responses. *Climatic Change*, *140*(2), 149–164. https://doi.org/10.1007/s10584-016-1837-4

Duan, R., Zwickle, A., & Takahashi, B. (2022). Refining the application of construal level theory: Egocentric and nonegocentric psychological distances in climate change visual communication. *Environmental Communication*, *16*(1), 92–107. https://doi.org/10.1080/17524032.2021.1964999

Fauville, G., Queiroz, A. C. M., & Bailenson, J. N. (2020). Virtual reality as a promising tool to promote climate change awareness. In *Technology and health* (pp. 91–108). Elsevier.

Fonseca, D., & Kraus, M. (2016). *A comparison of head-mounted and hand-held displays for 360° videos with focus on attitude and behavior change*. Academicmindtrek 2016 - proceedings of the 20th international academic mindtrek conference, 287–296.

Gibbs, J. K., Gillies, M., & Pan, X. (2022). A comparison of the effects of haptic and visual feedback on presence in virtual reality. *International Journal of Human-Computer Studies*, *157*, 102717. https://doi.org/10.1016/j.ijhcs.2021.102717

Hartmann, P., Apaolaza, V., D'Souza, C., Barrutia, J. M., & Echebarria, C. (2014). Environmental threat appeals in green advertising: The role of fear arousal and coping efficacy. *International Journal of Advertising*, *33*(4), 741–765. https://doi.org/10.2501/IJA-33-4-741-765

Hayes, A. F. (2017). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. Guilford publications.

Hayes, A. F., & Preacher, K. J. (2014). Statistical mediation analysis with a multicategorical independent variable. *British Journal of Mathematical and Statistical Psychology*, *67*(3), 451–470. https://doi.org/10.1111/bmsp.12028

Heeter, C. (1992). Being there: The subjective experience of presence. *Presence: Teleoperators and Virtual Environments*, *1*(2), 262–271. https://doi.org/10.1162/pres.1992.1.2.262

Hofman, K., Hughes, K., & Walters, G. (2021). The effectiveness of virtual vs real-life marine tourism experiences in encouraging conservation behaviour. *Journal of Sustainable Tourism*.

Hunter, E., & Röös, E. (2016). Fear of climate change consequences and predictors of intentions to alter meat consumption. *Food Policy*, *62*, 151–160. https://doi.org/10.1016/j.foodpol.2016.06.004

Jones, C., Hine, D. W., & Marks, A. D. G. (2017). The future is now: Reducing psychological distance to increase public engagement with climate change. *Risk Analysis*, *37*(2), 331–341. https://doi.org/10.1111/risa.12601

Kim, S. C., Pei, D., Kotcher, J. E., & Myers, T. A. (2021). Predicting responses to climate change health impact messages from political ideology and health status: Cognitive appraisals and emotional reactions as mediators. *Environment and Behavior*, *53*(10), 1095–1117. https://doi.org/10.1177/0013916520942600

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., … Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. *Environmental Innovation and Societal Transitions*, *31*, 1–32. https://doi.org/10.1016/j.eist.2019.01.004

Lorenzoni, I., Nicholson-Cole, S., & Whitmarsh, L. (2007). Barriers perceived to engaging with climate change among the UK public and their policy implications. *Global Environmental Change*, *17*(3–4), 445–459. https://doi.org/10.1016/j.gloenvcha.2007.01.004

Loy, L. S., & Spence, A. (2020). Reducing, and bridging, the psychological distance of climate change. *Journal of Environmental Psychology*, *67*, 101388. https://doi.org/10.1016/j.jenvp.2020.101388

Maddux, J. E., & Rogers, R. W. (1983). Protection motivation and self-efficacy: A revised theory of fear appeals and attitude change. *Journal of Experimental Social Psychology*, *19*(5), 469–479. https://doi.org/10.1016/0022-1031(83)90023-9

Markowitz, D. M., Laha, R., Perone, B. P., Pea, R. D., & Bailenson, J. N. (2018). Immersive virtual reality field trips facilitate learning about climate change. *Frontiers in Psychology*, *9*, 2364. https://doi.org/10.3389/fpsyg.2018.02364

Meijers, M. H. C., Smit, E. S., de Wildt, K., Karvonen, S. G., van der Plas, D., & van der Laan, L. N. (2022). Stimulating sustainable food choices using virtual reality: Taking an environmental vs health communication perspective on enhancing response efficacy beliefs. *Environmental Communication*, *16*(1), 1–22. https://doi.org/10.1080/17524032.2021.1943700

Meijers, M. H. C., Wonneberger, A., Azrout, R., & Brick, C. (2023). Introducing and testing the personal-collective-governmental efficacy typology: How personal, collective, and governmental efficacy subtypes are associated with differential environmental actions. *Journal of Environmental Psychology*, *85*, 101915. https://doi.org/10.1016/j.jenvp.2022.101915

Nielsen, K. S., Clayton, S., Stern, P. C., & Dietz, T. (2020). How psychology can help limit climate change. *American Psychologist*, *76*(1), 130–144. https://doi.org/10.1037/amp0000624

Oh, J., Jin, E., Sudarshan, S., Nah, S., & Yu, N. (2021). Does 360-degree video enhance engagement with global warming?: The mediating role of spatial presence and emotions. *Environmental Communication*, *15*(6), 731–748. https://doi.org/10.1080/17524032.2021.1891945

Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science*, *360*(6392), 987–992. https://doi.org/10.1126/science.aaq0216

Poortinga, W., Spence, A., Whitmarsh, L., Capstick, S., & Pidgeon, N. F. (2011). Uncertain climate: An investigation into public scepticism about anthropogenic climate change. *Global Environmental Change*, *21*(3), 1015–1024. http://dx.doi.org/10.1016/j.gloenvcha.2011.03.001

Raja, U. S., & Carrico, A. R. (2021). A qualitative exploration of individual experiences of environmental virtual reality through the lens of psychological distance. *Environmental Communication*, *15*(5), 594–609. https://doi.org/10.1080/17524032.2020.1871052

Schoemann, A. M., Boulton, A. J., & Short, S. D. (2017). Determining power and sample size for simple and complex mediation models. *Social Psychological and Personality Science*, *8*(4), 379–386. https://doi.org/10.1177/1948550617715068

Schöne, B., Wessels, M., & Gruber, T. (2019). Experiences in virtual reality: A window to autobiographical memory. *Current Psychology*, *38*(3), 715–719. https://doi.org/10.1007/s12144-017-9648-y

Slater, M., & Sanchez-Vives, M. V. (2016). Enhancing our lives with immersive virtual reality. *Frontiers in Robotics and AI*, *3*, 74. https://doi.org/10.3389/frobt.2016.00074

Slovic, P., Finucane, M. L., Peters, E., & MacGregor, D. G. (2004). Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk, and rationality. *Risk Analysis*, *24*(2), 311–322. https://doi.org/10.1111/j.0272-4332.2004.00433.x

Smit, E. S., Meijers, M. H. C., & van der Laan, L. N. (2021). Using virtual reality to stimulate healthy and environmentally friendly food consumption among children: An interview study. *International Journal of Environmental Research and Public Health*, *18*(3), 1088. https://doi.org/10.3390/ijerph18031088

Spence, A., Poortinga, W., Butler, C., & Pidgeon, N. F. (2011). Perceptions of climate change and willingness to save energy related to flood experience. *Nature Climate Change*, *1*(1), 46–49. https://doi.org/10.1038/nclimate1059

Spence, A., Poortinga, W., & Pidgeon, N. (2012). The psychological distance of climate change. *Risk Analysis: An International Journal*, *32*(6), 957–972. https://doi.org/10.1111/j.1539-6924.2011.01695.x

Strecher, V. J., & Rosenstock, I. M. (1997). The health belief model. *Cambridge Handbook of Psychology, Health and Medicine*, *113*, 117.

Tannenbaum, M. B., Hepler, J., Zimmerman, R. S., Saul, L., Jacobs, S., Wilson, K., & Albarracín, D. (2015). Appealing to fear: A meta-analysis of fear appeal effectiveness and theories. *Psychological Bulletin*, *141*(6), 1178–1204. https://doi.org/10.1037/a0039729

Tussyadiah, I. P., Wang, D., Jung, T. H., & Tom Dieck, M. C. (2018). Virtual reality, presence, and attitude change: Empirical evidence from tourism. *Tourism Management*, *66*, 140–154. https://doi.org/10.1016/j.tourman.2017.12.003

Van der Linden, S. (2015). The social-psychological determinants of climate change risk perceptions: Towards a comprehensive model. *Journal of Environmental Psychology*, *41*, 112–124. https://doi.org/10.1016/j.jenvp.2014.11.012

Vautard, R., Van Aalst, M., Boucher, O., Drouin, A., Haustein, K., Kreienkamp, F., … Wehner, M. (2020). Human contribution to the record-breaking June and July 2019 heatwaves in Western Europe. *Environmental Research Letters*, *15*(9), 094077. https://doi.org/10.1088/1748-9326/aba3d4

Witte, K. (1994). Fear control and danger control: A test of the extended parallel process model (EPPM). *Communication Monographs*, *61*(2), 113–134. https://doi.org/10.1080/03637759409376328

Appendix A

Figure A1. Magazine article on the link between pro-environmental behavior (e.g. dairy and meat consumption, donating to ENGOs) and climate change that all participants read.[4]
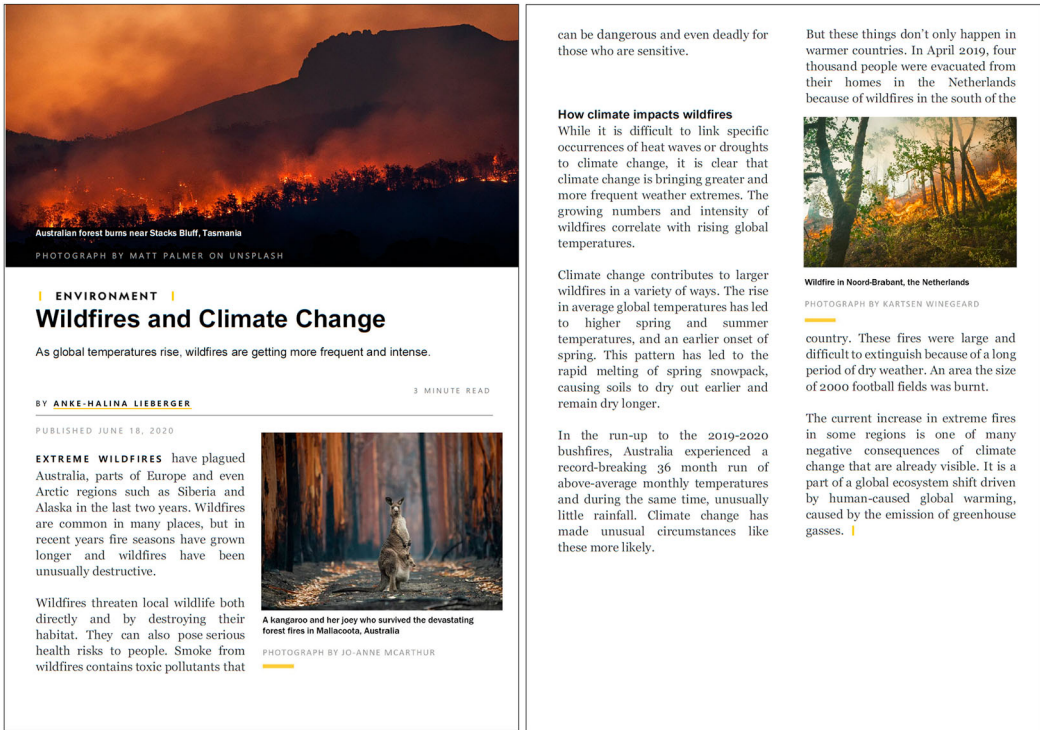
Figure A2. Magazine article on the link between wildfires and climate change that all participants read[4].

Table A1. Relative indirect effects of the articles-only vs the regular video or the articles-only vs Virtual reality condition on behavior change via spatial presence (Model 4, PROCESS; multi-categorical independent variable, indicator; the baseline is the articles-only condition; Hayes & Preacher, 2014)

Behavioral intentions	
Meat consumption intentions	
Regular video	$B_{boot} = 0.18$; $se_{boot} = 0.17$; $CI_{boot} = -0.14; 0.53$
Virtual reality	$B_{boot} = 0.23$; $se_{boot} = 0.21$; $CI_{boot} = -0.17; 0.64$
Dairy consumption intentions	
Regular video	$B_{boot} = 0.20$; $se_{boot} = 0.17$; $CI_{boot} = -0.12; 0.55$
Virtual reality	$B_{boot} = 0.25$; $se_{boot} = 0.20$; $CI_{boot} = -0.15; 0.66$
Behaviors	
Donation	
Regular video	$B_{boot} = 0.15$; $se_{boot} = 1.13$; $CI_{boot} = -2.11; 2.34$
Virtual reality	$B_{boot} = 0.18$; $se_{boot} = 1.41$; $CI_{boot} = -2.59; 2.93$
Food choice (vegan chocolate bar)	
Regular video	$B_{boot} = -0.07$; $se_{boot} = 0.25$; $CI_{boot} = -0.56; 0.40$
Virtual reality	$B_{boot} = -0.08$; $se_{boot} = 0.29$; $CI_{boot} = -0.68; 0.47$

Table A2. Relative indirect effects of the low (articles-only) vs medium (regular video) or the low vs high (virtual reality) immersive condition on intentions and behaviors via spatial presence and risk perceptions and spatial presence and emotional responses (Model 81, PROCESS; multi-categorical independent variable, indicator; the baseline is the low immersive condition; Hayes & Preacher, 2014)

Behavioral intentions	
Meat consumption intentions via spatial presence and risk perceptions	
Regular video	$B_{boot} = 0.14$; $se_{boot} = 0.06$; $CI_{boot} = 0.03$; 0.27
Virtual reality	$B_{boot} = 0.17$; $se_{boot} = 0.07$; $CI_{boot} = 0.04$; 0.33
Meat consumption intentions via spatial presence and emotional responses	
Regular video	$B_{boot} = 0.18$; $se_{boot} = 0.08$; $CI_{boot} = 0.05$; 0.35
Virtual reality	$B_{boot} = 0.22$; $se_{boot} = 0.09$; $CI_{boot} = 0.07$; 0.42
Dairy consumption intentions via spatial presence and risk perceptions	
Regular video	$B_{boot} = 0.10$; $se_{boot} = 0.05$; $CI_{boot} = 0.01$; 0.22
Virtual reality	$B_{boot} = 0.12$; $se_{boot} = 0.06$; $CI_{boot} = 0.02$; 0.26
Dairy consumption intentions via spatial presence and emotional responses	
Regular video	$B_{boot} = 0.19$; $se_{boot} = 0.08$; $CI_{boot} = 0.05$; 0.37
Virtual reality	$B_{boot} = 0.24$; $se_{boot} = 0.09$; $CI_{boot} = 0.07$; 0.44
Behaviors	
Donation via spatial presence and risk perceptions	
Regular video	$B_{boot} = 0.09$; $se_{boot} = 0.05$; $CI_{boot} = 0.01$; 0.21
Virtual reality	$B_{boot} = 0.11$; $se_{boot} = 0.07$; $CI_{boot} = 0.01$; 0.26
Donation via spatial presence and emotional responses	
Regular video	$B_{boot} = 0.07$; $se_{boot} = 0.09$; $CI_{boot} = -0.09$; 0.25
Virtual reality	$B_{boot} = 0.09$; $se_{boot} = 0.11$; $CI_{boot} = -0.11$; 0.31
Food choice (vegan chocolate bar) via spatial presence and risk perceptions	
Regular video	$B_{boot} = -0.04$; $se_{boot} = 0.05$; $CI_{boot} = -0.16$; 0.05
Virtual reality	$B_{boot} = -0.04$; $se_{boot} = 0.06$; $CI_{boot} = -0.19$; 0.06
Food choice (vegan chocolate bar) via spatial presence and emotional responses	
Regular video	$B_{boot} = 0.09$; $se_{boot} = 0.10$; $CI_{boot} = -0.10$; 0.29
Virtual reality	$B_{boot} = 0.10$; $se_{boot} = 0.11$; $CI_{boot} = -0.12$; 0.34

Table A3.

		Spatial Distance	Social Distance	Temporal Distance	Hypothetical Distance	Presence	Emotions	Risk Perceptions
		Correlations						
Social Distance	*Pearson Correlation*	.657**						
	Sig. (2-tailed)	.000						
Temporal Distance	*Pearson Correlation*	.446**	.395**					
	Sig. (2-tailed)	.000	.000					
Hypothetical Distance	*Pearson Correlation*	.238**	.212**	.153*				
	Sig. (2-tailed)	.000	.000	.011				
Presence	*Pearson Correlation*	.068	−.019	.070	.044			
	Sig. (2-tailed)	.261	.756	.246	.468			
Emotions	*Pearson Correlation*	−.049	−.131*	−.145*	−.102	.401**		
	Sig. (2-tailed)	.421	.030	.015	.091	.000		
Risk Perceptions	*Pearson Correlation*	−.270**	−.333**	−.159**	−.433**	.149*	.372**	
	Sig. (2-tailed)	.000	.000	.008	.000	.013	.000	
General Efficacy Beliefs	*Pearson Correlation*	−.202**	−.225**	−.041	−.365**	.142*	.345**	.493**
	Sig. (2-tailed)	.001	.000	.495	.000	.018	.000	.000

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).