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Environmental policy and immersive technologies

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Abstract
The level of environmental degradation caused by human activities has risen at an alarming rate. Under pressure to motivate people towards green behavior, governments rely on financial incentives, but traditional policy instruments often encounter public opposition and do not have the desired effect. Environmental policy-makers communicating about environmental issues face a challenge: people fail to recognize environmental problems because the consequences are usually temporally or physically distant from the causes. Immersive technologies, such as virtual and augmented reality, offer an opportunity to bridge this gap by providing direct experiences of environmental threats in a safe environment. These virtual experiences could reduce perceived psychological distance, enhance risk perception of environmental issues, and motivate behavior change before environmental damage is caused. Also, by bringing the field in the lab, virtual environments provide the context to laboratory experiments needed for investigating human behavior. Given these arguments, immersive technologies point to a promising tool for environmental policy implementation and evaluation. This article presents an original survey covering experimental studies that were 1) conducted in virtual environments and 2) have explicit implications for environmental policies. Recommendations for policy-makers and future studies are suggested.

JEL Classification: C91; D91; Q51; Q55; Q58; O35

Keywords
environmental policy — pro-environmental behavior — virtual experiments — immersive technologies — behavior change

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Introduction

Our planet currently faces many environmental problems with serious consequences. The role of humans in environmental degradation is substantial, as our everyday actions have an enormous negative impact on the environment (Grooten and Almond, 2018; Masson-Delmotte et al., 2018; UN, 2015).

Behavior change needs to occur quickly, but environmental agencies, educators, and policy-makers continue to face challenges in finding ways to implement effective environmental policies and incentivize people to engage in green behavior.

Environmental communication is complicated: not only are complex scientific findings difficult to understand, but the consequences of our everyday actions are not immediately observable, and therefore, they are often perceived as psychologically distant and unlikely to happen (Fiore et al., 2009; Trope and Liberman, 2010). Governments – mostly informed by standard economic theory – often rely on financial incentives (e.g., taxes or subsidies), but this type of policy has been shown to have unwanted side effects such as motivation crowding-out or a lack of acceptance by the public (Frey and Oberholzer-Gee, 1997). Fully aware of these challenges, policy-makers struggle to find alternative cost-effective and socially acceptable ways to orientate the public towards adopting green behavior without imposing strict regulations (Official Journal of the European Union, Official Journal of the European Union).

This paper suggests the use of immersive technologies, such as virtual reality (VR) and augmented reality (AR), to improve the evaluation and implementation of environmental policies. Virtual environments can provide experiences of possible future events, distant places, or detrimental side effects of people's behavior on nature. By thus simplifying and visualizing complex, abstract and psychologically distant environmental information, immersive technologies could serve as a powerful policy tool. Moreover, immersive technologies can provide context to lab experiments that investigate human behavior. Participants can virtually experience different scenarios, understand the context better and make realistic choices, but still under the full control of an experimenter. Therefore, virtual experiments offer a method to raise the external and internal validity of lab experiments (Fiore et al., 2009; Innocenti, 2017).

This survey summarizes the research findings from several experimental studies with direct implications for environmental policy and provides suggestions for researchers and policy-makers. With this paper, we want to initiate debate and

emphasize the importance of immersive technologies for environmental policy implementation and evaluation, in particular through the reduction of psychological (cognitive and social) distance as well as the enhanced perception of risk.

Immersive technologies, virtual experiments and environmental policy: Background

Controlled laboratory experiments are a widely accepted method to study economic and environmental behavior. Behavioral economics and its related ecological approach to human rationality have gained much attention concerning environmental issues (List and Price, 2016; Shogren and Taylor, 2008). However, a recent debate stressed the importance of the context in real decision-making processes, resulting in criticism of context-free lab environments, and the promotion of field experiments in the environmental domain (Harrison and List, 2004; List and Price, 2016). However, an approach using both laboratory and field experiments as complementary methods has been recommended, as it leads to higher internal and external validity of the results, and proper understanding of human behavior (Fiore et al., 2009).

Fiore et al. (2009) introduced a new experimental environment: the virtual experiment conducted in VR[1]. Virtual experiments reproduce the field in the lab, and generate the synthetic field cues necessary for more realistic decision-making in a fully controlled lab-like setting which allows testing of theories and replicability (Fiore et al., 2009). Virtual experiments can be divided into low-immersive virtual environments (LIVE) that are computer screen-based, and high-immersive virtual environments (HIVE) which require specialized equipment such as head-mounted displays (HMD), a cave automatic virtual environment (CAVE[2]), or smart AR glasses (Innocenti, 2017). Immersive technologies fall into the HIVE category. While VR completely immerses users in a synthetic world and replaces their reality, AR only enhances the real world by placing 3D digital objects in it in real time, creating the illusion that they actually exist there (Azuma, 1997).

Immersive technologies can improve not only lab experiments, but also the response to environmental policies. Personal experience of environmental issues reduces the psychological distance between an observer and an event, enhances the perception of environmental risks, and thus increases engagement (Akerlof et al., 2013; Spence et al., 2011). Since prospective perception is often challenging (complicated, costly or risky) to implement in real settings, the best alternative is to replace a real environment with a virtual one to communicate on environmental issues (Ahn et al., 2016; Bailey et al., 2015; Nelson et al., 2020). If simulations seem sufficiently real, users become immersed and virtual stimuli become dominant over their perception and cognition – they have a sense of "being there" (Fiore et al., 2009; Harrison et al., 2011)).

Due to their potential to produce a high level of immersion and presence, immersive technologies could enhance environmental communication and raise awareness of environmental issues (Ahn et al., 2016; Fauville et al., 2020). Without imposing strict regulations, policy-makers could motivate people to adopt eco-friendly behaviors by exposing them to virtual experiences of destructive future side-effects caused by today's actions. These features make immersive technology a tool with a lot of potential for improving environmental policy.

Methods

This paper provides an original survey of experimental studies in virtual environments with implications for environmental policies. Although the full potential of virtual environments can only be obtained in the high levels of immersion and presence generated by HIVE, due to a limited number of papers involving HIVE we also included experiments that were conducted in low-immersive virtual environments on a flat screen (LIVE). However, we are not interested in experiments conducted in virtual worlds[3].

The literature survey was conducted following a logical structure that allows replicability (Linnenluecke et al., 2020). The search was conducted in July 2020, through the databases Scopus and Web of Science, using the keywords "virtual reality" OR "augmented reality" OR "mixed reality" OR "immersive technologies" OR "virtual" AND "experiment" AND "environment" OR "environmental policy".

Due to the complex nature of environmental topics, we implemented an interdisciplinary approach, and gathered papers from several disciplines (such as economics, environmental science, computer science and engineering). Papers were selected based on their abstracts, and further analyzed according to these inclusion criteria: only peer-reviewed papers published in journals were included; only papers in English were included.

Virtual experiments and environmental policy: Results

We provide a general overview which displays the most important information about the surveyed papers (see Table 1). The order of the publications is based on the proximity of the study design to methodological practices of economics experiments[4]. We divided surveyed papers into three categories

[1] The term Virtual Reality (VR) here refers to any "computer-generated 3D real-time environments where users interact with the simulated environment" (Harrison et al., 2011), even on the flat screen.

[2] A CAVE is a cube-shaped room where digital content is projected on the walls.

[3] Virtual worlds are cyberspace environments such as Second Life that are dedicated to interaction with other humans represented by avatars. These environments do not offer a reliable method for investigating real-world behavior; unnatural avatar-based communication and possible users' misrepresentation of their identities in virtual worlds might lead to behavior deviations (Harrison et al., 2011; Innocenti, 2017).

[4] For experimental practices in economics, see Hertwig and Ortmann (2001).

Publication	Type of virtual experiment	Nature of the main task of the experiment [a]	Existence of a control treatment [b]	Sample size	Incentives [c]	Measures
Fiore et al., 2009	LIVE	Real	Yes	45	Monetary	policy choice; risk preferences; presence; prior experience and technology ease of use
Nelson et al., 2020	HIVE	Real	Yes	1006	Monetary	real donation; emotions
Matthews et al., 2017	LIVE	Hypothetical	Yes	1062	Monetary	hypothetical willingness to pay for erosion protection; headland development; tax increase cost emotions;
Zaalberg & Midden, 2013	LIVE	Hypothetical	No	55	Monetary	information search related to coping solutions; coping emotions and intentions; presence; instruction checks
Treuer et al., 2018	LIVE	Hypothetical	No	348	Monetary	the degree of worry about sea-level rise; willingness to move out of the region: willingness to take self-protective measures; the aspects that caused the highest source of worry; the information about the type of media that was clicked during the simulation
Fox et al., 2019	LIVE	Hypothetical	No	190	Non-monetary	psychological distance; interactivity; risk perception; environmental self-efficacy; environmental policy support; self-reported environmental behaviors
Bateman et al., 2009	LIVE	Hypothetical	No	288	-	willingness to pay land use preferences
Olschewski et al., 2012	LIVE	Hypothetical	No	129	-	willingness to pay for avalanche protection options

[a] The nature of the main task of the experiment is either real (in which participants face real monetary consequences, such as in the study by Fiore et al. (2009)), or hypothetical (in which participants only indicate their opinions and preferences, as in the study by Treuer et al. (2018))..,

[b] Control treatment refers to a group of participants that received no treatment, a baseline. For example, the study by Nelson et al. (2020) implemented a control treatment, while the study by Fox et al. (2020) did not. In policy evaluation, it is important to satisfy basic methodological requirements when dealing with experiments, i.e., randomization, measurement, and control (Jacquemet and L'Haridon (2018)),

[c] Monetary incentives improve performance in judgment and decision tasks, and increase control over preferences (Jacquemet and L'Haridon (2018); Camerer and Hogarth (1999)).

Table 1. Overview of virtual experiments with implications for environmental policy

based on their topic, reviewed their experimental design and summarized the main findings.

Experiments on environmental threat prevention

Virtual environments have been used in several experiments to evaluate policies concerning environmental threat prevention. In one virtual experiment, participants had the chance to experience and view long-term consequences of their choices related to wildfire prevention policy. In addition to the text that would appear in a real policy choice task – to make sure that participants obtain the information in a natural manner – the treatments differed in the information stimuli: one group of participants were given a standard Contingent Valuation Method questionnaire, where the wildfire scenarios were described with text and pictures; the other group was exposed to an interactive and vivid VR experience. After seeing scenarios that differ in prevention strategy, participants had to choose between policies and face the real monetary consequences of their choices. Results indicated that virtual experiments, compared with traditional survey instruments, reflect subjective beliefs closer to actual risks (Fiore et al., 2009).

Similar to the threat of fires, some cities and countries face flood risks due to their geographical characteristics. Choosing an effective strategy for coping could reduce material and health losses. The objective of one experiment was to investigate how virtual environments can enhance participants' risk perception of floods and their coping responses. Treatment manipulations varied in the level of immersion in a virtual environment; participants experienced either 3D interactive or 2D non-interactive flood simulations. Those in the former condition were more motivated to search for evacuation strategies and buy flood insurance (Zaalberg and Midden, 2013).

In another experiment, participants were exposed to an immersive computer simulation that provided a realistic experience of a future sea-level rise, with the goal of accelerating the consequences and reducing the temporal distance of such an event. During the simulation, the effect of social norms, rate of sea-level rise, and framing were manipulated. After the experience, more than 75% of the participants supported paying higher taxes for climate adaptation. Participants commented that the simulation experience was eye-opening (Treuer et al., 2018)).

From water and fire to ice: in many mountainous areas, forests provide natural protection from avalanches. However, there is little information about their estimated economic value. A group of scientists conducted a choice experiment determining which attributes influence willingness to pay for the avalanche protection of forests. Realistic GIS-based 3D visualizations in VR of the protection forest and avalanche danger zones helped participants to state their preferences (Olschewski et al., 2012).

Experiments on land use

The potential of virtual environments was also recognized in choice experiments eliciting land-use preferences. The purpose of these studies was to examine whether virtual envi-

ronments could reduce choice errors and anomalies in stated preference surveys. In one experiment related to coastal development preferences, participants were divided into two groups: one group was exposed to static images of a virtual beach in which the landscape changed due to an increased building footprint, headland, or dune, while the other was exposed to the same scenario in a 3D computer-generated virtual environment. The researchers wanted to investigate how different presentations of the landscape could impact the evaluability of alternatives, that is, how easy it is for participants to evaluate them. They found out that virtual environments, in comparison with static images, reduced choice error and left-right bias and improved respondents' engagement and retention (Matthews et al., 2017).

In another study, participants had to evaluate various alternative land-use scenarios. A split-sample experiment was used to investigate the evaluability of different presentations of the identical information by comparing a numerical presentation with a virtual reality presentation and a combination of both. Participants had to state their preferences regarding different land-use scenarios by estimating their willingness to pay (WTP) for gains and willingness to accept (WTA) the corresponding losses. Choice experiments that integrated VR visualizations reduced the variability of preferences and the asymmetry between WTP and WTA (Bateman et al. (2009).

Experiments on environmental conservation

A few experiments investigated the impact of virtual experiences on environmental conservation behavior. One experiment included a serious game, with the intention to educate and persuade users to perform a specific behavior. In the game, participants were involved in an environmental clean-up action of a virtual river. Psychological distance was manipulated across 4 different treatments[5]. One day after the experiment, participants did the online post-test, which indicated that virtual simulations offer a powerful method for encouraging environmental behavior. On the one hand, reduced psychological distance increased their perception of risk, while on the other hand interactivity lead to greater self-efficacy. Consequently, these two conditions increased pro-environmental behavior and environmental policy support (Fox et al., 2020).

Water pollution is not only a problem for humans: coral reefs, like many other marine species, are under threat of extinction. A group of scientists investigated whether virtual reality can increase empathy and motivate pro-environmental behavior (donation to a marine conservation charity). In a field experiment, participants were exposed to a short immersive film about coral reefs. Experimental treatments varied in the level of immersion (low vs. high) and message framing (positive vs. negative). Following the treatment, participants completed a questionnaire in which, besides emotions, real financial decisions were measured: participants were incentivized by a ten percent chance of winning 100,000 Indonesian Rupiah[6] in a lottery and were asked how much would they donate to the marine conservation charity in case of a victory. The study results revealed that using VR as a communication tool is more effective for increasing donations than textual proposals (Nelson et al., 2020).

[5]In the treatments, the polluted river was presented as close or distant in space and time. Also, interactivity was manipulated across treatments: either participants' actions impacted the environment, or it automatically changed.

From experiments to policy evaluation and implementation: Discussion

Policy evaluation

Increased realism of stated preference experiments

To make valuations of the environment and other non-market goods, researchers often rely on stated preference techniques, such as contingent valuations and choice experiments. These experiments usually consist of numerical and textual data presentation which might be difficult to interpret, and without a proper understanding of the content, its poor evaluability might lead to judgment errors (Matthews et al., 2017).

Addressing this criticism of choice experiments, a Virtual Reality Choice Experiment (VRCE) has been proposed as a new valuation methodology with enhanced visual presentation of the content (Bateman et al., 2009). The main benefit of virtual experiments is to provide the context with realistic field cues, in contrast to the artefactual cues (textual and pictorial descriptions) that are usually used in environmental valuations (Fiore et al., 2009).

Virtual experiments allow researchers to test realistic policy scenarios (Bateman et al., 2009) and therefore can serve as a useful method in environmental and resource economics (Fiore et al., 2009; Matthews et al., 2017). Compared to static images or numerical treatments, experimental treatments in virtual environments resulted in lower choice error variance and left-right bias (Matthews et al., 2017), subjective beliefs that are closer to actual risks (Fiore et al., 2009), lower judgment errors, decreased variability of preferences, and reduced asymmetry between WTP and WTA (Bateman et al., 2009).

Challenges of virtual experiments

Despite the methodological benefits for studying economic and environmental behavior, researchers should be aware that virtual experiments have certain limitations. Firstly, a different level of familiarity with the technology and the increased cognitive load can limit the user's capacity to process the information (Nelson et al., 2020). Moreover, the entertaining nature of such experiences might lead to unrealistic behavior, that is, in the simulations, participants are not making real-life decisions (Treuer et al., 2018). Considering the fact that it is impossible to physically observe participants in the virtual environment, we recommend using AR instead of VR.

Another important element is the nature of the main task. Although virtual experiments are proven to reduce the asymmetry between WTP and WTA, it does not necessarily solve

[6]Exchange rate at the date of conducting the study 1USD = 13762.24 IDR or 1EUR = 16902.1 IDR (Nelson et al., 2020).

the issue of the disparity between hypothetical and actual stated values that has been well documented in many experimental studies (Murphy et al., 2005; Neill et al., 1994). To avoid the hypothetical bias, we recommend including the real effort task in the experimental design that would elicit real economic decisions, rather than intentions. For example, the experimental procedure could be divided into two sessions: virtual environments could serve as a stimulus, after which participants would be asked to make real financial decisions (Nelson et al., 2020).

Policy implementation

Enhanced environmental and risk communication

Unlike traditional persuasive attempts that use text or pictures to inform individuals about environmental risks, virtual environments offer simulated experiences of environmental threats. Such experiences can reduce psychological distance, enhance risk perception, motivate pro-environmental behavior, and increase support for environmental policies (Fox et al., 2020). Realistic scenarios of future negative environmental events can raise concern and facilitate understanding, helping participants overcome psychological barriers to proactive action and support for environmental policies (Treuer et al., 2018). For example, compared to the film and slide simulation, exposure to interactive 3D flood experiences resulted in increased searching for information about evacuation strategies, higher motivation to evacuate, and higher intention to buy flood insurance (Zaalberg and Midden, 2013).

Therefore, virtual experiences are suitable for risk communication, and it is recommended to use them to enhance people's engagement with environmental issues (Olschewski et al., 2012; Treuer et al., 2018). However, "one-size-fits-all" rarely works; the messages and frames should be tailored to an organization and target audience (Nelson et al., 2020). Also, an event that an individual virtually experiences should not be too threatening, otherwise it could result in dismissing the threat (Fox et al., 2020).

Presence and coherence - necessary elements of virtual experiences

Besides negative emotions, the sensation of "being there" plays an important role in environmental and risk communication. Presence is considered as an additional psychological element that affects coping behavior (Zaalberg and Midden, 2013) and motivates environmental conservation (Nelson et al., 2020). If presence is achieved, the sensory inputs generated in the virtual environment become dominant and participants can directly experience any scenario in as if it were really happening to them. Obviously, technology matters: HIVE can produce a higher level of immersion than flat computer screens; the latter needs additional effort to produce the feeling of presence (Fiore et al., 2009).

It is important to note that virtual experiences should be physically and scientifically coherent, and navigation in the virtual environment should be realistic, smooth, and natural. If the simulation is not scientifically consistent or does not seem realistic to the observer, a scenario rejection can occur (Fiore et al., 2009). For these reasons consultations with experts are sometimes necessary (Olschewski et al., 2012).

Mobile AR as a powerful policy tool

One immersive technology in particular has the potential to become a powerful policy tool, namely mobile AR. Let's take, for example, the rapidly growing global threat of plastic pollution. Immersive AR experiences can be used as realistic graphic warning of the serious risk of environmental pollution. Visuals can consist of the most endangered animals, such as a sea turtle or a sea bird, entangled in plastic trash. Such a scenario might inform people of the consequences of their today's choices, which may cause higher empathy, concern, and motivation to act responsibly in the future.

The fact that AR has become widespread on social networks opens new avenues for positive influence at an individual and societal level. Not only can people experience it, but they can also easily share it with their friends and family. This embraces the power of social norms, a powerful lever to influence behavior. Moreover, by publicly publishing a pro-environmental message, in other words by making a precommitment to a certain goal, users might become more likely to engage in a certain action (Sunstein, 2014). Although this concept has not yet been empirically tested, we believe researchers from different domains will notice AR's potential and investigate it.

Conclusion

Governments and policy-makers struggle to find effective ways to motivate eco-friendly behaviors and reduce the negative impact of human actions on the environment. Monetary incentives are not well accepted by the public, and voluntary behavior change is difficult to achieve. In this paper, immersive technologies are proposed as a tool for improving environmental policy. We surveyed several experimental studies that used virtual environments with implications for environmental policy, and concluded that immersive virtual experiences can aid policy implementation and evaluation. Because they have the potential to provide realistic scenarios and create a sense of presence, immersive technologies could improve environmental and risk communication, bring environmental issues psychologically closer, and influence the emotional and cognitive perceptions of users. Also, virtual environments offer the context and field cues necessary for testing realistic decision-making, and therefore raise the external and internal validity of lab experiments. One immersive technology might especially enhance environmental policies in the near future: mobile AR. Now accessible to every smartphone user, its recent wide adoption on social networks offers new possibilities for motivating collective action. Although a technology in its infancy, we believe that its potential will be recognized for persuading citizens and stakeholders to engage in green practices. With this paper, we aim to initiate debate

and trigger curiosity among researchers, policy-makers and communication experts, by providing an overview of virtual experiments with implications for environmental policy.

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