Virtual reality is only mildly effective in improving forest conservation behaviors

Banerjee, Sanchayan and Ferreira, Alipio

The Policy Insitute, King's College London, London, United Kingdom, Department of Economics, Southern Methodist University, Dallas, USA

28 June 2024

scientific reports

Check for updates

OPEN

Virtual reality is only mildly effective in improving forest conservation behaviors

Sanchayan Banerjee[1,2]✉ & Alipio Ferreira[3]✉

Virtual Reality (VR) enables immersive experiences that can enhance awareness about environmental problems. We measure the effectiveness of VR versus 2D in an environmental campaign using a field experiment in Brazil. 617 passers-by at a mall were randomly assigned to watch a video clip about the Amazon Forest through VR or a traditional 2D device, with some being randomly interviewed before watching the movie (control group). We find that both the 2D and VR interventions increase individuals' propensity to (i) contribute to an Amazonian humanitarian campaign, (ii) share contact information, (iii) interact with a conservation campaign, and (iv) state pro-conservation opinions. We find no additional impact of VR compared to 2D, but VR participants were more likely to engage with pro-conservation content online 3 months later. Our findings provide cautionary evidence about the additional potential of using immersive technologies, like VR, to improve conservation behaviors compared to 2D methods.

Immersive technology, such as virtual reality (VR), is rapidly reshaping our connection and communication methods. Immersive experiences within virtual environments can elicit profound emotional responses and capture the viewer's attention, enabling the more effective transmission of messages and ideas. VR technologies have been posited as a potentially effective tool to enhance awareness about environmental problems[1,2], for example, by helping individuals visualize and comprehend future climate scenarios, otherwise perceived as distant and abstract. VR can deliver immersive experiences without physically displacing viewers to other contexts or locations. Therefore, it can be scaled up to foster pro-environmental attitudes and actions in large populations.

In this paper, we assess the effect of a VR movie about the Amazon Forest on pro-conservation preferences and behaviors. We designed and administered a preregistered field experiment (see here) in a shopping mall in BrasÃlia, Brazil. Passers-by in the shopping mall (N = 617) were invited to watch a movie and were randomly assigned to a VR or a 2D setting. All individuals were surveyed, with some randomly interviewed before and others after watching the movie. Set up this way, we had a control group made up of individuals interviewed before watching the movie and two treatment groups interviewed after watching the movie in two different mediums (2D or VR). In other words, by surveying passers-by before they were exposed to any information messaging, we measured their pre-treatment pro-environmental outcomes (namely, willingness to support a local rainforest conservation campaign, a donation to a rainforest conservation charity, and willingness to share contact information for future contact). The control group participants also watched the movie (randomly in 2D or VR format) and were later allowed to update their answers.

The movie, in VR or 2D conditions, was produced by the Interfaith Rainforest Initiative (IRI) (https://www.interfaithrainforest.org/), a United Nations project sponsored by the Norwegian government and environmental organizations. The movie lasted approximately 10 min and was an artistic rendering of a visit to the Tapajós region in the Brazilian Amazon Forest. It was awarded the "Best VR Film Prize" at the Barcelona Planet Film Festival 2023. The movie, filmed with a 360-degree camera, takes the viewer on a virtual trip to the Brazilian Amazon Forest, guided by an Indigenous girl who talks about its beauties and Indigenous traditions. She guides the viewer by highlighting the region's biodiversity in flora and fauna and deploring forest destruction, at which moment the movie shows a forest fire. The movie ends with the girl paying homage to nature by singing a prayer in an Indigenous language. When watched on a VR headset, the movie gives viewers an active role in deciding what to look at, as they can turn their heads and look in all possible directions. This active engagement is unavailable in the 2D movie. More details about the experimental design are available in Methods.

[1]The Policy Insitute, King's College London, London, United Kingdom. [2]Institute for Environmental Studies, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands. [3]Department of Economics, Southern Methodist University, Dallas, USA. ✉email: sanchayan.1.banerjee@kcl.ac.uk; alipioferreira@smu.edu

We find that after watching the movie (2D or VR), participants report meaningfully stronger pro-environmental attitudes and are more likely to take concrete pro-environmental actions. However, participants who watched the VR version of the movie did not engage in meaningfully different actions compared to participants who watched the 2D version. More specifically, participants were 9 p.p. (2D) and 12 p.p. (VR) more likely to enter the suggested web page of a conservationist movement after watching the movie, with no statistical difference between the two movie formats. Further, there was no impact on the probability of sharing a post by the said movement on their social media. After watching the movie, participants were also 11 p.p. (2D) and 10 p.p. (VR) more likely to share their WhatsApp number with the research team to receive more information about environmental campaigns by the Interfaith Rainforest Initiative, and again, there was no statistically significant difference between the two treatments. Finally, we find that the VR movie meaningfully increased the propensity to make a financial donation to a humanitarian cause for Indigenous peoples in the Amazon Forest by 8 p.p. relative to the control group, whereas the 2D version increased it by 4 p.p. (n.s.). All these effects are robust to the inclusion of demographic controls, enumerator fixed effects, and survey day fixed effects.

As a follow-up to the experiment, we contacted participants who had shared their phone numbers with the research team (in the control and treatment groups) 3 months after the experiment. We sent each participant a personalized link that landed on the official web page of the movie they had watched. The web page contains detailed information about the movie and videos with testimonials from influential people who have watched it. We tracked how many people clicked on the link, comparing the group that watched the 2D versus the VR movie (all participants, including the control group, eventually watched one version of the movie). Approximately 9% of participants who had watched the VR movie clicked on the link, versus 4.5% among participants who had watched the 2D movie. This difference is statistically significant at the 10% level. Once again, our results are robust to different econometric specifications, such as controlling for socio-demographic characteristics and enumerator and time-fixed effects.

Our findings contrast with previous experimental evidence suggesting that VR can promote environmental fundraising[3] and highlight the need to critically assess the benefits of immersive technologies as a communication tool to facilitate pro-environmental actions. In our experiment, the VR immersive experiences had only a mild additional impact on the participants' environmental attitudes and actions, with the VR version displaying stronger medium-term engagement effects than the 2D version. These findings suggest that VR technologies could likely lead to more persistent behavioral change over time, but our evidence does not allow us to establish this fact confidently. We also cannot discount if these long-term effects are driven by the novelty factor of the first contact with VR headsets. As such, given these findings, we suggest that practitioners should exert caution in scaling up the use of these technologies—given such low benefits yet high costs of implementation, it is likely that immersive technologies would not surpass conventional technologies in their cost-effectiveness for improving sustainable outcomes. We are hopeful, however, that our pessimism will be relieved in the long term with reduced costs of VR implementation and more external tests of such technologies.

Literature review

This study contributes to a growing literature assessing the causal impacts of Virtual Reality on socially relevant outcomes. There is early experimental evidence, for example, suggesting that VR can improve the uptake of environmental diets[4,5], encourage pro-conservation behavior[3,6,7] and boost disaster preparedness[8]. On the other hand, some studies found that VR technologies do not present stronger effects than more traditional communication approaches in eliciting charitable donations for humanitarian organizations[9–11], kidney donations[12], enhancing pro-environmental behaviors[13], or improving learning outcomes (see[14] for a meta-analysis). These studies are mainly lab-based and rely on student samples, with scarce evidence from the field on the effectiveness of using these immersive technologies. We contribute to this literature by testing the role of VR in facilitating the promotion of pro-conservation behaviors towards the Amazon Rainforest.

The closest study to ours is conducted by Nelson and colleagues[3]. They administer a field experiment that measures the impact of a movie on pro-conservation behavior for coral reefs in Indonesia. In this study, the authors show participants a movie done in "positive" and "negative" versions, as well as in 2D and VR versions. They show that the negative VR movie seems to elicit a stronger result than the other movies. In our setting, we did not have variation in the content of the movie. Moreover, we differ from[3] in our experimental design in the design of our control group. We ensured that our control group participants were recruited identically to the treatment group and agreed to complete the full cycle of watching a movie and being interviewed. In contrast[3], use a control group of participants who watched no movie. This methodological choice may raise issues in the comparability of the control group and the treatments, either through a difference in recruitment strategies or because of the potential disappointment effects of not being randomly selected to watch the movie. As explained below, we propose a study design that guarantees identical recruitment and precludes disappointment effects.

Finally, our study also contributes to a large literature on information provision for behavior change. This literature aims to understand how preferences can be affected. Governments and private organizations frequently undertake initiatives to shape people's opinions and affect their preferences and behaviors. In environmental settings, increasing socially responsible behavior can improve environmental outcomes and social welfare by mitigating market failures caused by environmental externalities[15]. Several studies have found cost-effective awareness-raising campaigns that elicited reductions in household electricity[16] and water consumption[17]. Moreover, the "nudge" literature provided evidence on cheap behavioral encouragements that can elicit cost-effective behavioral changes toward pro-social behaviors[18–21].

Methods

Experimental design

The experiment protocol was reviewed by the Institutional Review Board of Insper (São Paulo, Brazil) and approved on June 19th, 2023. All methods were performed in accordance with the relevant guidelines and regulations of the IRB.

The field experiment was conducted at the shopping mall Conjunto Nacional in BrasÃlia, Brazil's capital city. The shopping mall is next to the city's largest bus terminal and receives clients from different socio-economic backgrounds. The shopping mall administration kindly agreed to reserve a space for the experiment's set-up. The research team used the space to create two small environments to diffuse the movie: one containing tablets to display the 2D version of the movie and one with Virtual Reality headsets to diffuse the VR version. Any person walking past the experiment's location could not immediately see what was happening inside these environments, which were hidden from public view by a screen, so potential participants would not be aware of the technologies used for the movie diffusion. We disposed of four VR headsets and three tablets and could show the movie to seven people simultaneously. In rare occasions where there was high participation demand, this resource constraint was hit, but in all these instances, the participants waited a few minutes in line and could watch the movie.

The virtual reality (VR) setting allowed participants to get a 360-degree view of their visual surroundings in the movie which was not possible in the 2D setting. Watching a movie in VR provides a highly immersive experience, making the viewer feel like they are inside the scene and providing them with an active role whereby they choose to look in any direction. In contrast, a 2D movie on a traditional screen is a more passive experience, where the viewer watches the action unfold from a fixed perspective. VR enhances the sense of depth and spatial awareness, while 2D viewing limits you to what's displayed within the screen's boundaries, offering a less immersive but more familiar and straightforward experience. Screenshots of these experiences are provided in the Appendix (see 1–3). A 2D version of the movie can be viewed here.

The research team in the field consisted of nine enumerators hired by the Interfaith Rainforest Initiative. One of the lead researchers participated in the first week of the experiment in the field, training the enumerators, setting up the environment, and conducting interviews. At all times, six enumerators ran the experiment, with one being a supervisor to the others. The training happened on July 17th and 18th, 2023. On July 19th, 2023, the team ran pilots from 10 AM to 3 PM in the shopping mall, which helped enumerators get used to the questionnaire, spot mistakes in the text, and solve technical issues with the technologies. From then on, the data collection started, ending at 7 PM. For the next days, data collection happened until August 10th, 2023, except on Sundays, from 2 to 7 PM.

The enumerators wore a T-shirt indicating they were running a research project, and banners around the experiment's site displayed the sponsoring organization's logo. Recruitment happened by approaching potential participants among the clients walking in the shopping mall, inviting them *to watch a movie about the Amazon Forest* produced by the UN-sponsored Interfaith Rainforest Initiative and *to answer a questionnaire*. They were instructed to offer a gift in exchange for their participation (an eco-bag or a water bottle provided by the Interfaith Rainforest Initiative). They were advised not to mention that there was a Virtual Reality version of the movie. When a person accepted to participate in the research, the enumerator would accompany the person near the experiment's site and read the consent form. No person declined to continue after listening to the consent form.

The movie was produced and financed by the Interfaith Rainforest Initiative (IRI), a UN-sponsored project that is present in several tropical countries worldwide. The organization's main mission is to raise awareness about forest protection by leveraging religious networks. In Brazil, IRI regularly invites religious leaders, such as evangelical pastors and Catholic priests, to participate in lecture series with leading experts in climate change and forest protection. The movie Amazônia Viva was produced to meet IRI's goal of raising awareness for Amazon protection with an artistic lens. The movie does not contain a religious message, so IRI uses it to participate in various events and reach wide audiences, including non-religious ones. The movie lasts for almost 10 min. Its script consists of a trip to the Tapajós river, in the Brazilian Amazon Forest, guided by the Indigenous leader Raquel Tupinambá, who highlights the biodiversity and beauty of the place. In one scene toward the end, we also see a forest fire in a deforested area. The movie has two subtle references to religious themes: a one-time mention of the word "Creator" as the author of the natural beauties of the Amazon forest, and the final scene, in which the Indigenous leader performs a prayer in the Tupy language.

The experiment has a control group and two treatment arms, as displayed in Fig. 1. The control group consists of participants who are interviewed *before* watching the movie, but they also watch a movie later on. The two treatment arms are made of participants who are interviewed after watching either 2D or VR movies. Since the control group participants can also watch either 2D or VR movie, the randomization design splits participants into four different groups:

Treatment 1 (1/3 probability): The participant watched the 2D version of the movie and is interviewed after that.

Treatment 2 (1/3 probability): The participant watched the VR version of the movie and is interviewed after that.

Control 1 (1/6 probability): The participant is interviewed and then watches the 2D version of the movie.

Control 2 (1/6 probability): The participant is interviewed and then watches the VR version of the movie.

Randomization was done independently for each new participant. There were two levels of randomization in this field experiment. The first one determined whether we collect the outcome variables from the participant *before* of *after* by showing them the movie (the intervention). The second level of randomization determined whether the participant watches the 2D or VR version of the movie. The participants in the control groups were given a chance to update their answers after watching the movie, an option that some of them took. To maximize

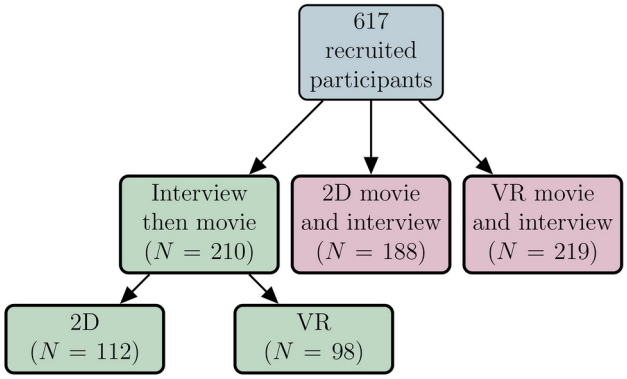

Fig. 1. Experimental design.

the statistical power of the comparisons between control, treatment 1 (2D) and treatment 2 (VR), we designed the experiment to have an equal probability of assignment to each of these groups (1/3).

Figure 1 graphically represents the experimental design. The green boxes denote the control group, where participants were interviewed before watching a movie. The red boxes show the two treatment arms. Since the participants were randomized "in real time" as they arrived to the experiment, the realized share of participants does not match exactly the "ex ante" assignment probability set for the experiment.

Survey design and data collection

The survey was designed using the software Qualtrics, and data was collected using the enumerators' smartphones and tablets. Each new participant was randomized to the treatment or control arms according to a pre-specified probability coded into Qualtrics. The survey would start with a consent form, which was read aloud to participants. After giving their verbal consent which was recorded as written consent in the survey, enumerators collected a few demographic characteristics of participants: sex, age, religion, and education level. These questions were asked before showing the movie to all groups. At this point, the survey diverged between control and treatment groups. For control participants, enumerators would continue the interview and collect the outcome variables, whereas treatment participants were led to a location where they could watch the movie assigned to them (2D or VR). Participants were informed about the type of movie only at this moment, and even enumerators did not know which movie the participant would watch until this moment. Participants were asked the outcome questions immediately after watching the movie.

Participants were recruited among the passers-by at Conjunto Nacional, one of the main shopping malls in Brasília. Enumerators were dressed in a T-shirt that indicated that they were part of a research group, with the logo of IRI, the sponsoring organization. There was a banner of the movie Amazônia Viva at the location of the experiment, with no indication about the VR component. The protocol for recruitment was to invite passers-by to watch a 10-min movie about the Amazon Forest and answer a few questions. Enumerators were instructed not to mention that the movie was available in a VR and 2D format.

The experiment and data collection always happened in the afternoon, starting at around 1:30 PM until 7 PM, from July 19th, 2023 until August 9th, 2023, skipping Sundays (July 23rd and July 30th). The shopping mall's administration reserved two different spaces for the experiment, which were used at different moments. The first space, on the floor of the food court for the experiment, was used during the first week of the experiment (July 19th–July 25th), whereas the second space was in a corridor at a lower floor. The research team created two spaces for the VR and 2D participants in both spaces. These spaces were visually hidden from other passers-by, so potential participants could not see the VR headsets or the tablets used in the 2D arms.

There are two types of outcome variables: self-reported attitudes toward environmental topics and concrete actions. The self-reported attitudes questions asked participants how much they agreed or disagreed with five statements. The available options were: "Entirely disagree", "Moderately disagree," "Neutral," "Moderately agree," and "Entirely agree," plus an option not to give any opinion. Set-up this way, we follow a recent stream of literature, mainly promoted by Douenne and Fabre[22,23], that relies on self-referenced attitudes reported by individuals in surveys to assess their opinions and beliefs about environmental issues. The five statements were:

1. "The Brazilian government has the obligation to protect the Amazon Forest",
2. "Rich nations should support Brazil financially in preserving the Amazon Forest",
3. "The Indigenous Peoples are protectors of the Amazon forest",
4. "Preserving the Amazon forest keeps the local population in poverty", and
5. "NGOs are essential to raise awareness of the public about Amazon conservation."

After collecting data about the state attitudes, enumerators invited participants to take some "actions". The actions were (in order):

1. Enumerators explained the initiative "Amazônia de Pé", a conservationist movement that proposed a law to make deforestation law more stringent in the Amazon. The enumerator then invited the participant to use their smartphone to enter a webpage containing information about the movement, by reading a QR code.
2. The enumerator asked the participant to share a post of the initiative "Amazônia de Pé" on the social media of their preference (Instagram, Twitter, Instagram).
3. The enumerator asked the participants to provide their WhatsApp number to share more information with them about the movie and other initiatives of the Interfaith Rainforest Initiative.
4. The enumerator explained the humanitarian campaign "SOS Ianomâmis", which collects funds for the Yanomami group in the Amazon Forest. The enumerator then asked the participant to make a financial donation for this initiative through a secured website that they could access through a QR code. The donation was made in the website of the NGO "SOS Ianomâmis", and the Interfaith Rainforest Initiative did not manage the money transfer. To guarantee that the donation actually occurred, the enumerators were instructed to record the data only when the participant gave proof that the donation went through.For the control group participants who did not take some action before the movie, they were subsequently asked if they would like to take the action now that they had watched it. However, they could not "undo" the action if they had already taken it.

Empirical strategy

In our main statistical analysis, we run a regression of the outcomes on dummy variables indicating whether the participant watched the 2D or VR version of the movie. This exercise can be expressed by the following regression equation:

$$y_i = \beta_0 + \beta_1 Treatment_i^{2D} + \beta_2 Treatment_i^{VR} + \xi X_i + \varepsilon_i \quad (1)$$

where y_i is an outcome of interest, $Treatment_i^{2D}$ indicates that the treated individual watched the 2D movie, and $Treatment_i^{VR}$ means that they watched the VR movie. X_i are demographic controls, enumerator fixed effects, and survey day fixed effects, and we run the regressions with and without them. ϵ_i is a zero-mean error term. To perform inference on the coefficients, we compute heteroskedasticity-robust White standard errors. We then test for the statistical difference between β_1 and β_2 using a t-test. Although the participants in the control groups also varied with respect to the movie version they watched, they were unaware of this at the moment in which they answered the questionnaire and were lumped into a single control group. Under the assumption of random treatment assignment, the coefficients β_1, β_2 of Eq. (1) identify the Average Treatment Effects (ATE) of the intervention among the population of individuals willing to participate in the experiment.

To assess the quality of the randomization, we ran a balancing test using the socio-demographic variables as outcomes. This test consists of a t-test for equality of means, and the results are reported in the main text in Table 1.

Several individuals in the control group refused to take the actions proposed to them by the enumerator but were given the chance to take these actions after watching the movie. Some individuals took this opportunity. We estimate Eq. (1) with the updated results to test whether there is a difference between control and treatment

	All groups	Control group	Treatment 2D	Treatment VR	*p*-value $(2D = C)$	*p*-value $(VR = C)$	*p*-value $(VR = 2D)$
Age	30.70	29.92	31.54	30.74	0.21	0.49	0.53
	(12.58)	(12.20)	(13.15)	(12.44)			
Female	0.62	0.58	0.70	0.60	0.01	0.64	0.03
	(0.49)	(0.50)	(0.46)	(0.49)			
Higher education	0.61	0.62	0.59	0.63	0.43	0.89	0.35
	(0.49)	(0.49)	(0.49)	(0.48)			
No religion	0.32	0.32	0.31	0.33	0.83	0.83	0.68
	(0.47)	(0.47)	(0.47)	(0.47)			
Catholic	0.28	0.23	0.30	0.30	0.15	0.14	0.98
	(0.45)	(0.42)	(0.46)	(0.46)			
Evangelical	0.28	0.32	0.28	0.24	0.36	0.06	0.37
	(0.45)	(0.47)	(0.45)	(0.43)			
N	617	210	188	219			

Table 1. Summary statistics and balance tests. This table shows summary statistics of the characteristics of participants in the field experiment. The collected variables were age, gender, education, and religion. The three first columns show the mean and standard deviation of the variables for the control group and the two treatment groups (2D and VR). The following three columns show *p*-values for t-tests of equality of means between the 2D treatment group and the control group ($2D = C$), VR treatment group and the control group ($VR = C$), and the VR treatment group and the 2D treatment group ($VR = 2D$).

groups once every participant has watched the movie. Moreover, to test whether the VR version of the movie increased the chances that an individual updates their answers, we run the following regression:

$$y_i = \delta_0 + \delta_1 Control_i^{VR} + \mu X_i + u_i \quad (2)$$

where $Control_i^{VR}$ indicates that individual *i* was in the control group, meaning they were interviewed before watching the movie and watched the VR version of the movie. This regression is only used for the group of control individuals who refused to take the actions. We then assess whether the control individuals who watched the VR movie were more likely to take the action after the movie than control individuals who watched the 2D movie. Under randomization of individuals into the 2D or the VR movie, the coefficient δ_1 captures the causal effect of making them change their minds because of the VR movie relative to the 2D movie, among individuals who initially refused to take the proposed action.

Finally, we also collected data from the participants who gave their WhatsApp numbers to the enumerators. Approximately 3 months after the experiment, the research team sent a message to each of these participants, inviting them to click on a link providing supplementary information about the movie they had watched. Although all links landed on the same web page, the links were individual and allowed the researchers to track how many times someone had clicked on the links. We estimate Eq. (2) using the sample of people who provided their WhatsApp number before receiving the treatment, to test whether the VR experience made them more likely to engage with environmental content 3 months after the experience, relative to the 2D movie. Moreover, we also run a regression including treatment individuals as follows:

$$y_i = \phi_0 + \phi_1 VR_i + \theta X_i + \nu_i \quad (3)$$

where VR_i lumps all individuals who watched the VR movie and provided their WhatsApp numbers, regardless of whether they were control or treatment groups. This specification has the benefit of including a larger sample of people as a population of interest, but it fails to meet the randomization assumptions needed for causal inference. The reason is that people who gave their Whatsapp numbers after watching the movie may have done so as a consequence of this treatment, and it is possible that the treatment effect of 2D or VR movies were different. Consequently, the population of 2D-movie watchers who gave their WhatsApp numbers does not an ideal counterfactual for the group of VR-movie watchers. Therefore, the results for this specification must be seen only as suggestive evidence and interpreted with caution.

Results

Table 1 shows summary statistics for the 617 participants of the field experiment. The first four columns show the means and standard deviations for the whole sample, the control group, and the two treatment groups. The average age of participants was 31 years old, 62% of them female, 61% with (complete or incomplete) higher education, 32% with no religion, 28% Catholics, and 28% Evangelicals. The three remaining columns show the *p*-values of mean equality tests. Overall, the groups were well balanced in the measured socio-demographic characteristics—age, gender, education, and religion—except for a larger proportion of female participants was higher in the 2D treatment group and a smaller proportion of Evangelicals in the VR treatment group, compared with the control group.

No short-term differences between 2D and VR formats

Figure 2 plots raw mean scores (with 95% confidence intervals) for participants in the control and treatment groups for our first set of preregistered outcomes, which reflect pro-conservation actions taken by the participants. These outcomes were the willingness to access a webpage of a pro-conservation campaign ("See Page"), to share a post by the same conservation campaign on social media ("Share"), to share their personal contact information for future contact ("WhatsApp"), to make a financial donation to a rainforest conservation charity ("Donation"). We also recorded the value of the donation.

All these outcomes are observed actions made before an enumerator and, as such, record revealed behaviors. To measure the impact of the movie on people's actions, we compare the outcomes of the two treatment groups, that is, individuals who were interviewed after they were shown the movie in the VR or 2D format, with the control group, that is, those who were interviewed just before being shown any movie. Table 2 presents these findings using linear regression models using three different specifications. Panel A shows the estimated coefficients without controls, Panel B shows the coefficients of the regressions with demographic controls, and Panel C adds enumerator-level fixed effects and survey date fixed effects. In all specifications, statistical inference is done using heteroskedasticity-robust White standard errors. Following our preregistration plan, we correct for multiple outcomes and hypotheses following[24], and report the *p*-values in brackets in Panel C. In the following paragraphs, we discuss the results using the numbers in Panel C.

Both VR and 2D formats increased participants' participation in pro-conservation behaviors relative to the control group. For example, participants who watched the 2D and VR were 9 p.p. and 12 p.p. more likely to access the web page of the suggested conservationist movement after watching the movie using their smartphones. However, despite viewing these pages, we do not find a significant effect on the probability of sharing this post on their social media for any treatment group. Participants were also 11 p.p. (2D) and 10 p.p. (VR) more likely to share their WhatsApp numbers with the research team to receive more information about environmental campaigns.

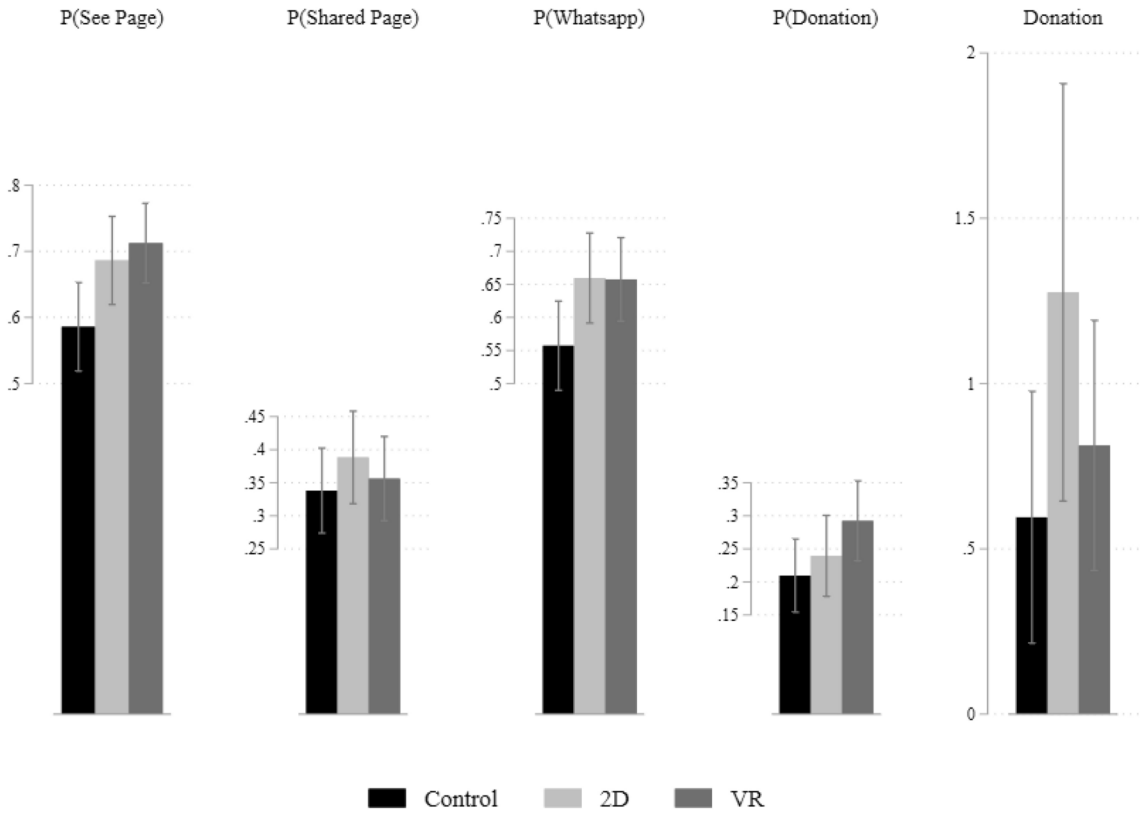

Fig. 2. Mean outcomes of control and treatment groups. Obs: 95% confidence interval bar plots for outcomes (left to right) across 2D and VR treatments: seeing page, sharing page, sharing Whatsapp number, making a donation and donation value.

Finally, we found that the VR movie increased the propensity to make a financial donation to a humanitarian cause for Indigenous peoples in the Amazon Forest by 8 p.p., whereas there was no significant difference observed for the 2D format with respect to the control group. However, the mean value of donations is only statistically different from the control group's mean donation value for the 2D group, suggesting that an increase in propensity to donate in the VR condition did not translate into higher donations. All these findings are robust across the three specifications. The participants were free to select any value for their donations but were prompted to donate 5 Brazilian Reais (approximately 1 USD). The mean donation among those who made a donation was 9.5 Brazilian Reais (approximately 2 USD).

Although both the VR and 2D formats are individually effective versus the baseline for several outcomes, we do not find significant differences between the effect of 2D and VR. Table 2 reports the *p*-values of equality tests of the VR and 2D coefficients, all of which are larger than 20%. These results suggest that the two interventions seem to activate similar responses in viewers. Panel C also reports, in square brackets, the *p*-values of a randomized test with multiple hypothesis correction following[24]. These *p*-values do not alter the main results of the statistical tests, though they suggest that the increase in donation values of the 2D group is not significant at the 10% level. As long as the variance of the outcome variable is constant across groups, the equal sample sizes of the three groups (control, 2D, and VR) implies that the equality test between VR and 2D coefficient has the same statistical power as the test between any treatment group and the control group.

To further test the movie's impact on outcomes and the relative impact of 2D versus VR, we allowed the individuals in the control group to update their answers (on the "actions" outcomes only) after watching the movie. For practical reasons, the participants were only allowed to update their answers in one direction; that is, they could share a post on their social media, share their WhatsApp information, and make a donation if they had not done it before, but they could not "undo" the action taken previously. Consistent with the results presented so far, after watching the movie, the individuals who update their answers make the average outcomes among the control group indistinguishable from the average in the treatment groups. Moreover, we continue to find no difference between 2D and VR. These results are shown in the Appendix (see Table A1). Indeed, in the sample of individuals in the control group who did not take action during the interview, watching the VR movie did not make them more likely to update their actions than watching the 2D movie, except for the "sharing" outcome. For control individuals who had not entered the page of the conservation campaign, the proportion that decided to visit the page and share a post on social media was 15 p.p. higher among VR participants than 2D participants. These results are shown in Appendix Table A2.

We perform a heterogeneity analysis based on the participant's age (above or below the median of 30 years old), gender, education (complete or incomplete higher education), and religion (no religion or with some

	P(see page)	P(share)	P(whatsapp)	P(donation)	Donation
	(1)	(2)	(3)	(4)	(5)
Panel A: no controls					
2D	0.100**	0.0449	0.102**	0.0298	0.681*
	(0.0481)	(0.0483)	(0.0488)	(0.0420)	(0.375)
VR	0.127***	0.0226	0.100**	0.0827**	0.217
	(0.0458)	(0.0461)	(0.0471)	(0.0417)	(0.273)
R2	0.0136	0.00141	0.00983	0.00655	0.00669
p-value $\beta^{VR} = \beta^{2D}$	0.568	0.644	0.966	0.228	0.217
Panel B: + controls					
2D	0.103**	0.0386	0.105**	0.0304	0.718**
	(0.0464)	(0.0476)	(0.0493)	(0.0431)	(0.363)
VR	0.123***	0.0213	0.0960**	0.0842**	0.185
	(0.0452)	(0.0455)	(0.0471)	(0.0421)	(0.273)
R2	0.0823	0.0660	0.0230	0.0139	0.0301
p-value $\beta^{VR} = \beta^{2D}$	0.654	0.714	0.844	0.231	0.154
Panel C: + enumerator and survey day fixed effects					
2D	0.0905*	0.0277	0.110**	0.0399	0.594*
	(0.0465)	(0.0438)	(0.0489)	(0.0395)	(0.337)
	[0.0679]	[0.6396]	[0.0221]	[0.3258]	[0.1109]
VR	0.120***	0.0184	0.0985**	0.0802**	0.193
	(0.0454)	(0.0407)	(0.0467)	(0.0370)	(0.279)
	[0.0106]	[0.70561]	[0.0268]	[0.04541]	[0.61097]
R2	0.149	0.282	0.0908	0.251	0.102
p-value $\beta^{VR} = \beta^{2D}$	0.508	0.831	0.816	0.330	0.240
N	617	617	617	617	617
Mean control	0.586	0.338	0.557	0.210	0.595

Table 2. Treatment effects estimation on actions. This table shows the results for OLS regressions of the outcomes (in columns) on the treatment. Standard Errors in parentheses. Legend: * 0.10 ** 0.05 *** 0.01 significance levels. The two treatment groups refer to people randomly assigned to watch the movie Amazônia Viva and interviewed after watching the movie. The control group comprises participants randomly assigned to be interviewed before watching the movie. Panel A shows the results for the specification without any controls. Panel B controls for dummies of religion (Catholic, evangelical, atheist, no religion, others), dummies of highest attained education level (incomplete basic education, complete basic education, incomplete higher education, complete higher education, graduate studies), and age in years. Panel C shows the specification for the same set of controls, plus dummies for the enumerator who conducted the interview. In all specifications, inference is done by computing robust (White) standard errors. Young's[24] randomized-t p-values reported in box brackets in Panel C.

religion). The effects on the probability of entering the web page of the environmental campaign and WhatsApp sharing are not heterogeneous across these dimensions, but the effect on donations is driven by participants with higher education and with no religion. These results are shown in Appendix (see Table A4).

As a follow-up to the experiment, we also contacted participants who had shared their WhatsApp numbers with the research team (in the control and treatment groups) 3 months after the experiment. In this intervention, all participants had watched the movie, so we only compared those who watched the VR with those who watched the 2D version. We sent each participant a personalized link that landed on the official web page of the movie they had watched. On tracking engagement with the link, by comparing individuals in the two conditions, we find that 9% of participants who had watched the VR movie eventually clicked on the link, whereas only 4.5% in the 2D condition clicked on the link. This difference is statistically significant at the 10% significance level, as shown in Table A3 (see Appendix), and it is robust to the inclusion of demographic controls and enumerator fixed effects (Columns 1, 2, and 3). There was no difference in the number of clicks on the link (Columns 4, 5, and 6). Moreover, when using only the control individuals (that is, individuals who gave their WhatsApp before watching any movie), we do not find any statistical difference. We did not pre-register this test and, therefore, this finding is exploratory.

Impacts on self-reported beliefs and attitudes

Figure 3 plots raw means (with 95% confidence intervals) for variables reflecting the pro-environmental attitudes of participants. The bars depict the share of respondents stating that they "agree completely" with five statements:

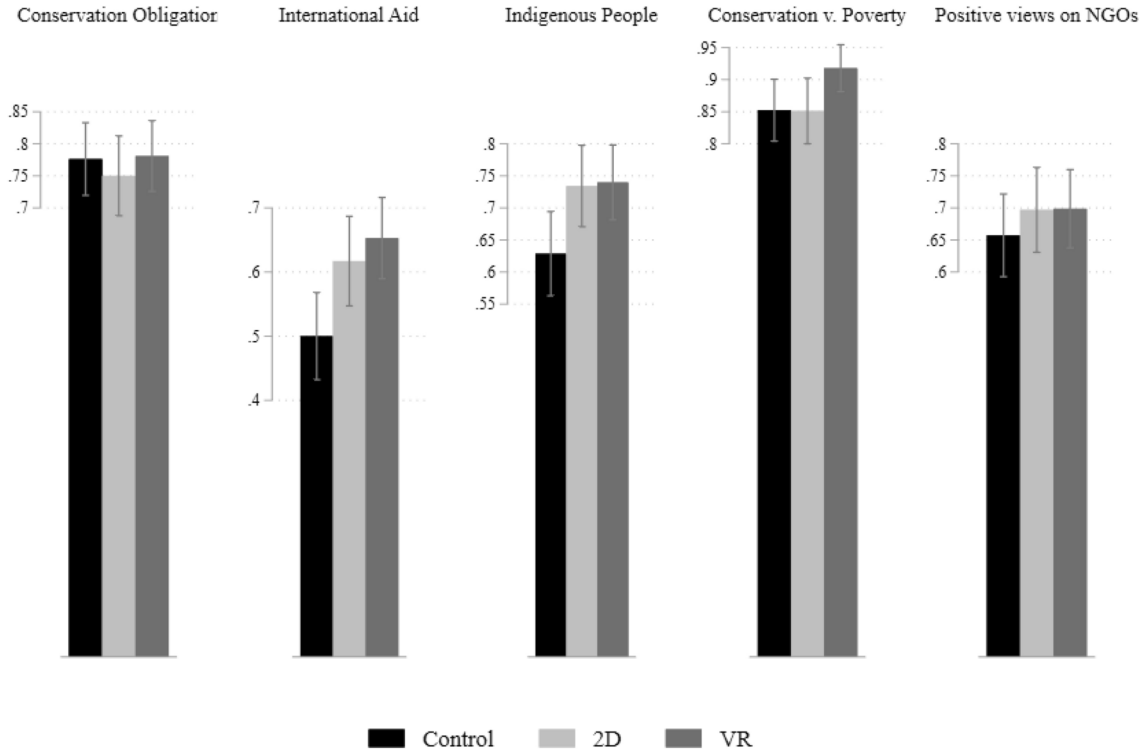

Fig. 3. Mean pro-conservation attitudes of control and treatment groups. Obs: 95% confidence interval bar plots for attitudinal variables (left to right) across 2D and VR treatments: conservation obligation, international financial aid, Indigenous people, conservation versus poverty trade-off and positive views on NGOs.

"The Brazilian government has the obligation to protect the Amazon Forest" (Conservation Obligation), "rich nations should support Brazil financially in preserving the Amazon Forest" (International Aid), "The Indigenous Peoples are protectors of the Amazon forest" (Indigenous People), "Preserving the Amazon forest keeps the local population in poverty" (Conservation v. Poverty), and "NGOs are essential to raise awareness of the public about Amazon conservation" (Positive views on NGOs). For the "Conservation v. Poverty", we report the share of participants who *disagree* completely with the statement to present all variables in the direction of pro-conservation attitudes.

We assessed the impact of the intervention on self-reported beliefs and attitudes of individuals, again by comparing the stated answers of individuals after watching the VR and 2D movies against the answers of individuals who had not yet watched the movie. In Table 3, we show the estimated results for five questions, where the outcome is the probability that the respondent "agrees completely" with a particular statement. Among the control group, the share of people who agreed completely with the statements varied from 50% and 86%. Like in Table 2, Panel A presents the coefficients on the treatment groups without any controls, Panel B includes socio-demographic controls, and Panel C adds enumerator and survey day fixed effects. Panel C also contains *p*-values of randomized inference with multiple hypothesis correction, reported in square brackets. In the discussion below, we cite the coefficients of Panel C, but all panels have similar findings.

As with the observed actions, we find significant differences between the treatment groups and the control groups in their level of agreement with most statements. However, we only detect a statistically significant difference between the effect of 2D and VR treatments for one outcome (Column 4). In Column 1, we show that watching the movie in either format did not affect participants' stated belief that "the Brazilian government has the obligation to protect the Amazon Forest". Similarly, a null effect is found in Column 5, which shows the impact of the intervention on the stated belief that whether "NGOs play an important role in raising awareness on forest conservation". The level of agreement with these statements was 78% and 66% in the control group.

Columns 2, 3, and 4 show positive effects of the treatment on the probability of agreeing with the statements. Watching the movie increased the probability that participants agree completely that "rich nations should support Brazil financially in preserving the Amazon Forest" by 9 (2D) and 13 (VR) percentage points, with no significant difference between the two coefficients (Column 2). This outcome had the lowest baseline level of complete agreement (50%). The movie also increased the perception of Indigenous people as protectors of the forest, with the movie increasing the probability that participants agree entirely with this view by 9 p.p. (2D) and 10 p.p. (VR) from a baseline of 63% (Column 3). This effect probably reflects the salient presence of Indigenous characters in display in the movie.

Finally, only the VR version made people more likely to disagree entirely with the statement that "forest conservation imposes poverty on the local populations", with an effect of 6 p.p. (Column 4). This is the only outcome for which the difference between the 2D and VR treatment is statistically significant at the 10% level, as

	Conservation obligation	International financial aid	Indigenous people	Conservation vs poverty trade-off	Positive view on NGOs
	(1)	(2)	(3)	(4)	(5)
Panel A: no controls					
2D	− 0.0262	0.117**	0.105**	− 0.00132	0.0397
	(0.0428)	(0.0496)	(0.0465)	(0.0358)	(0.0470)
VR	0.00463	0.153***	0.111**	0.0654**	0.0415
	(0.0402)	(0.0473)	(0.0447)	(0.0308)	(0.0452)
R2	0.000996	0.0181	0.0126	0.00915	0.00172
p-value $\beta^{VR} = \beta^{2D}$	0.466	0.454	0.897	0.0374	0.968
Panel B: + controls					
2D	− 0.0147	0.110**	0.0949**	− 0.00267	0.0352
	(0.0433)	(0.0498)	(0.0459)	(0.0354)	(0.0470)
VR	0.00686	0.144***	0.102**	0.0615**	0.0408
	(0.0403)	(0.0476)	(0.0442)	(0.0308)	(0.0451)
R2	0.0329	0.0304	0.0554	0.0419	0.0342
p-value $\beta^{VR} = \beta^{2D}$	0.611	0.482	0.876	0.0451	0.903
Panel C: + enumerator and survey day fixed effects					
2D	− 0.0326	0.0939*	0.0901**	− 0.00215	0.0330
	(0.0419)	(0.0490)	(0.0455)	(0.0358)	(0.0455)
	[0.3996]	[0.5657]	[0.4947]	[0.5037]	[0.7412]
VR	0.0139	0.133***	0.103**	0.0577*	0.0357
	(0.0387)	(0.0452)	(0.0415)	(0.0315)	(0.0426)
	[0.5371]	[0.0373]	[0.1577]	[0.0374]	[0.5650]
R2	0.154	0.175	0.180	0.0865	0.173
p-value $\beta^{VR} = \beta^{2D}$	0.253	0.394	0.760	0.0732	0.951
N	617	617	617	617	617
Mean control	0.776	0.500	0.629	0.852	0.657

Table 3. Treatment effects estimation on stated environmental attitudes. This table shows the results for OLS regressions of the outcomes (in columns) on the treatment. Standard Errors in parentheses. Legend: * 0.10 ** 0.05 *** 0.01 significance levels. The outcomes are the probability that participants agree completely with a statement read to them, except for the outcome in Column 4, which measures the probability that participants *disagree* completely with the statement. Participants were asked to give their degree of agreement, ranging from disagree completely to agree completely, plus an option not to answer the question. The statements for Columns 1 to 5 were "The Brazilian government has the obligation to protect the Amazon Forest", "rich nations should support Brazil financially in preserving the Amazon Forest", "The Indigenous Peoples are protectors of the Amazon forest", "Preserving the Amazon forest keeps the local population in poverty", and "NGOs are essential to raise awareness of the public about Amazon conservation." The two treatment groups refer to people randomly assigned to watch the movie Amazônia Viva and interviewed after watching the movie. The control group comprises participants randomly assigned to be interviewed before watching the movie. Panel A shows the results for the specification without any controls. Panel B controls for dummies of religion (Catholic, evangelical, atheist, no religion, others), dummies of highest attained education level (incomplete basic education, complete basic education, incomplete higher education, complete higher education, graduate studies), and age in years. Panel C shows the specification for the same set of controls, plus dummies for the enumerator who conducted the interview. In all specifications, inference is done by computing robust (White) standard errors. Young's[24] randomized-t *p*-values reported in box brackets in Panel C.

seen in the reported *p*-values of the equality test between the two coefficients in Table 3. The difference is even more significant for Panels A and B. This outcome is also the one with the highest level of baseline consensus, with 86% of participants in the control group completely disagreeing with it.

We did not preregister any subgroup analyses. We do not find any (exploratory) meaningful heterogeneous effects across socio-demographic characteristics namely age, gender, education, and religion. These results are reported in Table A5 in the Appendix and the interaction terms of treatment and socio-demographic characteristics are generally small and not statistically significant. The only exception is that female participants were more likely to agree that the Brazilian government must protect the forest after watching the movie.

Discussion

This paper provides novel experimental evidence from the field on the effectiveness of VR and 2D technologies for improving forest conservation behaviors and attitudes in the Amazonian Rainforest in Brazil. We find significant effects of the movie on behavior and attitudes but no differences between immersive (VR) and conventional (2D), with mild evidence of longer-lasting engagement for the VR intervention. Relative to the literature, this study innovates in two main ways. First, we partner with an international conservation organization to leverage an immersive movie and evaluate its impact in a preregistered field experiment. These features mitigate concerns about the sample's representativeness and the project's potential for scalability. Second, besides collecting data on stated pro-environmental attitudes, we also measure concrete pro-environmental behavior and follow up with participants 3 months after the intervention. These features mitigate concerns about intention-behavior gaps and short-term responses associated with experimental demand.

The literature on messaging intervention highlights two main mechanisms that may explain why a movie might affect people's pro-environmental actions and attitudes: *activating values* already held by information receivers or shifting their beliefs through *novel information*. Through the value activation channel, the messaging intervention does not necessarily add information to the participants' knowledge but awakens a latent set of ideas that encourage their immediate pro-social behaviors[25]. The literature has documented that messaging interventions can activate people's sense of identity and pro-social values, particularly by using images[26,27]. Moreover, messages that appeal to social norms and environmental values seem to be more effective than messages that appeal to individuals' self-interest and economic gain[28].

Besides value activation, messaging can also change behavior through novel information. For example, the airing of documentaries about climate change and air pollution seems to affect the behavior of people who watched the movies regarding conservation[29] and self-protection[30]. In a political context[31], provided evidence of how a few minutes of canvassing for a candidate increases the chances of voting for this candidate. Using videos and images is widely seen as a means to increase engagement and transmit information more effectively. For example[32], show that videos boost the treatment effect of agricultural extension services in a developing country setting. Indeed, educational activities tend to rely heavily on videos and the newest communication technologies to convey information in a persuasive way, including with the use of Virtual Reality.

Both mechanisms could potentially be present in our experiment with the immersive movie in the Amazon Forest. On the one hand, the movie may have awakened the participants' underlying ideas about the importance of the rainforest. On the other hand, it may have exposed them to a totally new experience regarding the extension and beauty of the forest, the dangers of deforestation, and the forest's importance for Indigenous communities. While it is impossible to precisely establish whether the mechanism behind the effects is the enticement of pro-social behavior or the provision of novel information, it is more likely that the intervention is related to activating pro-social values because of the Brazilian political context, in which the Amazon Forest is highly covered and debated in public forums. Moreover, the movie does not convey scientific facts, theories, or facts, providing viewers with an artistically rendered immersive experience instead. Moreover, we also acknowledge the possibility that experimenter demand effects or social desirability bias could have played a role in our positive results, such as in soliciting donations.

One important potential application of Virtual Reality is to raise awareness of environmental issues and potentially affect people's behaviors and beliefs about them[1,2]. Virtual reality can be particularly appealing for organizations working on environmental topics because environmental issues, such as forest conservation or climate change, can be perceived as distant or abstract to city dwellers. At the same time, in countries where most of the population lives in cities, urban dwellers considerably impact conservation through their consumption behavior and electoral impact in shaping environmental policies. In a study with politicians from six Western countries[33], found that politicians displayed more interest in procuring scientific information about environmental topics when their constituents were more environmentally aware. At the same time[34], document that constituencies with more pro-environmental voters tend to vote for politicians with stronger pro-environmental views. Therefore, citizens' attitudes toward conservation are highly consequential to environmental outcomes, regardless of their ability to directly engage in environmental damage.

VR can deliver immersive experiences without physically displacing viewers to other contexts or locations. Virtual reality has been shown to complement tourism[35,36], and also substitute it in some cases, such as during lockdowns in the COVID-19 pandemic[37]. People's experiences often improve their valuation for such services, as has been suggested in studies evaluating nature-based tourism and conservation actions[38]. Therefore, it is plausible to hypothesize, as we do in this study, that VR might approximate an actual immersive experience in a forest and thus improve conservation attitudes towards it.

In light of the high potential of shaping preferences and the emergence of immersive technologies, our findings provide some points of caution. We do not find any additional effects of VR on pro-conservation behavior compared with 2D. While our study concurs with some lab experimental results in finding that 2D and VR elicit similar effects on pro-social behavior[9–11], field experimental results in Indonesia by Nelson and colleagues[3] show additional effects of VR relative to 2D on donations for coral reef conservation, though only when the message in the movie is "negative." Unlike that study, we ran our experiment among an urban population geographically distant from the conservation issue discussed in the study. Our study does not use this gain-loss frame explicitly, so we are unable to test whether such framing would have generalized in our setting. There is also mixed evidence in the literature about the impact of fear-mongering (when communication is designed to emphasize negative effects) on pro-environmental actions[39,40].

In our experiment, the video experiment elicited strong effects from participants, producing promising evidence for easily scalable interventions, such as showing a 10-min video. However, the result suggests that the VR technology, despite its much richer experience, does not yield a uniquely large treatment effect, with cheaper platforms such as a 2D tablet performing almost just as well. Although the VR experience led to a longer-

lasting engagement of participants with pro-environmental content, the additional effects of VR on behavior seem to be marginal relative to the 2D experience. The appeal of immersive experiences has grown with recent technological developments allowing large groups of people to live these experiences. However, the enhanced experience does not seem to induce stronger behavioral changes relative to more conventional technologies. We call for more research into how VR technologies can be optimally used to induce additional behavioral responses for environmental conservation.

Data availability

The datasets generated by the survey research during and/or analysed during the current study will be made available in Figshare. Queries related to data can be made to the corresponding author via email: S.Banerjee@vu.nl.

Code availability

The analytic codes used for data cleaning and analysis during the current study will be made available in OSF.

Received: 28 June 2024; Accepted: 5 November 2024
Published online: 05 December 2024

References

1. Thoma, S. P. et al. Increasing awareness of climate change with immersive virtual reality. *Front. Virtual Real.* **4**, 897034 (2023).
2. Fauville, G., Queiroz, A. C. M., & Bailenson, J. N. Virtual reality as a promising tool to promote climate change awareness. In J. Kim & H. Song (Eds.), Technology and health: Promoting attitude and behavior change (pp. 91–108). Elsevier Academic Press. https://doi.org/10.1016/B978-0-12-816958-2.00005-8 (2020).
3. Nelson, K. M., Anggraini, E. & Schlüter, A. Virtual reality as a tool for environmental conservation and fundraising. *PLoS ONE* **15**, e0223631 (2020).
4. Plechatá, A., Morton, T., Perez-Cueto, F. J. & Makransky, G. A randomized trial testing the effectiveness of virtual reality as a tool for pro-environmental dietary change. *Sci. Rep.* **12**, 14315 (2022).
5. Plechatá, A., Morton, T., Perez-Cueto, F. J. & Makransky, G. Why just experience the future when you can change it: Virtual reality can increase pro-environmental food choices through self-efficacy. *Technol. Mind Behav.* **3**(4: Winter). https://doi.org/10.1037/tmb0000080 (2022).
6. Hofman, K., Walters, G. & Hughes, K. The effectiveness of virtual vs real-life marine tourism experiences in encouraging conservation behaviour. *J. Sustain. Tour.* **30**, 742–766 (2022).
7. Pimentel, D. & Kalyanaraman, S. The effects of embodying wildlife in virtual reality on conservation behaviors. *Sci. Rep.* **12**, 6439 (2022).
8. Mol, J. M., Botzen, W. W. & Blasch, J. E. After the virtual flood: Risk perceptions and flood preparedness after virtual reality risk communication. *Judgm. Decis. Mak.* **17**, 189–214 (2022).
9. Martingano, A. J., Konrath, S., Henritze, E. & Brown, A. D. The limited benefits of using virtual reality 360 videos to promote empathy and charitable giving. *Nonprofit Volunt. Sect. Q.* **52**, 1434–1457. https://doi.org/10.1177/08997640221125804 (2023).
10. Gürerk, Ö. & Kasulke, A. Does virtual reality increase charitable giving? An experimental study. *An Experimental Study (August 19, 2021)* (2021).
11. Breves, P. Bringing people closer: The prosocial effects of immersive media on users' attitudes and behavior. *Nonprofit Volunt. Sect. Q.* **49**, 1015–1034 (2020).
12. Li, B. J. & Kyung Kim, H. Experiencing organ failure in virtual reality: Effects of self-versus other-embodied perspective taking on empathy and prosocial outcomes. *New Media Soc.* **23**, 2144–2166 (2021).
13. Van Horen, F. et al. Observing the earth from space: Does a virtual reality overview effect experience increase pro-environmental behaviour?. *PLoS ONE* **19**, e0299883 (2024).
14. Kaplan, A. D. et al. The effects of virtual reality, augmented reality, and mixed reality as training enhancement methods: A meta-analysis. *Human Factors* **63**, 706–726 (2021).
15. Bénabou, R. & Tirole, J. Individual and corporate social responsibility. *Economica* **77**, 1–19 (2010).
16. Allcott, H. & Rogers, T. The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. *Am. Econ. Rev.* **104**, 3003–3037 (2014).
17. Torres, M. M. J. & Carlsson, F. Direct and spillover effects of a social information campaign on residential water-savings. *J. Environ. Econ. Manag.* **92**, 222–243 (2018).
18. Banerjee, S. et al. Thinking about default enrollment lowers vaccination intentions and public support in G7 countries. *PNAS Nexus* **3**, 093 (2024).
19. Thamer, P., Banerjee, S. & John, P. Pledging after nudging improves uptake of plant-based diets: A field experiment in a German university cafeteria. Environ. Res. Commun. (2023).
20. Banerjee, S., Galizzi, M. M., John, P. & Mourato, S. Sustainable dietary choices improved by reflection before a nudge in an online experiment. *Nat. Sustain.* **6**, 1632–1642 (2023).
21. Banerjee, S. & Picard, J. Thinking through norms can make them more effective. Experimental evidence on reflective climate policies in the UK. *J. Behav. Exp. Econ.* **106**, 102024 (2023).
22. Douenne, T. & Fabre, A. Yellow vests, pessimistic beliefs, and carbon tax aversion. *Am. Econ. J. Econ. Policy* **14**, 81–110 (2022).
23. Douenne, T. & Fabre, A. French attitudes on climate change, carbon taxation and other climate policies. *Ecol. Econ.* **169**, 106496 (2020).
24. Young, A. Channeling fisher: Randomization tests and the statistical insignificance of seemingly significant experimental results. *Q. J. Econ.* **134**, 557–598 (2019).
25. Van Zomeren, M., Spears, R. & Leach, C. W. Exploring psychological mechanisms of collective action: Does relevance of group identity influence how people cope with collective disadvantage?. *Br. J. Soc. Psychol.* **47**, 353–372 (2008).
26. Casas, A. & Williams, N. W. Images that matter: Online protests and the mobilizing role of pictures. *Political Res. Q.* **72**, 360–375 (2019).
27. Gulliver, R., Chapman, C. M., Solly, K. N. & Schultz, T. Testing the impact of images in environmental campaigns. *J. Environ. Psychol.* **71**, 101468 (2020).
28. Bolderdijk, J. W., Steg, L., Geller, E. S., Lehman, P. K. & Postmes, T. Comparing the effectiveness of monetary versus moral motives in environmental campaigning. *Nat. Clim. Change* **3**, 413–416 (2013).
29. Jacobsen, G. D. The Al Gore effect: an inconvenient truth and voluntary carbon offsets. *J. Environ. Econ. Manag.* **61**, 67–78 (2011).
30. Tu, M., Zhang, B., Xu, J. & Lu, F. Mass media, information and demand for environmental quality: Evidence from the "Under the Dome". *J. Dev. Econ.* **143**, 102402 (2020).

31. Pons, V. Will a five-minute discussion change your mind? A countrywide experiment on voter choice in France. *Am. Econ. Rev.* **108**, 1322–1363 (2018).
32. Baul, T., Karlan, D., Toyama, K., & Vasilaky, K. Improving smallholder agriculture via video-based group extension. *J. Dev. Econ.* **169**, 103267. (2024).
33. Pereira, M. M., Giger, N., Perez, M. D. & Axelsson, K. Encouraging politicians to act on climate. A field experiment with local officials in six countries. *Am. J. Polit. Sci.* (2024).
34. Angrist, N., Winseck, K., Patrinos, H. A. & Zivin, J. G. Human capital and climate change. *Rev. Econ. Stat.* 1–28 (2024).
35. Sussmann, S. & Vanhegan, H. Virtual reality and the tourism product substitution or complement? *ECIS 2000 Proceedings* (2000).
36. Rauscher, M. Virtual reality in tourism: Is it 'real'enough? *Acad. Tur. Tour. Innov. J.* **13** (2020).
37. Sarkady, D., Neuburger, L. & Egger, R. Virtual reality as a travel substitution tool during COVID-19. *Information and Communication Technologies in Tourism 2021: Proceedings of the ENTER 2021 eTourism Conference, January 19–22, 2021,* 452–463 (2021).
38. Hehir, C., Scarles, C., Wyles, K. J. & Kantenbacher, J. Last chance for wildlife: Making tourism count for conservation. *J. Sustain. Tour.* **31**, 1271–1291 (2023).
39. Tang, H., Chen, L., Liu, S., Tan, X. & Li, Y. Reconsidering the effectiveness of fear appeals: An experimental study of interactive fear messaging to promote positive actions on climate change. *J. Health Commun.* 1–11 (2024).
40. Weinstein, N., Rogerson, M., Moreton, J., Balmford, A. & Bradbury, R. B. Conserving nature out of fear or knowledge? Using threatening versus connecting messages to generate support for environmental causes. *J. Nat. Conserv.* **26**, 49–55 (2015).

Acknowledgements

We thank Interfaith Rainforest Initiative Brazil, Shopping Conjunto Nacional, and Abdul Latif Jameel Poverty Action Lab's Latin American Office for their logistical and financial support. We especially thank the support by Carlos Vicente from Interfaith Rainforest Initiative, insightful discussions with him, José Moulin, Francisco Almendra. We also thank seminar participants at Southern Methodist University and Vrije Universiteit Amsterdam and conference participants at EAERE 2024, AERE 2024, EE4E 2024, RIDGE BRAIN 2024, and AFE 2024, where this work was presented. Sanchayan Banerjee acknowledges financial support from the Policy Institute at King's College London.

Declarations

Competing interests

The authors declare no competing interests.

Ethical approval and consent to participate

The experiment protocol was reviewed by the Institutional Review Board of Insper (São Paulo, Brazil) and approved on June 19th, 2023. The experiment did not present health risks to the participants and did not involve deceit. Consent was sought verbally at the beginning of the interview which was then recorded as written consent into the survey tool. While reading the consent form, enumerators informed participants that the movie contained images recorded by drones, which might be uncomfortable to some viewers. No participant declined to participate after the consent form.

Additional information

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1038/s41598-024-78970-7.

Correspondence and requests for materials should be addressed to S.B. or A.F.