

SPECIAL COLLECTION: LEARNING IN IMMERSIVE VIRTUAL REALITY

Why Just Experience the Future When You Can Change It: Virtual Reality Can Increase Pro-Environmental Food Choices Through Self-Efficacy

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Immersive virtual reality (IVR) has the potential to play an important role in increasing environmental literacy by providing individuals the opportunity to experience plausible scenarios of climate change directly. However, there is currently little evidence for the role of IVR, and for specific design features, in increasing environmental self-efficacy. The main objective of this study was to investigate the effects of an IVR intervention on pro-environmental intentions, knowledge, and transfer. A total of 90 middle school students were randomly assigned to two IVR intervention conditions: (a) Awareness, in which students experience the impact of their current food choices on future environmental change; (b) Awareness + Efficacy, in which students had the opportunity to change their food choices and experience the positive impact of this on future environmental change. Both interventions resulted in significant increases in intentions, knowledge, and transfer. However, the Awareness + Efficacy condition resulted in further significant increases in intentions and transfer than the awareness condition. Finally, mediation analysis showed that the effect of the Awareness + Efficacy condition on intentions and transfer was fully mediated by self-efficacy. These results suggest that allowing students not just to experience climate change but also to see the positive impact of changed personal choices can maximize the effectiveness of IVR on intentions and transfer.

Keywords: immersive virtual reality, climate change education, self-efficacy, sustainable diets, transfer**Supplemental materials:** <https://doi.org/10.1037/tmb0000080.supp>

Climate change is arguably the most pressing challenge of our time. Nevertheless, although scientific consensus has consistently pointed toward the reality of climate change and its sources in human activities (Intergovernmental Panel on Climate Change [IPCC], 2021), individuals and governments have been slow to adopt the wide-ranging behavioral and lifestyle changes necessary to mitigate the problem. In this context, it is vital to identify ways to communicate climate change effectively and encourage individual change in the domains of behavior that have the highest environmental impact.

Today's food industry contributes to 26% of emissions from anthropogenic greenhouse gases (GHGs; Poore & Nemecek, 2018),

and according to some analyses (Springmann et al., 2018), shifting toward a diet that is less meat-based (e.g., <300 g red meat per week) could result in a 29% reduction of GHGs emissions. Based on these data, dietary change is both environmentally impactful and open to change. Given the pressing nature of climate change and current knowledge of the drivers of (in)action (Gifford et al., 2011), it is vitally important to identify innovative interventions that both engage individuals with climate change and provide them with the knowledge and skills that would support effective action. The goal of the present study is to test immersive virtual reality (IVR) as one possible intervention and to investigate which design principles can enhance its effectiveness to promote pro-environmental attitudes.

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Drivers of Environmental Action

Reviews of the literature suggest that inaction on climate change is determined by multiple structural and psychological barriers (Gifford et al., 2011). However, specific features of climate change are thought to be particularly disruptive to direct and immediate action. Principally, climate change is intangible—it is beyond the realm of direct experience, its consequences are uncertain, and it is most likely to affect the lives of others who are distant in space and time. Accordingly, climate change is not experienced as a salient risk in the lives of many individuals around the globe. Nevertheless, research also shows that simply perceiving risks is rarely enough to stimulate action. A sense of risk alone can, in fact, undermine adaptive intentions when this triggers maladaptive fear and avoidance (Ajzen, 1991; Grothmann & Patt, 2005; Stern et al., 1999). Addressing perceived *efficacy*—that is, the belief that individual actions can reduce the threat—is argued to be critical for ensuring positive behavior change in response to perceived risks, threatening or fear-inducing information (Witte, 1992). As in many other domains, in the environmental domain, *efficacy* is often understood as comprising two components: *response efficacy*, and *self-efficacy* (Floyd et al., 2000). As already summarized, *self-efficacy* is an individual's belief in their capacity to execute behaviors necessary to produce the desired adaptive action (Bandura, 1977; Witte, 1992). *Response efficacy* is instead the belief that proposed adaptive actions will work and they will be effective at reducing the risk that is perceived.

As the previous attempts to increase both self- and response efficacy using efficacy messages have been only partially successful (Hart & Feldman, 2014, 2016), it was proposed that efficacy perceptions are resistant to change via cognitive processing (Hornsey et al., 2021) and more emotionally engaging interventions might be necessary to shift efficacy beliefs—for example, using visual images that offer more affective processing (O'Neill, 2013) or using strong narratives (Green et al., 2003).

Virtual Reality and Education

IVR is one promising tool for communicating efficacy, which might effectively tap the emotional engagement and visual imagery that appears necessary for stimulating individual change. IVR enables the creation of scenarios that resemble real-life situations and reactions (Blascovich & Bailenson, 2011), and has been successfully applied in the context of environmental awareness and action (e.g., Ahn et al., 2015; Meijers et al., 2022).

The cognitive affective model of immersive learning (CAMIL; Makransky & Petersen, 2021) provides a theoretical explanation of how IVR can influence learning and behavior change. The CAMIL proposes that IVR has two main technical characteristics—interaction and immersion—that promote the experiential affordances of *presence* (the sense of being there) and *agency* (being in control of one's actions). Presence and agency, in turn, can lead to higher levels of interest and self-efficacy, which act as drivers for knowledge acquisition, transfer, and behavioral change—thereby enhancing learning outcomes. In short, CAMIL provides a constructivist view of learning where IVR can increase learners' involvement in the learning process by providing realistic experiences that they have control over.

Although CAMIL is concerned with learning in various contexts, the highlighted processes of presence and agency seem especially relevant to climate change education. By inducing a high sense of *presence*, IVR creates realistic experiences (Blascovich & Bailenson, 2011) and thereby might bridge the gap between distant, intangible climate impacts and current, concrete individual experiences (Breves & Schramm, 2021; Markowitz & Bailenson, 2021). Indeed, the particular capacity of IVR to visualize the consequences of climate change, for example, through accelerated time-lapses (Hsu et al., 2018) or seeing climate affected landscapes like melting icebergs or bleaching coral reefs (Makransky & Mayer, 2022; Markowitz et al., 2018; Nim et al., 2016; Petersen et al., 2020), has been shown to be an effective tool for increasing knowledge, pro-environmental attitudes and awareness of the severity and urgency of this risk. Moreover, IVR-based interactive curricula are also gaining popularity in climate change education, precisely because they are seen to promote an experientially based deeper understanding of ecology and ecosystems (Dickes et al., 2019; Reilly et al., 2021).

Virtual Reality–Based Climate Change Interventions

An increasing number of studies have investigated the different features of IVR interventions that contribute to increased pro-environmental attitudes and behavior (Fauville et al., 2020). In general, the findings from this work suggest that IVR can be more efficient in promoting pro-environmental attitudes compared to the less immersive desktop interventions (Ahn et al., 2014, 2016; Breves & Schramm, 2021; Fonseca & Kraus, 2016; Soliman et al., 2017). For example, IVR interventions have been shown to enhance the impact of embodying animals on subsequent felt connections with nature (Ahn et al., 2016) and reduce climate change's psychological distance via spatial presence (Breves & Schramm, 2021).

Experienced climate change educators (Fauville et al., 2021) consider invisibility, difficulty feeling empowered to act, or visualizing the problem as crucial challenges of climate change education that can be efficiently targeted using IVR. The second biggest challenge—empowerment can be linked to the perception of efficacy and locus of control (the feeling that we have control over the action).

Two IVR studies conducted by Ahn et al. (2015, 2014) specifically tested the mediating role of efficacy-related constructs on pro-environmental behavior. The first study (Ahn et al., 2014) focused on reducing article consumption after actively cutting a tree in IVR, seeing it on video, or reading about the experience. The results showed that the IVR indirectly influenced article consumption by increasing the locus of control (a concept theoretically similar to self-efficacy) measured in follow-up. In the second study (2015), 114 participants either experienced cutting down a tree (a “loss” experience) or planting a tree (a “gain” experience) with a low or high level of interactivity. Overall, their results confirmed that gain-focused (planting trees) and interactive experiences enhanced response efficacy, which in turn influenced article consumption immediately after the intervention. Nevertheless, self-reported behavior did not differ between the conditions, and the effects of the intervention were only indirect via response efficacy. The authors account for this based on their intervention's lack of specific instructions for environmental action and propose that future interventions should address this by providing individuals with the opportunity to practice concrete behavior.

Another recent VR study drew on feedback to increase pro-environmental behavior. As proposed before, real-time feedback can efficiently regulate behavior (e.g., onboard feedback in cars can improve driver's fuel economy: Sanguinetti et al., 2020). Drawing on this idea, Meijers et al. (2022) tested the effects of health and environmental impact messages on the shopping behavior of 249 participants in a virtual supermarket. Participants were instructed to choose products from four categories (fruit, vegetables, fruit biscuits, sauces) with six options in each category. When selecting the products, pop-up information was displayed differing in the appeal type (health vs. environment vs. control factual information) and vividness (textual vs. image). The results showed that these impact messages increased immediate pro-environmental choices in the virtual supermarket relative to a control condition, and the effect was mediated through response efficacy. However, this positive effect did not directly translate into subsequent (self-reported) pro-environmental behavior outside of the VR supermarket, although there were again indirect pathways to the pro-environmental behavior via response efficacy. The manipulation of vividness did not result in the increased subjective perception of vividness, suggesting that static pictures may not have been sufficient for enhancing this experiential feature. It seems plausible that more immersive elements, like 360° videos or emotional stories, might be more effective in creating a vivid experience that stimulates change.

Maximizing Efficacy With IVR

The abovementioned recent studies bring crucial insights into the underlying processes of behavioral change through IVR and particularly point to roles for self- and response efficacy. Nevertheless, the role of environmental self-efficacy, a key component of our efficacy beliefs, and how it can be enhanced in VR remains unclear. As was already proposed by Bandura (1977), self-efficacy is a crucial predictor of successful behavioral change, and similar arguments have been made in the specific domain of environmental behavior (Grothmann & Patt, 2005). A recent meta-analysis of factors motivating adaptive climate change behavior (van Valkengoed & Steg, 2019) confirms that both response and self-efficacy are important drivers of pro-environmental behavior. This raises the question of what might maximize the capacity of IVR interventions to stimulate efficacy and produce stronger effects on behavior.

Bandura defined key sources of self-efficacy as performance accomplishments, vicarious experience, verbal persuasion, and physiological states. Of these, performance accomplishment is thought to be one of the strongest predictors of self-efficacy (Bandura, 1977). IVR is a perfect tool for enabling performance accomplishments through a first-person interactive experience (Makransky et al., 2019; Makransky & Petersen, 2021). Directly linking individual decisions and actions to their outcomes is a way of providing performance accomplishment. Consistent with this idea, in participatory research by Fauville et al. (2021), experienced climate educators proposed that being able to see the impact of everyday decisions, for example, through displaying different virtual scenarios, could be an efficient tool to empower students to take action. Previous IVR research also shows that being able to see the real-time, gradual consequences of our behavior can stimulate behavior change (Ahn, 2015; Ahn et al., 2019; Hsu et al., 2018), and this effect can be even stronger when using more vivid and concrete images (Bailey et al., 2015; Chirico

et al., 2021). In addition to maximizing this kind of performance feedback, providing participants with explicit guidelines about the impact of their individual actions (Ahn et al., 2015) should further positively contribute to feelings of empowerment and increase specific pro-environmental intentions.

With the above ideas in mind, the present study investigates how communicating not only negative consequences but also our ability to make a positive change can efficiently increase environmental self-efficacy and consequently influence other drivers of pro-environmental action.

Present Study

Following the CAMIL (Makransky & Petersen, 2021) and instructional design principles for multimedia learning (Mayer & Fiorella, 2021), we developed an immersive and interactive VR intervention with high fidelity to increase awareness about the importance of a sustainable diet for mitigating climate change. In addition, attending to the call for more IVR studies included in actual teaching or learning interventions (Radianti et al., 2020), we present an experimental study that was an integrated educational activity in a middle school context.

As in previous work (e.g., Meijers et al., 2022), we aimed to increase participants' efficacy by visualizing the impact of selected foods on the natural environment. Because the previous research also suggests that gradual feedback can be efficient for eliciting behavioral change (Ahn, 2015; Ahn et al., 2019; Bailey et al., 2015; Hsu et al., 2018), we showed participants continuous environmental change following general food choices accompanied by an emotional narrative. The latter, in particular, moves beyond the static imagery used by Meijers et al. (2022) to create a more vivid and emotionally engaging experience. Furthermore, the presented simulation focused on a broader range of foods, including high impact categories, such as beef products, cheese, and fish, to increase the educational and environmental potential of the simulation.

Our basic intervention was intended to facilitate the main IVR affordances of agency and presence by providing an interactive and multisensory experience of visualizing the impact of our food choices on the natural environment. In addition, by visualizing participants' carbon footprint, we aim to communicate the impact of human activity on climate change and empower the students by eliciting their response efficacy as proposed by previous studies (Fauville et al., 2021; Meijers et al., 2022; Nim et al., 2016). Furthermore, compared to the previous study focused on increasing response efficacy and thus facilitating the switch to more sustainable eating, we focused on (a) gradual and more vivid feedback accompanied by emotional narrative and providing clear guidelines about the different variety of food and their environmental impacts (b). Thus the intervention is designed in a way to increase not only factual knowledge but also pro-environmental intentions and transfer. As a result, we expected that experiencing this IVR intervention would, relative to baseline, produce significant increases in:

1. pro-environmental intentions (Hypothesis 1),
2. knowledge gain about carbon emissions (Hypothesis 2),
3. transfer (Hypothesis 3).

We were also interested in whether an optimized Awareness + Efficacy version of the intervention designed according to environmental psychology findings would be maximally effective. In optimizing the intervention, we were guided by theories that highlight self-efficacy (Bandura, 1982; Bostrom et al., 2019; Grothmann & Patt, 2005; Witte, 1992) as being central to behavior change, and therefore tried to engage this pathway through a feedback loop in the simulation. Following meta-analytic evidence (Sheeran et al., 2014) and recent findings of the mediating mechanisms in VR studies (Ahn et al., 2015; Meijers et al., 2022), we expected that adding a efficacy induction would further increase the effectiveness of the intervention. Compared to the recent study by Meijers et al. (2022), which only allowed to select the foods once increasing response efficacy, the Awareness + Efficacy version of the simulation actively supported the participants to reselect more sustainable foods and consequently allowed them to experience gradual restoration of nature with the aim to foster their environmental self-efficacy.

This resulted in the following hypotheses:

4. the Awareness + Efficacy condition will significantly increase pro-environmental intentions relative to awareness alone (Hypothesis 4).
5. the Awareness + Efficacy condition will significantly increase transfer relative to the awareness condition (Hypothesis 5).

Finally, to improve our understanding of psychological processes underlying possible increases in pro-environmental intentions and successful transfer, we investigated the mediating pathways to personal change. Since our intervention aimed to increase both response and self-efficacy, we hypothesized that:

6. the effect of the Awareness + Efficacy condition on behavioral intentions will be mediated via increasing self-efficacy and response efficacy (Hypothesis 6).
7. the effect of Awareness + Efficacy condition on transfer would be mediated by an increase in self-efficacy and response efficacy (Hypothesis 7).

Method

Participants

Ninety students aged 13–16 ($M = 14.29$, $SD = 0.64$) and attending either 7th grade (19) or 8th grade participated (71) in the experiment. They reported themselves to be female (49%), male (40%), nonbinary (5.5%) or preferred not to provide this information (5.5%). The study was conducted in three Danish middle schools in the English language with supporting personnel to answer participants' questions. The experiment was incorporated as a part of students' mandatory course.

Materials

IVR Scenario

Before the start of the IVR simulation, participants indicated their gender using the Oculus Quest controller. Then, the IVR simulation started in the virtual living room, where participants were instructed

to use a tablet to select the food they would like to purchase for breakfast, lunch, dinner, and snacks (see Figure 1A). After this, participants visited the Rocky Mountain National Park (Figure 1B) as the simulation was initially created for a U.S. audience, and the Rocky Mountain was chosen as the most iconic park that is also very susceptible to climate change consequences. By traveling 30 years to the future, they experienced the gradual devastation of the natural environment according to the food-related emissions released in the atmosphere (Figure 1C). Finally, during the direct instruction phase, a pedagogical agent in the form of a park ranger instructed the participants about the environmental consequences of the specific foods and informed the participant about his/her current dietary carbon footprint (see Figure 1D). The whole experience was narrated (see Supplemental Material 1) by the pedagogical agent and accompanied by ambient nature sounds to support presence.

In the awareness condition (see Figure 2), the IVR simulation stopped after participants responded to a presence and emotions questionnaire (for details, see Supplemental Material 2). In the Awareness + Efficacy condition, participants had the opportunity to reselect the food in the shopping simulation and were instructed to decrease the carbon footprint as much as possible. In the reselection phase, the foods in the shopping simulation were highlighted according to their dietary carbon footprint from light green to dark red, the participants were not otherwise forced to make more sustainable choices. According to the new choices, the natural environment gradually changed based on what would happen if everyone adopted the same diet. The ambient change was accompanied by agent verbal feedback. The simulation is programed in 10 levels from complete degradation to complete regeneration based on the student's food choices. Therefore, the Awareness + Efficacy condition allowed users to gain feedback about their behavior, and the feedback was visualized as experiencing the future. This is an example of a first-person performance accomplishment which is highlighted as the most effective way to build self-efficacy by Bandura (1982).

Following the redundancy and modality principle (Mayer & Fiorella, 2021), the voiceover narration was used with only a limited amount of textual information. Consistently with personalization and voice principles (Mayer & Fiorella, 2021), the professionally narrated pedagogical agent used a friendly and conversational style to make the simulation authentic and immersive. Consistent with typical IVR research, we measured presence on a 5-point scale, and the average perceived presence was 3.27 ($SD = 0.74$) and 3.56 ($SD = 0.81$) for the awareness and the Awareness + Efficacy conditions, respectively.

Questionnaire

Participants were asked about their basic demographic characteristics (age and school grade) in the pretreatment questionnaire. In the pre- and post-treatment questionnaire, participants filled out questions about their level of self-efficacy on a 5-point scale (*strongly agree–strongly disagree*) using two items, for example, *I feel capable of adopting more climate-friendly eating habits*. Students also responded to three items about response efficacy (Hunter & Rööß, 2016), for example, *Consumption of food with a low carbon footprint is an effective measure to mitigate climate change*. on a 5-point scale from *strongly agree* to *strongly disagree*.

Figure 1
IVR Scenario Preview



Note. IVR = immersive virtual reality. The figure depicts the main IVR simulation phases: food selection where participant indicate their preferred food choices (A), traveling to the Rocky Mountain national park with the pedagogical agent (B), experiencing nature degradation according to the current dietary emissions (C), and receiving information about the environmental impact of specific foods during the direct instruction phase (D).

Main Outcome Variables

In a knowledge test, participants were asked to indicate the level of emissions associated with the production of 12 specific foods, ranging from *very low* (<1 kg CO₂ per kg) to *very high* (>15 kg CO₂ per kg). Students could receive one point for every correct answer with a total score calculated as the sum of the individual scores (maximum = 12, minimum = 0). For details, see Supplemental Material 2.

Behavioral intentions were measured by asking students four questions about their future eating behavior (e.g., *In the future, I intend to cut the number of meals with meat to half*). Students responded on a 5-point scale (*strongly agree–strongly disagree*). For details, see Supplemental Material 2.

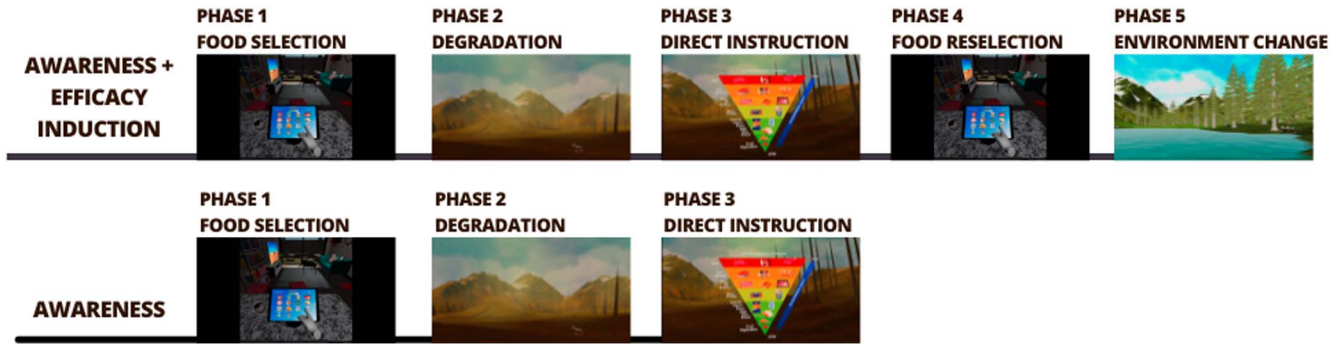
Transfer is defined as the ability to generalize the learned knowledge or skills (Subedi, 2004) and successfully apply and adapt it to different contexts (Presseau & Frenay, 2004). Since the main objective of the simulation is to teach students about the dietary consequences of their food choices, transfer was assessed by asking participants how many times during the week they would like to eat food from 13 main food categories (e.g., pasta, rice, beef, fish, sweets, etc.; see Supplemental Material 2) if they could choose the

food by themselves. Then, using the average carbon footprint for each category (CONCITO, 2021), we calculated the sum of dietary carbon footprint for each participant and reversed the score ($(x) = \max(x) + 1 - x$) in order to generate a score on which higher numbers indicated higher transfer. This measure can be understood as reflecting horizontal transfer, where we ask students to apply the gained knowledge and attitudes in a different contextual situation—the students transfer the behavior from the IVR simulation to their preferred behavior in real-life (Subedi, 2004). Making more sustainable choices in the subsequent task requires that the student has gained knowledge related to the carbon emissions associated with specific foods (the primary learning content of the simulation), but also has an intention to use that knowledge, which requires adopting a positive attitude toward a climate-friendly diet.

Apparatus

The IVR simulation was presented to the students using Oculus Quest or Oculus Quest 2 (the distribution of the Oculus Quest and Oculus Quest 2 was balanced across the conditions). The participants interacted with the IVR using the controllers either

Figure 2
Study Design



Note. IVR = immersive virtual reality. In the basic version of the IVR simulation, the participants chose their preferred foods, traveled to Rocky Mountain, witnessed the natural degradation, and were educated about the emissions of specific foods in a highly immersive virtual environment. In the Awareness + Efficacy condition participants were further instructed to reselect more pro-environmental foods which allowed them to experience restoration of the natural environment. The last two phases (4 and 5) allowed participants to experience self-efficacy.

by point and click when responding to the questionnaire or simply by touching the virtual tablet in the IVR environment with their index finger to select food.

Procedure

The study was approved by the Research Ethics Committee at the Faculty of Social Sciences, University of Copenhagen, approval number IP-IRB/05032021. Before the IVR intervention, the students were asked to fill out the prequestionnaire on their own devices (laptop or smartphone). After completing the questionnaire, participants were randomly assigned to the awareness condition (i.e., the control; $n = 46$) or the Awareness + Efficacy condition (i.e., the intervention; $n = 44$), and after finishing the IVR intervention, the students completed the posttreatment questions and were offered to ask any questions regarding the experience. The IVR intervention lasted on average 12.33 min ($SD = 2.48$) and 16.36 min ($SD = 6.22$) in the awareness condition and Awareness + Efficacy condition, respectively.

Statistical Analyses

Statistical analyses were performed using R (R Core Team, 2020). To investigate Hypotheses 1–3, we used Wilcoxon signed-rank test as the outcome variables were not normally distributed. To test Hypotheses 4 and 5, we investigated linear regression models with intentions and transfer postscores adjusted for pretest scores. To identify potential pathways that lead to attitude change and transfer, we investigated the role of two essential predictors of pro-environmental behavior—*self-efficacy* and *response efficacy*. We ran regression and mediation analysis using *PROCESS* macro in R to explain the observed effects of efficacy induction on our main outcome variables. Indirect effects were tested for significance using bootstrapping procedures, with the unstandardized indirect effects computed using 10,000 bootstrapped samples and 95% confidence intervals computed by determining the indirect effects at the 2.5th and 97.5th percentiles. For the purposes of mediation analyses, we used posttest scores.

Results

Baseline Differences Between Groups

Before the main analysis, we focused on investigating the pre-treatment group characteristics and outcome measures to ensure the randomization procedure was successful. Independent t tests showed that the Awareness + Efficacy group ($M = 14.3$, $SD = 0.68$) and Awareness group ($M = 14.2$, $SD = 0.60$) did not differ on mean age, $t(85.693) = -.75$, $p = .455$. A χ^2 test showed that although the Awareness + Efficacy group had relatively more women than the Awareness group, this difference was not significant, $\chi^2 (N = 90) = 7.632$, $p = .054$. Nonetheless, as a robustness check, we included gender as a covariate in our analyses. In case the model did not differ, we reported only the results of the analysis without the covariate.

Independent groups' t tests showed no significant differences between the Awareness + Efficacy group and Awareness only group in pretreatment *self-efficacy*, $t(79.49) = -1.41$, $p = .162$, or *response-efficacy* scores, $t(84.77) = -0.902$, $p = .37$, *intentions*, $t(87.49) = -1.561$, $p = .122$, *knowledge*, $t(87.25) = -0.23$, $p = .815$, *transfer*, $t(86.58) = -1.367$, $p = .175$.

Effects of IVR on Intentions, Knowledge, and Transfer

As hypothesized, we found a significant increase in *intentions* from the pretest ($Mdn = 12.5$, interquartile range [IQR] = 5.0) to the posttest ($Mdn = 14.0$, IQR = 5.75), $V = 1,470$, $p < .001$, $r = 0.40$. Similarly, the analysis confirmed a significant increase in *knowledge* scores from pre- ($Mdn = 3.0$, IQR = 2.75) to postintervention ($Mdn = 4$, IQR = 3), $V = 457$, $p < .001$, $r = 0.45$. Finally, *transfer* also increased from pretest ($Mdn = 414.66$, IQR = 145.57) to posttest ($Mdn = 455.94$, IQR = 139.04, $V = 3,373$, $p < .001$, $r = 0.56$). These analyses therefore confirm Hypotheses 1, 2, and 3.

Value-Added Effects of Efficacy Induction

In the Efficacy + Awareness condition, we attempted to induce students' environmental efficacy by showing them the impact of their personal choices on the natural environment (response

efficacy) and by providing them with the positive experience of nature restoring itself (self-efficacy).

Before the main analyses, we focused on the behavioral change in the IVR simulation and the impact of the conditions on self- and response efficacy. The analysis confirmed that the participants in the Awareness + Efficacy group, significantly reduced their dietary carbon footprints from the first selection ($M = 6.12$, $SD = 5.03$) to the second selection ($M = 1.23$, $SD = 2.95$) by 4.89, 95% CI [3.64, 6.13], $t(137.16) = 7.77$, $p < .001$, with large effect size, $d = 0.93$, 95% CI [0.57, 1.28]. Therefore, we considered the efficacy manipulation successful. Furthermore, we investigated the impact of the IVR conditions on self-efficacy and response efficacy. A regression analysis controlling for pretest self-efficacy score showed that the Efficacy + Awareness condition increased posttest self-efficacy to a larger extent compared to the awareness condition, $b = 0.66$, 95% CI [0.16, 1.17], $p = .011$. Analyzing the pre-post differences in the self-efficacy for the both conditions separately, we confirmed that the participants in the Awareness + Efficacy condition increased self-efficacy by 1.02 points, 95% CI [1.49, 0.55], $t(43) = 4.38$, $p < .001$, which corresponds to medium effect size, $d = 0.67$, 95% CI [0.33, 1.00], compared to the participants in the awareness only condition that increased self-efficacy by 0.46 points, 95% CI [0.85, 0.07], $t(45) = 2.36$, $p = .023$, which corresponds to small effect size, $d = 0.31$, 95% CI [0, 0.62]. Conversely, when controlling for pretest score, the analysis showed that the Awareness + Efficacy condition did not result in a significantly larger increase in response efficacy compared to the awareness only condition, $b = 0.61$, 95%

CI [-0.04, 1.26], $t(87) = 1.85$, $p = .068$, indicating that the efficacy manipulation was more effective in inducing self-efficacy than response efficacy.

A regression analysis controlling for pretest intentions showed that the Awareness + Efficacy condition increased posttest *intentions* by 0.35 points on the 5-point scale compared to the only awareness condition, $b = 0.35$, 95% CI [0.13, 0.58], $p = .003$ (see Figure 3). This pattern supports Hypothesis 4.

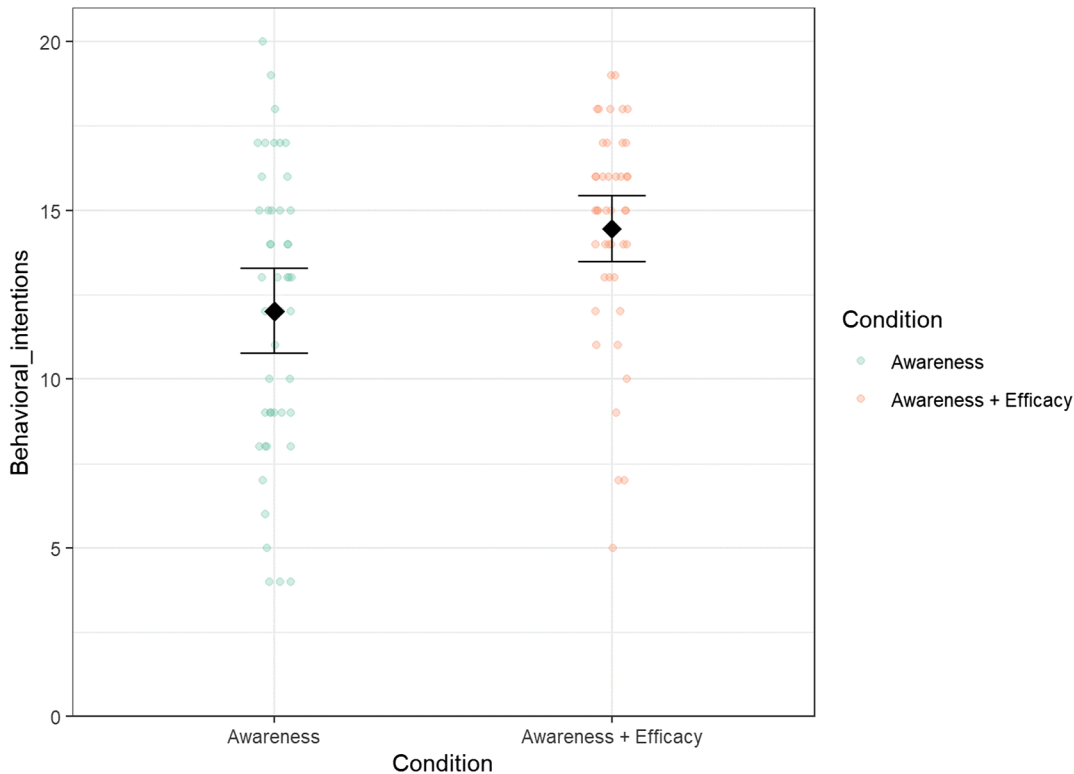
We ran the same model on posttest *transfer* (controlling for the pretest score). The results indicate that the Awareness + Efficacy condition significantly increased transfer compared to the awareness condition, $b = 35.44$, 95% CI [66.93, 3.95], $t(87) = -2.24$, $p = .028$, see Figure 4. This result supports Hypothesis 5.

Mediational Pathways to the Intention and Transfer

To explain these effects of the Efficacy induction on *intentions* and *transfer*, we ran a mediation analysis positioning *self-efficacy* and *response efficacy* as mediators between condition and outcome.

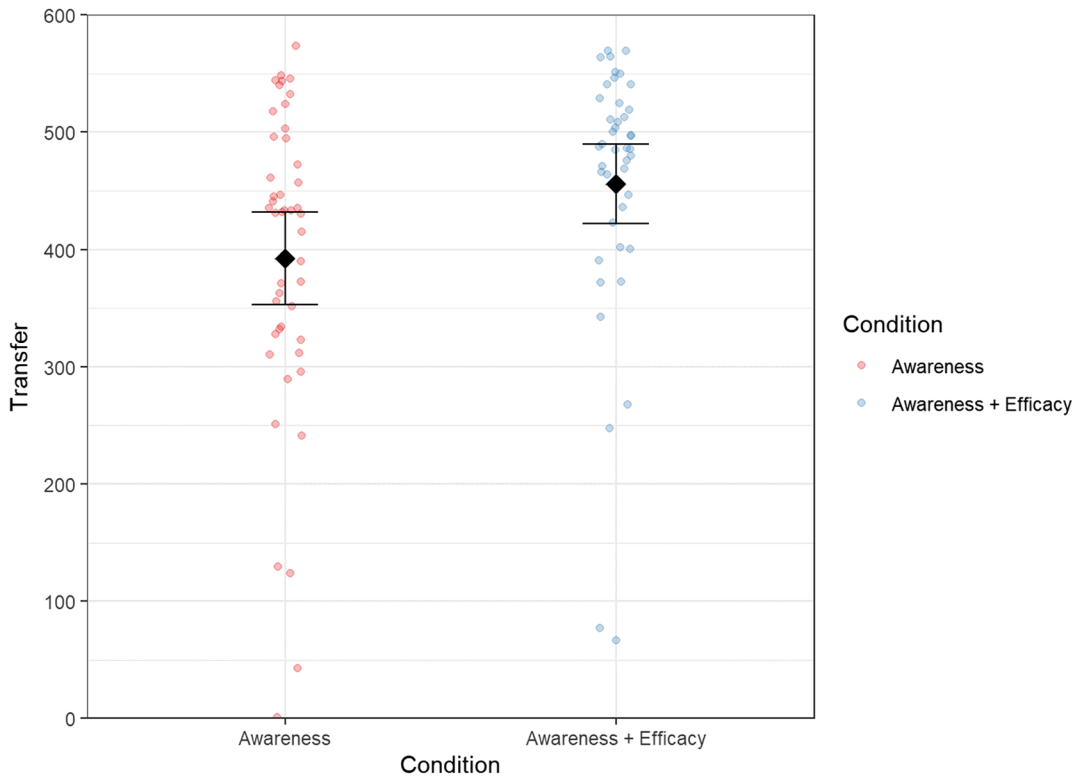
As Figure 5 illustrates, *self-efficacy* was a significant predictor of *intentions*, and the unstandardized indirect effect linking the condition to intentions via *self-efficacy* was also significant. The bias-corrected bootstrapped confidence interval of this indirect path using 10,000 samples did not span zero, 95% CI [0.41, 0.17]. *Response efficacy* was not a significant predictor of *intentions*, and as such, this indirect path was also not significant. Therefore, Hypothesis 6 was partially supported.

Figure 3
Mean Posttest Intentions for Each Condition



Note. Error bars show 95% confidence intervals in a normal distribution.

Figure 4
Mean Posttest Transfer for Each Condition



Note. Error bars show 95% confidence intervals in a normal distribution.

Running the same model with the transfer as the outcome variable, we again found a significant indirect effect of self-efficacy on the *transfer* (see Figure 6, for details). The bias-corrected bootstrapped confidence interval of the indirect path using 10,000 samples did not span zero, 95% CI [2.54, 55.60]. Again, there was no relationship between response efficacy and outcome, and therefore no indirect pathway via this variable. We, therefore, partially accept Hypothesis 7.

Discussion

Empirical Contributions

We investigated the effect of an IVR simulation that focused on the impact of food choices on the natural environment in a sample of middle school students. The IVR intervention resulted in a significant pre- to post-treatment increase in both our conditions on all measured variables: intentions, knowledge gain, and knowledge transfer with moderate to large effect size ($r = 0.4\text{--}0.56$).

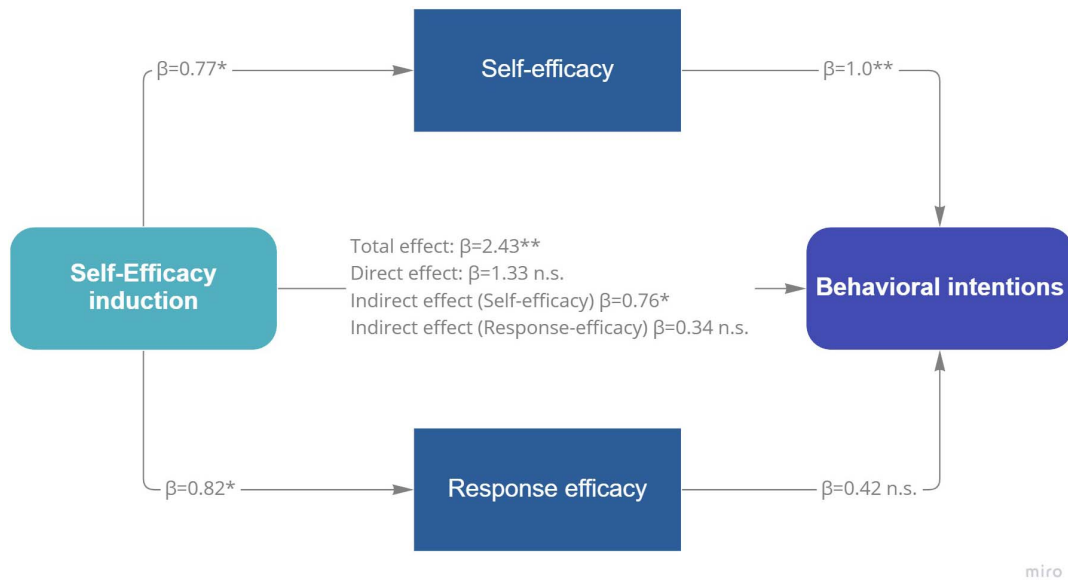
Compared to previous studies (Bailey et al., 2015; Hsu et al., 2018; Meijers et al., 2022), which have found that being able to see the impact of choices or behavior on the natural environment can increase pro-environmental intentions via response efficacy, we investigated if experiencing the positive effects of revised choices on the environment could further boost self-efficacy and its behavioral consequences. In the tested “value-added” Awareness + Efficacy condition, the participants were allowed to change the

future by making more pro-environmental decisions. Consistent with the previous research, participants reselected foods with significantly lower environmental impact in the virtual simulation when the product impact had been displayed. Importantly, as hypothesized, the results showed that the Awareness + Efficacy condition increased pro-environmental intentions and knowledge transfer to a larger extent than the awareness only condition.

Our results show that interactive and high fidelity IVR experience that induced self-efficacy through the positive experience of consequences of personal revised food choices has a larger impact on pro-environmental intentions and transfer than just visualizing the collective negative impact on the natural environment that was a method applied in previous VR studies (Hsu et al., 2018; Meijers et al., 2022). Furthermore, mediation analysis showed that the effect of efficacy induction on intentions and transfer was fully mediated via self-efficacy. This is consistent with Bandura’s theory that self-efficacy can be increased by performance accomplishments (Bandura, 1977) and with the findings that self-efficacy is a crucial predictor of eating behavior (Shannon et al., 1990; Strachan & Brawley, 2009).

Although the Awareness + Efficacy condition enhanced intentions and transfer over the Awareness alone, the students in this study significantly increased their knowledge about carbon emissions regardless of the applied condition. These results are consistent with the previous studies showing that visualizing the negative impact of climate change on the natural environment can increase knowledge gain (Markowitz et al., 2018; Petersen et al., 2020).

Figure 5
Indirect Effects of Self-Efficacy and Response Efficacy on Intentions



Note. Schematic diagram of mediation analysis results. Self-efficacy fully mediated the effect of self-efficacy induction on behavioral intentions. Path values are standardized regression coefficients.

* $p < .05$. ** $p < .01$.

Theoretical Contributions

Our findings support sociocognitive theories emphasizing the role of efficacy in behavioral change interventions (Ajzen, 1991; Grothmann & Patt, 2005; Stern et al., 1999). However, converse to these approaches, we did not find any mediating role for response efficacy in intention or transfer change.

Response efficacy has been linked to public engagement with climate issues through policy support and donations (Thaker et al., 2019) rather than personal actions, which tends to be more strongly linked to self-efficacy (Shannon et al., 1990; Strachan & Brawley, 2009). Given the variety of targets to which efficacy can attach—self, collective, response—and the importance of all of these for genuine and sustained climate action, we do not rule out any of these processes and encourage future research to differentiate the interventions that might drive change in each form of efficacy, as well as their consequences.

As we did not measure objective behavior, we cannot be confident that the students would adhere to their intentions, and similarly, we cannot rule out a possible role of response efficacy in supporting longer term behavior change. Importantly, our study manipulation focused on the addition of positive experiences due to our personal choices, which is more in line with the concept of environmental self-efficacy. Students experienced the negative impact of overall food choices on the natural environment in both conditions, which is in contrast with Meijers et al. (2022). Thus, it is crucial to interpret the results of this study as an investigation of how to maximize the impact of VR simulations on pro-environmental behavior by experiencing self-efficacy, thereby consequently minimizing the risk of maladaptive behavior.

Practical Contributions

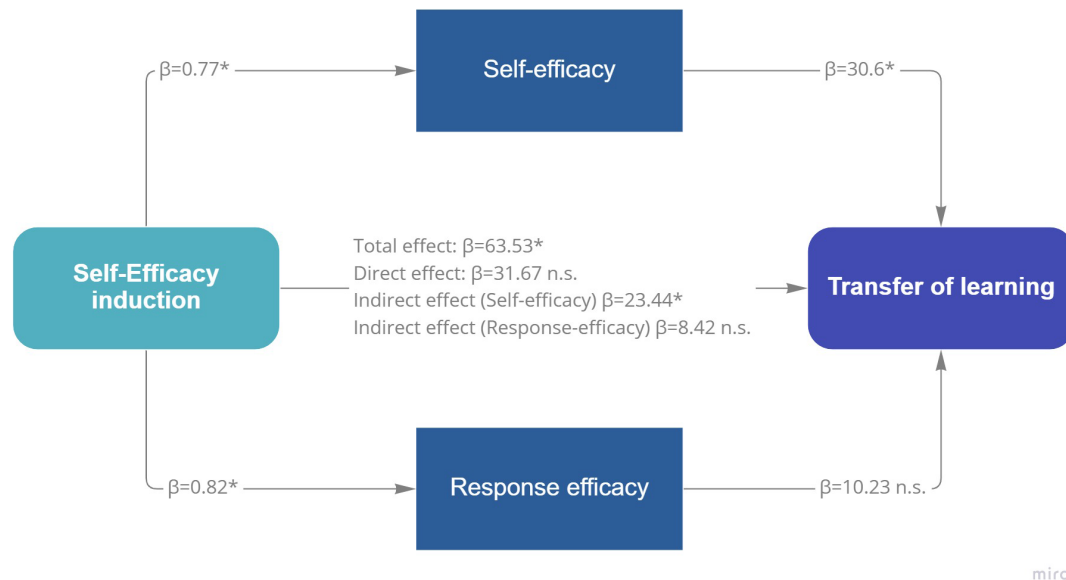
Our results imply that when applying IVR methods in climate change education, visualizing the climate change consequences by

using exaggerated feedback can effectively increase students' knowledge about carbon emissions. This finding is consistent with studies showing the impact of climate change by traveling to highly impacted places on knowledge gain and interest (Markowitz et al., 2018; Petersen et al., 2020) and by showing the impact of specific behavior on the natural environment (Hsu et al., 2018; Meijers et al., 2022). Unfortunately, due to the missing control group, we cannot draw any conclusions about its effectiveness compared to standard learning methods—such as those that do not use immersive media.

IVR has been argued to be a suitable tool for promoting learning transfer (Cooper et al., 2021; Liu et al., 2017; Narciso et al., 2019), as it offers the possibility for the endless practice of desired skills that can be expensive, dangerous, or even impossible in the real-world setting (Bailenson, 2018). Moreover, VR enables training and learning in different contextual situations with a high level of presence and agency (Makransky & Petersen, 2021). Our results indicate that the Awareness + Efficacy induction significantly increased transfer in comparison to the awareness condition. That implies that IVR mastery experience (Bandura, 1982) is essential to advance the transfer of learned knowledge. Indeed the indirect effect of the Awareness + Efficacy condition via an increase in self-efficacy confirms the importance of the experience of success in the knowledge transfer. As was proposed by Bossard et al. (2008), a successful transfer can be interpreted as the IVR efficacy measure as a learning tool. In our case, this means that self-efficacy experience can increase not only factual knowledge but also willingness to act according to that knowledge.

More generally, this study contributes to current discussions of the “green transition” by providing insights into the methods that might be useful for communicating the issues and the urgency of substantial lifestyle changes to younger generations. Although

Figure 6
Indirect Effects of Self-Efficacy and Response Efficacy on Transfer



Note. Schematic diagram of mediation analysis results. Self-efficacy fully mediated the effect of self-efficacy induction on transfer. Path values are standardized regression coefficients.

* $p < .05$.

IVR may have one time seemed a niche education tool that time is rapidly passing. In response to the recent pandemic, lockdowns, and the reliance on remote learning and technology, these kinds of interventions may become more routine—and knowledge of the processes and pathways to enhanced learning through such technologies is even more important.

Limitations and Future Directions

One of the limitations of the present study is the absence of a media control group which does not allow us to conclude if the IVR intervention would be more or less effective for increasing students' knowledge, intentions, or transfer than other, less-immersive methods (e.g., slide shows, desktop delivery). Recent findings suggest that it is more relevant to investigate how, when, and why IVR is effective, in addition to the basic question of whether it is (Makransky et al., 2020; Petersen et al., 2020). Nevertheless, future studies could focus on conducting media and method comparisons to investigate whether the impact of efficacy inductions is consistent across media and how variations in presence across media formats might modify this.

In so doing, it would be important to work toward more balanced presentations of content across conditions. Inevitably, our Awareness + Efficacy condition was longer than the awareness condition. Ideally, one would try to separate the effects of content length, format, and the psychological processes targeted by that content. Furthermore, to conclude on the effectiveness of IVR to enhance behavioral competencies, it would be necessary to measure the actual behavior and not just intentions—for example, by offering participants to choose between vegetarian and nonvegetarian options (Fonseca & Kraus, 2016). Even though according to the theory of planned behavior (Ajzen, 1991), the intentions are the direct antecedent of actual behavior, a gap between intentions and actual behavior is

well known (Faries, 2016; Grimmer & Miles, 2017; Sheeran & Webb, 2016). Thus the impact of the intervention and role of the adaptive capacity, especially response efficacy, on the actual food choices should be further investigated. Additionally, future studies could focus on positive spillover effects by measuring factors such as intentions to adhere to different types of pro-environmental behavior.

Furthermore, the results of mediation analyses should be interpreted with caution, and further research is necessary. First, the applied self-efficacy measure consisted of only two items. Therefore, future studies should investigate self-efficacy manipulations in more detail, potentially using a more thoroughly standardized self-efficacy measure. Second, the sample size could be considered small for drawing conclusions about mediation pathways. Third, the specificity of the sample (middle school students) and the context of the experiment (being a part of the school curriculum) could further influence the participants' motivation.

Therefore, this study provides preliminary results on how the specific IVR design could indirectly influence environmental literacy via its effect on pro-environmental drivers, and these mechanisms should be further investigated.

Conclusions

Our results indicate that IVR intervention can be an effective tool for increasing knowledge about sustainable foods and pro-environmental intentions in middle school students and that this knowledge can be successfully transferred. Additionally, during the IVR simulation, participants also selected food items with a significantly lower carbon footprint ($d = 0.93$) compared to their initial choice. Furthermore, the value-added Awareness + Efficacy condition results demonstrate that giving students an option to change

their food behavior and seeing its impact in the IVR simulation further increases their pro-environmental intentions and transfer of learning through an enhanced sense of self-efficacy.

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