



The Potential of Augmented Reality for Tackling Environmental Sustainability Challenges: An Approach Combining Design Science and Behavioral Science

Barbara Buljat Raymond

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THÈSE DE DOCTORAT

Le potentiel de la réalité augmentée pour
aborder les questions environnementales : une
approche combinant Design Science et sciences
du comportement

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du grade de docteur en Sciences de gestion
d'Université Côte d'Azur**

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Résumé

Notre société est confrontée à une crise globale de la pollution environnementale. Huit millions de tonnes de plastique sont déversées chaque année dans les océans principalement du fait de l'activité humaine - surconsommation, culture du jetable et tri insuffisant des déchets. Comme beaucoup d'autres phénomènes environnementaux, le problème de la pollution plastique n'est pas tangible et est souvent perçu comme lointain et peu digne d'intérêt, ce qui rend les outils de communication traditionnels inefficaces pour susciter les changements de comportement néanmoins indispensables.

Cependant, les progrès des technologies numériques offrent des modalités de présentation de l'information de plus en plus innovantes, ouvrant ainsi de nouvelles opportunités pour encourager les comportements pro-environnementaux (PEB). Par exemple, la réalité augmentée (RA), qui superpose en temps réel des objets numériques tridimensionnels à un environnement réel, pourrait être utilisée pour simuler de manière dynamique des expériences directes avec les menaces environnementales. Si certaines campagnes de communication ont commencé à reconnaître le potentiel de la RA, la recherche scientifique dans ce domaine n'en est encore qu'à ses débuts. Mon objectif est de combler cette lacune et d'étudier le potentiel de la RA pour susciter des PEB.

Cette thèse vise à répondre à deux questions de recherche : (1) Comment concevoir, évaluer et mettre en œuvre en pratique un artefact « vert » de RA pour encourager le PEB ? (2) L'artefact « vert » de RA est-il susceptible de réduire la distance psychologique et d'inciter les individus à adopter un PEB ? Pour répondre à ces questions, nous mobilisons une double perspective théorique : la Design Science pour concevoir un prototype d'artefact qui utilise la RA pour illustrer les conséquences de la pollution plastique sur la faune marine ainsi que les sciences du comportement pour tester son efficacité.

Au niveau méthodologique, nous avons recours à une « approche mixte » - une combinaison de techniques qualitatives (groupes de discussion et entretiens) et quantitatives (expériences) – afin d'enrichir la littérature sur les systèmes d'information « verts ». Nous avons en particulier produit des résultats sur l'efficacité de la RA dans la promotion de PEB, défini des principes de conception pour des artefacts « verts » basés sur la RA, suggéré des prolongements possibles de notre recherche, et proposé des lignes directrices pour la mise en œuvre effective de tels artefacts.

Les résultats suggèrent que les simulations de problèmes environnementaux via la RA ont le potentiel d'améliorer la communication environnementale, mais seulement sous certaines conditions. Plus précisément, l'efficacité des artefacts « verts » fondés sur la RA peut dépendre : (1) de la fidélité visuelle et du contenu de l'expérience de RA, (2) de la nature interactive de l'artefact, (3) des interactions sociales qui peuvent résulter de l'utilisation de l'artefact, (4) des caractéristiques personnelles des utilisateurs et enfin (5) des barrières contextuelles potentielles qui peuvent décourager les individus. En résumé, les résultats soulignent la nécessité d'interventions pro-environnementales personnalisées qui tiennent compte de l'hétérogénéité du public ciblé.

Cette thèse fournit une contribution théorique et pratique. D'une part, elle informe les chercheurs, en particulier la communauté académique sur les systèmes d'information « verts », s'agissant de l'efficacité et de la conception d'artefacts écologiques fondés sur la RA. D'autre part, elle aide les acteurs de la communication pro-environnementale, tels que les décideurs politiques, les organisations à but non lucratif ou les autres parties prenantes, afin de mieux promouvoir les PEB. Les leçons tirées de ce projet pourraient également nourrir le dialogue avec les concepteurs d'artefacts ayant un objectif similaire (par exemple, en alertant sur le risque d'effets pervers futurs invisibles).

Mots clés: comportement pro-environnemental (PEB), communication environnementale, réalité augmentée (RA), Design Science, science du comportement.

The Potential of Augmented Reality for Tackling Environmental Sustainability Challenges: An Approach Combining Design Science and Behavioral Science

Abstract

Our society is facing a global environmental pollution crisis. Eight million tons of plastic are thrown into the sea each year, and human activities on land – excessive consumption, throwaway culture, and improper waste disposal - are the biggest contributors to it. As with many other environmental problems, plastic pollution is often ‘out of our sight’ and therefore perceived as an irrelevant and distant issue, which makes traditional communication tools ineffective in bringing about much-needed behavioral changes.

However, ongoing advances in digital technologies offer innovative ways to present information that open up new opportunities to promote pro-environmental behavior (PEB). For example, augmented reality (AR), a system that superimposes three-dimensional digital objects on the real world in real time, could be used to vividly simulate direct experiences with environmental threats. Recently, environmental communicators have begun to use AR to enhance their communication efforts, but scientific research in this area is still in its infancy. My objective is to address this gap and investigate the potential of AR in promoting individuals’ PEB.

More specifically, this thesis seeks to answer two research questions: (1) *How can a green AR artifact for promoting pro-environmental behavior be designed, evaluated, and implemented in practice?* (2) *Is the green AR artifact able to reduce psychological distance and motivate individuals to adopt pro-environmental behavior?* We used Design Science to design an artifact that illustrates the consequences of plastic pollution on marine fauna through AR experiences, and then ‘borrowed’ methods from Behavioral Science to test the artifact’s utility. The mixed-methods approach – a combination of qualitative (focus groups and interviews) and quantitative (experiment) techniques – generated new Green Information Systems (Green IS) knowledge: we provided evidence of effectiveness of AR in promoting PEB, defined design principles for

green AR artifacts, suggested possible ideas for project extension, and proposed guidelines for effective implementation of such artifacts in practice.

The results suggest that AR simulations of environmental issues have the potential to enhance environmental communication, but only under certain conditions. More precisely, the effectiveness of green AR artifacts may depend on: (1) the visual fidelity and content of AR experiences, (2) the interactive nature of the artifact, (3) the social interactions that may result from using the artifact, (4) personal characteristics of users, and finally (5) potential contextual barriers that may distract individuals in adopting PEB. In summary, the results point to the need for personalized pro-environmental interventions that take into account the heterogeneity of target audience.

This thesis has contributions at both theoretical and practical levels. On the one hand, it informs researchers, particularly the Green IS community, about efficacy and design of green AR artifacts. On the other hand, it helps practitioners in the field of environmental communication, such as policymakers, nonprofit organizations, and other stakeholders, in their efforts to promote PEB. The lessons learned in this project could also be used for designing artifacts with a similar purpose (e.g., for enhancing risk perception of future negative outcomes that are ‘out of sight’).

Keywords: pro-environmental behavior (PEB), environmental communication, augmented reality (AR), Design Science, Behavioral Science.

Preface

I was lucky enough to grow up by the sea. And not just any sea, but the Adriatic sea, on the coast of Croatia - a small Mediterranean country known for its natural beauty (and football). I spent my summers underwater, playing with seahorses and looking for shiny abalone shells. However, diving no longer gives me the same pleasure. These days, instead of playful sea creatures, I often come across plastic straws, cigarette butts and disposable food packaging.

Every year thousands of marine animals suffer and die because they swallow or get entangled in plastic. Unfortunately, this is happening because of human activities on earth, and the time has come to rethink our everyday behavior. Plastic pollution has become a major environmental problem on a global scale, and empirical evidence warns us that the situation is getting out of control. I was motivated to tackle this problem, which led me to apply for a Ph.D. project.

My employment as a teaching assistant at the Faculty of Economics and Business Rijeka offered me the unique opportunity to find a doctoral study of my choice in Europe. For numerous reasons, I chose France, a country to whose culture I have always felt very attached. I knew that the academics at Université Côte d'Azur, the renowned university on the Mediterranean coast, would understand me, because we certainly have one thing in common: a love of the sea. And I was right. I was warmly welcomed by prof. Agnès Festré, prof. Lise Arena, and prof. Srdjan Redzepagic, who offered me support I needed for this journey. I am very grateful for that.

That's how it started. Then, I realized that motivating individuals to adopt pro-environmental behaviors is more complicated than I thought, and here is why: sometimes we are aware of a problem, but if the problem is out of our sight, we perceive it as psychologically distant and irrelevant. This is often the case with environmental issues, because the consequences of our everyday actions are not immediately visible in the environment. Therefore, we need to find a way to bring environmental issues *into everyone's backyard*.

Recently, thanks mainly to social media, augmented reality (AR) has become very popular, easy to use and affordable. This motivated my research team and me to investigate how to design AR experiences through which people can 'live' the consequences of environmental issues, and whether they could motivate individuals to adopt pro-environmental behavior by bringing these *out-of-sight* problems *psychologically closer*.

The work presented here could be useful to both industry and academic audiences. On the one hand, improvements in environmental communication may provide new opportunities for policymakers as well as environmental communicators trying to persuade people to adopt sustainable behaviors. On the other hand, studies on Green Information Systems (i.e. technological solutions for addressing environmental sustainability challenges) are still lacking in academic literature, and this study fills this gap.

I modestly hope that this thesis will inspire others besides academics and professionals to consider their role in tackling this important global issue. Every tiny step is important, and if we join together, these tiny steps could lead to a global movement for a better future.

Barbara Buljat Raymond,

Nice, June 16th 2023

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GENERAL INTRODUCTION

At the very beginning of this PhD thesis, I introduce readers to the primary motivation for this project: addressing the urgent and growing global problem of plastic pollution. Similar to many other environmental crises, pollution is often not immediately apparent to those responsible for it and is therefore perceived as an irrelevant and distant issue. There is a need for an effective solution that would make such '*out of sight*' problems immediate, tangible, and personally relevant.

With the goal of finding a way to make environmental communication more compelling, in this PhD project I investigate the role of emerging technologies, namely augmented reality (AR), for promoting pro-environmental behavior. In the General Introduction, I present current facts about global environmental situation, and explain the challenges environmental communicators face. Next, I describe the possible solution and support it with current examples from academic and practical sources. I then explain how it led me to formulate two main research questions and my expectations in regards to research outcomes. Finally, I introduce the structure of the thesis and list the articles published or presented within the framework of the doctoral study.

1. Research motivation

Our planet is facing a serious environmental crisis. One of the fastest growing problems, plastic pollution, is mainly caused by the unsustainable production, overconsumption, and inadequate waste disposal of single-use plastic products. The situation worsened during the COVID-19 pandemic, due to the excessive use of personal protective equipment (United Nations Environment Programme [UNEP], 2021b). Numerous researchers, organizations, governments, royalty, and even religious leaders have joined the discussion and set out to combat this global problem (UNEP, 2021b; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2021; Francis, 2015).

Plastic is a material with many advantages - it is cheap, durable and light. For those reasons, we today we find plastic everywhere: in the clothes we wear, vehicles we drive, toys we play with, and electronics we use. In 2018 alone, 360 million tons of plastics were produced

worldwide - mostly for packaging (which accounts for 39.9% of the end-use market for plastics). This is due to the shift from reusable products to single-use products such as bottles or bags, which we use only once and then throw away (PlasticsEurope, 2019). Yet, 25% of plastic waste ends up in landfills (PlasticsEurope, 2019), and about 8 million tons of plastic are thrown into the ocean each year (Jambeck et al., 2015). If these trends continue, there will be as much plastic as fish in the world by weight by 2050 (World Economic Forum, 2016).

What contributes to this problem is the fact that less than 10% of plastics are recycled worldwide (UNEP, 2021b). The plastics typically used for manufacturing are not biodegradable, which means that traditional methods of waste disposal such as burying or burning waste are no longer efficient (Jambeck et al., 2015). Therefore, any product made from this material that ends up in nature remains there and is broken down into smaller pieces known as microplastics (UNEP, 2021b). This leads to a massive accumulation of plastic in the environment and to the alteration of the surface of our planet (Barnes et al., 2009).

Besides microplastics, which pose a direct threat to the food chain and human health when ingested by marine animals, marine debris could have many negative socioeconomic impacts (UNEP, 2021b). In addition, more than 800 species are at risk from plastic pollution (World Wildlife Fund [WWF], 2018): researchers estimate that 100% of sea turtles, 90% of seabirds, and 56% of whales have ingested plastic (Duncan et al., 2018; Wilcox et al., 2015; Baulch & Perry, 2014).

It is confirmed that human behavior and activities on the land strongly influence the quality of our environment (IPCC, 2022), and therefore, it has become urgent to implement more effective initiatives to tackle this global problem and address individuals' behaviors. In its 15 Sustainable Development Goals, the United Nations [UN] listed targets for various areas of human and environmental sustainability. One of these is ensuring sustainable consumption and production patterns, which the UN describes as key to sustaining the livelihoods of current and future generations (UN, 2020). Unfortunately, changes we are making as a society are still not enough, while people and ecosystems least able to cope are the most vulnerable (Intergovernmental Panel on Climate Change [IPCC], 2022).

The world is urgently seeking more effective ways to combat the global environmental crisis and motivate individuals to adopt sustainable behaviors, and the academic community is expected to respond (Watson et al., 2021; Elliot & Webster, 2017). One of the core areas that

need improvement is environmental communication, as current practices often fail to convince public about the seriousness of environmental issues (Siegel et al., 2018; Kollmuss & Agyeman, 2002). However, how to convince someone to change behavior *now* – when their consequences can only be felt *far in the future*? These are the challenges environmental communicators face, as discussed in the next section.

2. Challenges of promoting pro-environmental behavior

Numerous academic papers and debates aimed at finding out what motivates individuals to adopt pro-environmental behavior (hereafter: PEB¹). PEB describes any behavior undertaken with the intention to positively change the environment (Stern, 2000) and “consciously seeks to minimize the negative impact of one’s actions on the natural and built world” (Kollmuss & Agyeman, 2002, p. 240).

As is the case for many other types of behavior, there are many internal and external factors that influence PEB, for example: individual motivations (perceived costs and benefits, moral and normative concerns, including environmental concerns and social norms, and affect), context (such as physical and technical infrastructure, the availability of products), and habits (Steg & Vlek, 2009). Changing one’s behavior is certainly not easy, but promoting PEB is particularly difficult for one reason: possession of environmental knowledge and awareness does not necessarily lead to PEB (Siegel et al., 2018; Kollmuss & Agyeman, 2002).

Insights from psychology suggest that it can be difficult for people to understand environmental problems because their consequences are often not directly or immediately observable (van der Linden et al, 2015). Even when people recognize a spatially distant problem, they may feel powerless and less responsible for it because the problem is psychologically distant from them (Uzzell, 2000; van der Linden et al, 2015). The lack of immediate connection between the cause (actions that negatively affect the environment) and the effect (environmental degradation)

¹ Note that PEB could be conceptualized as a form of a prosocial behavior – a behavior performed with the intention of benefiting (human and non-human) others. Namely, one’s environmental engagement often reflects a person’s prosocial nature (Kaiser & Byrka, 2011, Otto et al., 2021).

could make the problem perceived as distant in time and unlikely to happen (Trope & Liberman, 2010; Ahn et al., 2016)

Evidence suggests that personal experience with environmental problems increases people's concern and perception about environmental risks. For example, people who have experienced flooding are likely to be more concerned about environment and believe that their behavior has an impact on climate change (Spence et al., 2011). However, it could be complicated, costly, and dangerous to use this method to raise awareness about plastic pollution, since it would mean taking people to hard-to-reach places (e.g., exotic beaches and under the sea) to observe pollution that is sometimes even barely visible (e.g., when plastic becomes microplastic). Thus, there is a need for an efficient alternative solution for communicating risk experiences, and recent advances in digital technologies promise a possible solution.

3. Augmented reality artifacts as *Green Information Systems*?

People have always been impressed by being in one reality while being present in another. The idea of teleportation has inspired artists, innovators, and storytellers to explore the possibilities of digital technology to enable such experiences (Zambetta, 2017). Immersive virtual technologies – virtual reality (VR) and augmented reality (AR) – allow users to experience this phenomenon to some degree, by providing fully or partially immersive virtual experiences. While VR requires a specific head-worn device looking like a “giant ski goggles” that completely covers the eyes of users and fully immerses them into an artificial tridimensional environment (Farshid et al., 2018, p 4), AR uses mobile devices or AR glasses to superimpose three-dimensional digital objects over the real environment in real-time (Azuma, 1997).

Nowadays, complex environmental data are still mostly presented in two-dimensional form on sheets and tables, making it difficult to understand and absorb. The three-dimensional presentation of content in AR and VR could help to facilitate the assimilation of environmental data and make learning more engaging (Markowitz et al., 2018). With the continued advancement of digital technologies, the Internet, and mobile devices, we are witnessing the rapid advancement and adoption of AR and VR technologies (Statista, 2022), which now offer new opportunities for environmental communicators.

Namely, by creating a sense of presence (Steuer, 1992), immersive technologies can simulate direct experiences with environmental threats, which are necessary to bring these issues psychologically closer and develop a sense of urgency about environmental issues (Ahn et al, 2014; van der Linden et al, 2015; Spence et al, 2011). For those who have not yet experienced environmental degradation firsthand, immersive visual simulations could serve as immediate feedback that is otherwise delayed in the case of environmental problems (we may not see the consequences of our today's actions for years or decades).

Over the past decade, academics and practitioners have initiated a debate about the ability of immersive technologies to address environmental sustainability issues. UNEP, a global leader in the field of environmental communication, recently partnered with social media influencers to run an AR campaign '100 days to beat plastic pollution', asking users to participate in short interactive educational AR games on the social media platform Instagram. This campaign is an example of how AR can be used in a social context to promote individuals' PEB (UNEP, 2019; UNEP, 2021a).

Albeit slowly, science followed, and some researchers have presented empirical evidence of how immersive technologies can affect real-world behavior. For example, experiments have been conducted to examine how the immersive experience of cutting down a tree in VR affects paper consumption (Ahn et al., 2014), how the embodiment of endangered animals affects environmental conservation (Pimentel & Kalyanaraman, 2022), and how a mobile application that provides real-time product information in AR affects consumer choice (Isley et al., 2017). However, the research field is still in its infancy and we cannot draw firm conclusions from these studies (see Sections 1 and 2 of Chapter 1 for a comprehensive review of the relevant literature).

Although examples are few, they suggest that digital artifacts based on AR and VR technology can serve as a type of Green Information System (hereafter: Green IS) - a type of information system designed to promote or facilitate green practices at the individual, organizational, industrial, societal, or governmental levels (Melville, 2010; Elliot, 2011). The term artifact refers to something that is artificial, constructed by humans (as opposed to natural constructs) (Simon 1996), and it has been adopted by Design Science researchers to describe digital constructs created by humans in an attempt to solve a real-world problem (Hevner et al., 2004).

The IS community is called upon to respond and contribute to the global fight against climate change and other environmental sustainability challenges (Elliot & Webster, 2017; Watson et al. 2021). Association for Information Systems (AIS) has formed Special Interest Group in Green IS (SIGGreen) for supporting *green* initiatives², which is persistent in offering conference tracks and journal special issues to motivate Green IS research³.

However, to our knowledge, there is little academic work on the use of emerging technologies such AR and VR for addressing environmental sustainability problems, especially in the leading IS literature (see Section 1 in Chapter 1). The goal of this thesis is to fill this gap and to contribute to the research on Green IS, by empirically evaluating the utility of AR technology for promoting PEB, but also by defining design guidelines for building green, behavior-changing AR-based artifacts.

4. Research questions and objectives of the thesis

Studying the main research problem and having an idea of a possible solution guided the development of a research questions and objectives of this PhD thesis. Motivated by the urgent call for contributions to the field of Green IS (Watson et al. 2021; Elliot & Webster, 2017) and in line with the objectives of the AIS Sustainability Task Force to tackle the challenges associated with the UN Sustainable Development Goals (Watson et al. 2021), the main **objectives (O)** of this thesis are:

- *O1: to specify design principles for a green AR artifact;*
- *O2: to test the impact of a green AR artifact on individuals' pro-environmental behavior;*
- *O3: to define guidelines for the implementation of a green AR artifact in practice.*

² For more information on SIGGreen, see <https://communities.aisnet.org/siggreen/about-sig-green/new-item3>

³ For SIGGreen Tracks & Special Issues, see <https://communities.aisnet.org/siggreen/trackssi>

In line with the research objectives, this thesis aims to address two specific exploratory and confirmatory **research questions (RQ)**:

- **RQ1 (exploratory):** *How can a green AR artifact for promoting pro-environmental behavior be designed, evaluated, and implemented in practice?*
- **RQ2 (confirmatory):** *Is the green AR artifact able to reduce psychological distance and motivate individuals to adopt pro-environmental behavior?*

To address these research questions, we adopted mixed methods approach, combining Design Science and Behavioral Science methods and techniques. The most significant value of the mixed methods approach is the ability to address confirmatory and exploratory research questions simultaneously (Teddlie & Tashakkori, 2009). The summary of research activities and their knowledge outcomes are presented in Table 1.

RQ	Focus	Methods	Objective (O)	Knowledge outcomes
RQ 1	Design, Implementation	Qualitative (focus groups, interviews)	O1 (to specify design principles for a green AR artifact); O3 (to define guidelines for the implementation of a green AR artifact in practice)	- Design principles about user activity and an artifact (Gregor et al., 2020) - Knowledge about the impact of AR as a Green IS (Melville, 2010) - Grounded theory model (Glaser & Strauss, 1967)
RQ 2	Impact	Quantitative (laboratory and lab-in-the-field experiment)	O2 (to test the impact of a green AR artifact on individuals' pro-environmental behavior)	

Table 1. Summary of research activities and their knowledge outcomes

Given the research objectives, this research project relies on two interdependent yet complementary research approaches: Design Science and Behavioral Science (Hevner & Chatterjee, 2010), explained in detail in the Sections 1 and 2 of Chapter 2. Design Science – a problem-solving approach intended to produce an artifact to solve a real-world problem (Hevner et al., 2004; Gregor & Hevner, 2013) – was used to address the first, exploratory

research question (RQ1) and to design a green AR artifact. More specifically, to find out how green AR artifact for promoting pro-environmental behavior can be designed, evaluated, and put into practice, we first defined the theoretical background and justificatory knowledge that will lead the artifact's design (Chapter 1) and then conducted qualitative, exploratory empirical studies with different types of users (Chapter 3). Note, however, that we do not aim to design, develop or test the *final* product (instantiation). Instead, we are rather focused on evaluating the *concept* of introducing AR to environmental communication.

Then, we applied Behavioral Science to answer the second, confirmatory research question (RQ2). More specifically, we tested the utility of the artifact (its impact on reducing psychological distance and promoting pro-environmental behavior) through two controlled experimental studies (Chapter 4). The mixed methods approach, namely, the combination of qualitative and quantitative methodological techniques contributed to the investigation of a phenomenon from multiple perspectives (Pascal et al., 2013; Venkatesh et al., 2013).

This thesis is at the intersection of two research fields: management of IS (design of artifacts for promoting behavior change) and experimental economics (using controlled experiments to test the utility of a designed artifact). At more peripheral level, this project is interdisciplinary since it incorporates insights from economics, management, computer science, and behavioral science. It is expected that the challenges of communicating across disciplines will be met with rigorous research design and a spirit of innovation (Hevner et al., 2004). This interdisciplinary approach is expected to result in important contributions, as explained in the next section.

5. Expected research contributions

Having established a set of research questions and objectives that guide this research project, this section provides an overview of the expected research outcomes and contributions of this PhD thesis, namely theoretical, practical, and methodological contributions.

The first expected contribution of this thesis is theoretical. Results from empirical studies should generate two types of theoretical contribution: (1) *design theory* - a prescriptive theory that gives explicit instructions and explains how to build a green AR artifact (Gregor, 2006); and (2) *theory for explaining and predicting* - a descriptive theory that implies explaining and

understanding causal relationships between the artifact and individuals' PEB (Gregor, 2006). This theory contributes to the domain of Green IS (Elliot, 2011).

The most significant expected contribution is practical, and is expected to serve stakeholders in the domain of environmental communication: e.g. policy makers, educators, communicators, and researchers. It comes in a form of a green AR artifact – an instantiation in its early conceptual phase, with the main goal to motivate individuals to adopt PEB (presented in Section 3 of Chapter 2). The artifact uses AR technology to simulate direct experiences with an environmental issue (plastic pollution), that are, according to research, an effective precedent of PEB (direct experiences increase people's concern, awareness, and motivation to act (Spence et al., 2011)). In more general terms, the artifact developed in this thesis aims at communicating future risks that are usually *out of sight*. Another expected practical contribution of the study is the project extension ideas and implementation guidelines needed to create final product. Based on the empirical studies with different users (see Chapter 3 and Chapter 4 for empirical studies), we expect to be able to define several possible instantiations of the final version of the artifact.

This thesis also makes a methodological contribution, as it provides guidelines and concrete examples for evaluating AR artifacts in their early conceptual stages (e.g., Chapter 3 and Chapter 4). Unlike traditional media such as photography or video that are consumed by viewing, AR is consumed by experiencing. Therefore, this thesis includes a number of challenges that may arise during the evaluation of AR artifacts (for example, how to demonstrate an AR artifact in its conceptual phase) and practical advices on how to overcome them (for example, how to use opensource software tools to build simple AR prototypes).

In summary, this thesis explores the potential of the green AR artifact in addressing an important real-world problem: the plastic pollution crisis and the challenges of communicating distant environmental issues to promote pro-environmental behavior. More generally, the insights gained in this work are intended to inform environmental communication practitioners and educators, as well as IS community and other researchers, about the potential of digital artifacts in raising awareness and changing behavior about issues that are distant in time or space. The following table (Table 2) shows the outcomes of the studies conducted as part of this doctoral project.

Study	Section / Chapter	Author(s)	Outcomes
<i>Immersive technology at the service of environmental sustainability: Survey in the leading Information Systems literature</i>	Chapter 1 Section 1	Barbara Buljat Raymond	<ul style="list-style-type: none"> Presented at Conférence AIM - Association Information et Management 2021 (Nice, France / online) Presented at the 1st GREDEG PhD Workshop 2020 (Sophia Antipolis, France / online)
<i>Immersive virtual experiences affecting drivers of pro-environmental behavior: A systematic literature review</i>	Chapter 1 Section 2	Barbara Buljat Raymond	<ul style="list-style-type: none"> Published in Journal of Behavioral Economics for Policy (JBEP), 2022 Presented at International Conference on Information Systems (ICIS) 2022, Pre-ICIS French AIM Workshop (Copenhagen, Denmark)
<i>Artifact description</i>	Chapter 2 Section 3	Barbara Buljat Raymond	<ul style="list-style-type: none"> Conditionally accepted at the European Conference on Information Systems (ECIS) 2023 (Kristiansand, Norway) (V2 submitted in 2023) Presented at AIM PRE-ECIS2023 Paper Development Workshop, 2022 (online)
<i>Gathering early opinions on the use of augmented reality in environmental communication: Pilot focus group with end users</i>	Chapter 3 Section 1	Barbara Buljat Raymond (Daniel Pimentel, Kay Vasey)	<ul style="list-style-type: none"> Published in Croatian journal Ekonomski pregled (eng. Economic review), 2023 Presented at the conference IEEE VR 2023 (Shanghai, China / online) (a poster co-authored with Daniel Pimentel and Kay Vasey).
<i>Augmented reality for promoting pro-environmental behavior: Evaluation through a qualitative study with end users</i>	Chapter 3 Section 2	Barbara Buljat Raymond	<ul style="list-style-type: none"> Presented at European Conference on Information Systems (ECIS) 2022 (Timisoara, Romania) Presented at the 2nd GREDEG PhD Workshop 2022 (Sophia Antipolis, France / online)
<i>Augmented reality for environmental communication: Evaluating the artifact with professionals from the domain of environmental communication</i>	Chapter 3 Section 3	Barbara Buljat Raymond & Lise Arena	<ul style="list-style-type: none"> Conditionally accepted to the journal Communication of the Association for Information Systems (CAIS) (Major revisions, V2 submitted in 2023) Presented at the International Conference on Information Systems (ICIS) 2022, Pre-ICIS SIGGreen Workshop (Copenhagen, Denmark)
<i>Augmented reality for environmental fundraising: Two experimental studies</i>	Chapter 4 Section 1	Giuseppe Attanasi, Barbara Buljat Raymond, Agnès Festré, & Andrea Guido	<ul style="list-style-type: none"> Submitted to the Journal of Environmental Economics and Management (JEEM) (V1 submitted in 2023) Presented at workshop BLUE-INNOV “Entrepreneurial Ecosystem, Blue Economy, And Sustainable Innovation” 2022 (Cannes, France) Presented at International Conference of the French Association of Experimental Economic (ASFEE) 2022 (Lyon, France) Presented at Conference of the International Association for Research in Economic Psychology (IAREP) 2022 (Kristiansand, Norway)

Table 2. List of studies and their outcomes

6. Thesis structure

This thesis is organized as follows (see Figure 1). The main empirical and theoretical contents are divided into two main parts. Part 1 presents problem awareness, methodology, and design principles. Part 2 consists of two design cycles: scenarios of use and experimentation – the results of exploratory and confirmatory empirical studies conducted with the aim of evaluating the artifact with different types of users.

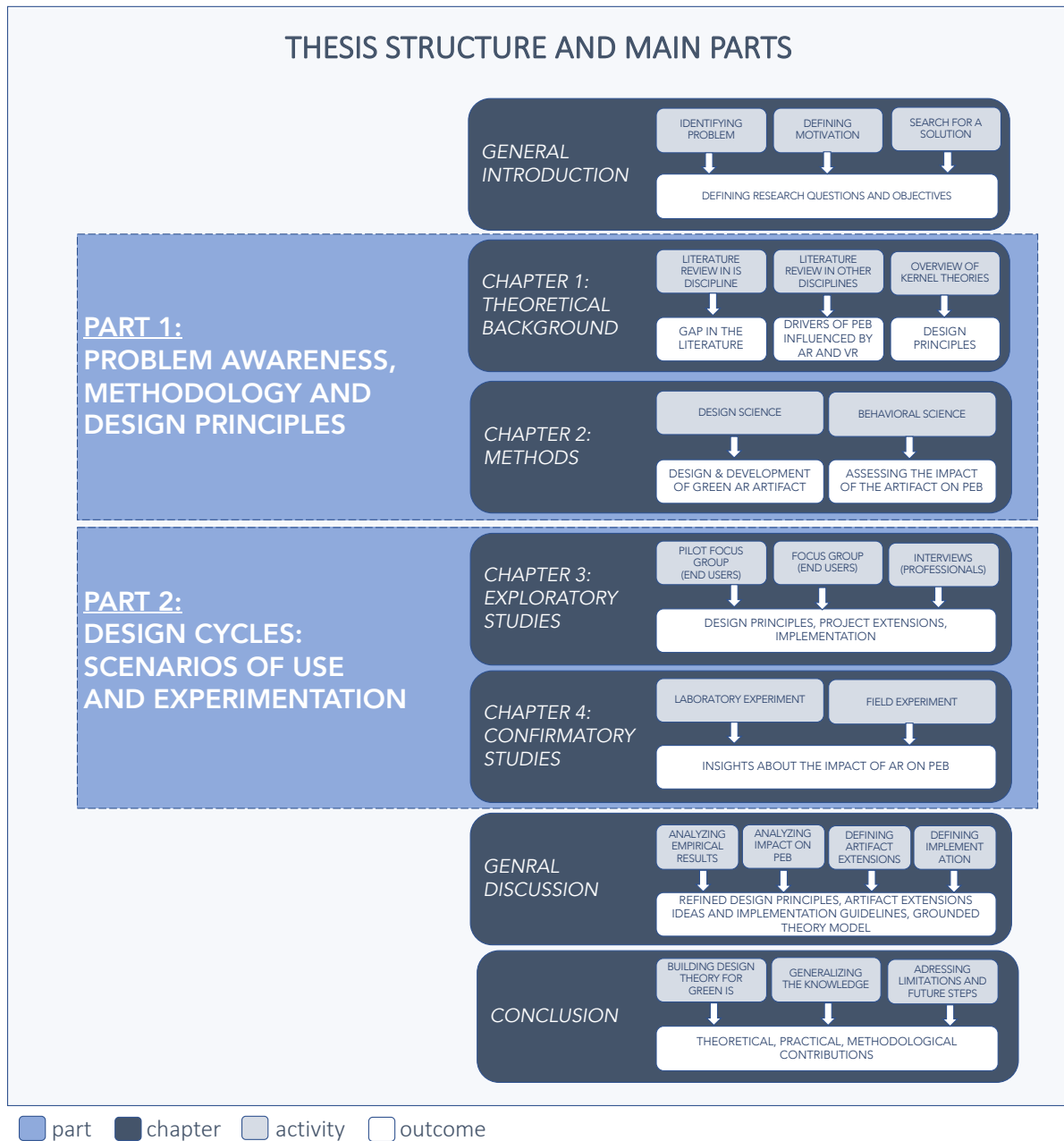


Figure 1. Thesis structure

Chapter 1 - Theoretical Background - contains an extensive review of relevant literature aimed at assessing the state of the art and strengthening the researcher's theoretical understanding of the phenomena of interest. The chapter begins with the literature review of the leading academic IS knowledge base - AIS (Association of Information Systems) basket of 8 leading IS journals. Due to the lack of relevant publications, the literature review is then extended to other academic disciplines. The chapter is then narrowed down to kernel theories - the justificatory knowledge on which the artifact was designed and built.

Chapter 2 - Methodology - presents the general methodological approach for this doctoral project. The project is based on the DSR approach (Gregor & Hevner, 2013), especially in the processes of designing the artifact. However, the use of methods from Behavioral Science allowed for testing the utility and effectiveness of the artifact. In this chapter, we explain in detail the rationale for the methodological approach, present the general research design, and then explain each step in more detail. We also introduce and demonstrate the artifact: the design and development process of the artifact is followed by a demonstration of its features, functions, and potential use in the field.

Chapter 3 - Exploratory Studies - and Chapter 4 - Confirmatory Studies - present empirical studies conducted with the goal of evaluating the artifact with different types of users (end users and professional users). The studies are presented chronologically, and the results of each study informed the design of the artifact in the next evaluation cycle. The evaluation consisted of qualitative and quantitative studies. These studies were very informative for exploratory and confirmatory investigation of the design requirements and utility of the artifact.

In General Discussion, we review the main findings of the empirical studies, explain their relevance, and discuss the implications of the study for theory and practice. Here, the findings from the empirical studies were used to refine the initial design principles of the artifact and to stimulate further ideas for extending the project. We also highlight the limitations of the study and provide recommendations for overcoming them in the future.

Finally, the General Conclusion contains a summary of the results, the main theoretical and practical contributions, and the most important *take-home messages*.

PART ONE:

**PROBLEM AWARENESS,
METHODOLOGY AND
DESIGN PRINCIPLES**

CHAPTER ONE:

THEORETICAL BACKGROUND

This chapter presents the theoretical background of the thesis. It consists of two extensive literature reviews, and justificatory knowledge (kernel theories) that served as the theoretical basis for the design of the artifact.

In the first section, I examined the main literature in the field of Information Systems (IS), namely the Association for Information Systems (AIS) basket of 8 leading IS journals. The aim of the study was to find out which are the most important IS studies dealing with immersive technologies as Green IS. More specifically, I wanted to understand the current state of the art in the domain of Green IS (Melville, 2010; Elliot, 2011) and investigate whether IS researchers have already studied the AR and VR technologies in this context. The results of this systematic literature review suggests the complete absence of studies in the leading IS literature on the role of immersive technologies for environmental sustainability.

Therefore, in the second section, I expanded the survey sample outside the IS field and found 25 relevant studies in other disciplines such as computer science and psychology. For example, these studies examined the role of VR for facilitating environmental education (Markowitz et al., 2018), the ability of VR to reduce psychological distance (Fox et al., 2019), or the effectiveness of AR in promoting pro-environmental behaviors by providing real-time product information during shopping (Isley et al., 2017). The studies were compiled, reviewed, and systematically analyzed, which allowed me to understand the ability of immersive virtual experiences to influence drivers of pro-environmental behaviors.

Finally, in the third section, I present and elaborate on the justificatory knowledge that underlies the design of the artifact – three kernel theories (Gregor & Hevner, 2013), each underpinning one aspect of the design of the artifact, namely: information, social, and technology aspect (De Leoz & Petter, 2018): Construal Level Theory (Trope & Liberman, 2010), Social Influence Theory (Kelman, 1958), and the Theory Of Persuasive Technology (Fogg, 2003).

1. Immersive technologies at the service of environmental sustainability: Survey in the leading Information Systems literature⁴

Technology plays a crucial role in shaping people's beliefs about the environment and improving eco-friendly performances (Melville, 2010). Along with researchers from various disciplines, IS scholars have the responsibility to tackle global environmental challenges. An urgent call for action has been issued several times to the IS community, to highlight the need for research on Green IS – information systems designed to minimize the negative impact on the environment and leverage green awareness among its users (Watson et al., 2021; Elliot & Webster, 2017; Gholami et al., 2016; vom Brocke et al., 2013). This study examines the leading academic literature in the field of IS – the basket of 8 leading IS journals according to the Association for Information Systems (AIS) – aiming to find out “*What are the main IS studies addressing immersive technologies as Green IS?*”. The answer to our research question relies on a meta-research (Rowe, 2014; Templier & Paré, 2015) resulting from a systematic literature review.

1.1. Related work

1.1.1. Past research on Green Information Systems

Green IS refer to “design and implementation of information systems that contribute to sustainable business processes” (Watson et al., 2008, p. 2). At the organizational level, Green IS could imply the design and implementation of information systems that support businesses in their environmentally sustainable processes, while at the individual level it provides information and aids consumers in their effort to make more sustainable choices (Watson et al., 2008).

It is true that technology could be the source of many environmental and social problems, but on the other hand, it could also be crucial for tackling climate change and related issues (UN,

⁴ This study was presented at the 1st GREDEG PhD Workshop 2020 (Sophia Antipolis, France), and at Conférence AIM - Association Information et Management 2021 (Nice, France)

2022). The interest of IS scholars for environmental sustainability has appeared over a decade ago, but despite urgency to act, the research field has been forming slowly (Watson et al., 2021; Elliot & Webster, 2017).

In 2010, Melville indicated the lack of research on Green IS, concluding the search in IS literature with one single article on environmental sustainability (Melville, 2010). One year after, the state of the art did not change much; Elliot (2011) conducted a broad transdisciplinary review of literature on environmental sustainability, concluding with only five papers listed under the IS discipline (Elliot, 2011). After two years, the Green IS knowledge was richer by 14 articles (Malhotra et al., 2013). Still, leading Green IS scholars converge in issuing an urgent call for action to the IS community (Elliot & Webster, 2017; vom Brocke et al., 2013).

In 2019, AIS took more ambitious steps in addressing global environmental sustainability challenges by establishing the AIS Sustainability Task Force (AIS STF). The primary goal of AIS STF is to improve the scope and scale of the IS community's contributions to the UN Millennium Development Goals (MDGs, 2000-2015) and UN Sustainable Development Goals (SDGs, 2016-2030) (Watson et al., 2021). In addition, AIS has established a community of IS scholars working on environmental sustainability, namely the Special Interest Group in Green IS (SIGGreen), which stimulates research in Green IS by offering relevant conference tracks and journal special issues⁵. Perhaps the constant technological advances and digitalization – for example, the rise of immersive technologies – could motivate researchers to investigate new possibilities for creating and applying Green IS solutions.

1.1.2. Immersive technologies as Green Information Systems?

The concept of experiencing one reality while living in another has always sparked curiosity among people. Today, it is easier than ever to unleash imagination in digitally created virtual environments. Immersive technologies – under the umbrella term Mixed Reality (MR) – provide experiences of a fully or partially virtual environment. While VR is completely immersive and blocks users' sight by immersing them into fully virtual and artificial

⁵ See SIGGreen tracks and special issue calls: <https://communities.aisnet.org/siggreen/trackssi>

environment, AR merges real and virtual by supplementing 3D digital objects over the real environment in real-time (Azuma, 1997).

These vivid simulations can create presence – the sense of ‘being there’ – tricking the human mind to treat such experiences as real (Steuer, 1992). For such advanced features, we witness wide applications of immersive technologies in various contexts, for example in the context of smart and sustainable cities. Technologies like AR or VR are of great potential for environmental sustainability purposes: they can benefit the environment by serving as a tool for education, monitoring, raising ecological awareness, and improving resource efficiency (Rambach et al., 2020; Bekaroo et al., 2018).

We want to go beyond existing *green* applications of immersive technologies such as smart retail or urban planning (Dacko, 2017; Jamei et al., 2017). Immersive technologies can serve as a practical and accessible policy tool for enhancing risk perception of environmental threats, by replacing real experiences of natural disasters with virtual ones. Namely, environmental communication is tricky: people often lack direct experiences of environmental crises, which in turn leads to treating environmental problems as spatially, temporally, and socially distant risk (Trope & Liberman, 2010; van der Linden et al., 2015). With the help of AR and VR, one could experience events that are difficult or even impossible to conduct in reality because they are unpredictable, unsafe, costly, or impractical (for example, exposing somebody to a natural hazard such as a wildfire or floods may be life-threatening).

Research has shown the potential of immersive technologies for rising engagement around environmental issues (Ahn et al., 2014; Chirico et al., 2021). By providing hypothetical virtual experiences of environmental degradation, these technologies can have emotional and cognitive effects on users, and consequently impact their behavior (Nelson et al., 2020). Environmental organizations have also recently used AR to engage people around environmental issues (Reuters, 2018; WWF, 2017). Because of their persuasive nature, immersive technologies could be used as a widely accessible Green IS for raising awareness of environmental issues, promoting PEB, and improving the implementation of environmental policies.

1.2. Methods

We conducted a systematic literature survey, to find out what are the main IS studies addressing immersive technologies as Green IS. The literature search was performed in November 2020 in the databases Scopus and Web of Science using keywords: (1) “Green IS” OR “environmental sustainability” OR “environment” OR “nature” OR “climate change” ;(2) “augmented reality” OR “virtual reality” OR “Mixed Reality” OR “Virtuality” OR “Immersive technologies”.

The sample of this literature review covers the Association for Information Systems (AIS) basket of top eight IS journals, as they are globally accepted as holders of the leading scientific IS knowledge (EJIS, ISJ, ISR, JAIS, JIT, JMIS, JSIS, and MISQ). We are aware that our journal selection may obtain some important articles of the trend, however, we wanted to ensure the credibility of the references.

Papers were downloaded, fully read, reviewed, and filtered based on inclusion/exclusion criteria: only peer-reviewed empirical and conceptual journal articles were included; only papers including high-immersive virtual environments were included; only papers in the English language were included; editorials were excluded. We did not find any result that matched both criteria, so we did two separate searches. We categorized papers following Elliot (2011) who proposed six categories of research on environmental sustainability (Table 3).

Category	Description
Environmental (ENV)	<i>Identifies literature that establishes the nature of environmental challenges and the potential contribution of IT to their resolution</i>
Societal (SOC)	<i>Identifies literature that addresses environmental issues specific to societies locally, nationally, and internationally at individual and collective levels</i>
Governmental (GOV)	<i>Identifies literature that determines and evaluates policies and initiatives to achieve environmentally sustainable outcomes</i>
Industrial and Alliances (IAA)	<i>Identifies literature to facilitate the implementation of business transformation for environmentally sustainable outcomes through industry and cross-industry groups and alliances</i>
Organizational (ORG)	<i>Identifies literature on determining and implementing initiatives for business transformation by business and other organizations with a strategic focus on achieving environmental sustainability</i>
Individuals and groups within organizations (IGO)	<i>Identifies literature on organizational initiatives and transformations influenced by individuals and groups within organizations with an interest in or responsibility for environmental sustainability</i>

Table 3. Major categories of the literature on environmental sustainability (adopted from Elliot, 2011)

1.3. Results and discussion

1.3.1. Green Information Systems literature

A total of 31 papers were included in this literature survey. The distribution of the papers within journals and categories is presented in the table below (Table 4).

		Categories of the literature on environmental sustainability							Total
		ENV	SOC	GOV	IAA	ORG	IGO	All categories	
Journal	EJIS					2	1		3
	ISJ	1	1	1		4			7
	ISR								0
	JAIS	1	1		1		1		4
	JIT		1						1
	JMIS					1			1
	JSIS	3	1	1		5			10
	MISQ		1			1	1	2	5
	TOTAL	5	5	2	1	13	3	2	31

Table 4. Number of papers on Green IS per journals per category of the literature on environmental sustainability

The graph below (Figure 2) shows the distribution of papers on Green IS in the leading IS journals over the past 20 years.

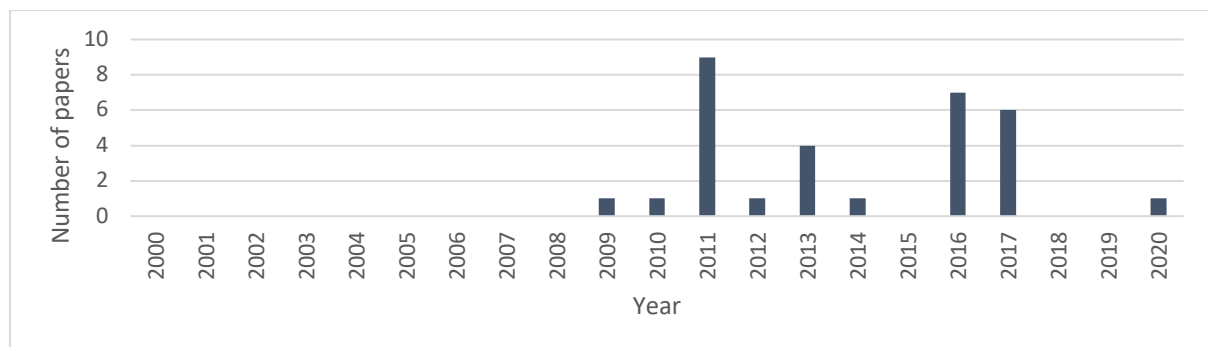


Figure 2. Trends of publishing papers on Green IS over the last 20 years in the leading IS literature

Although there is a growing number of environment-oriented papers in leading IS journals, there was no study found which proposed any type of immersive technology as IS for addressing environmental sustainability, which demonstrates that these technologies are still

emerging and their applications for societal challenges are in the early days. The overview of leading papers on Green IS, their research questions, methodology, and the category is presented in Table 5 (see Appendix 1.A for the list of references).

Reference	Research question	Methodology	Category
Elliot (2011)	What is meant by environmental sustainability? What are its major challenges? What is being done about these challenges? What needs to be done?	Conceptual (literature survey)	All
Melville (2010)	What is the research agenda on information systems innovation for environmental sustainability that demonstrates the critical role that IS can play in shaping beliefs about the environment, in enabling and transforming sustainable processes and practices in organizations, and in improving environmental and economic performance?	Conceptual (literature survey)	All
Hasan et al. (2016)	How IS researchers and practitioners can make a positive contribution to climate change adaptation by seeking to determine the potential of IS to impact, support, and transform the planning and execution of climate change adaptation activities?	Empirical (Canonical action research)	Environmental
Fridgen et al. (2016)	How can one quantify the monetary value of IS-enabled, short-term flexibility in consumer demand for electricity using real options analysis?	Conceptual (design science research)	Environmental
Zhang et al. (2011)	What is the framework to support the IT system design decision support based on the system's environmental impact?	Conceptual	Environmental
Pitt et al. (2011)	In which ways smartphones, both as green technologies and as integral parts of green information systems, are beginning to make serious contributions toward a sustainable environment?	Conceptual	Environmental
DesAutels & Berthon (2011)	What is the market price of "sustainable" notebooks?	Empirical (secondary)	Environmental
Corbett & Mellouli (2017)	How do IS support cities in their efforts to manage water quality and green space? What type of IS are needed by cities to achieve the SDGs by 2030?	Empirical (The grounded theory)	Governmental
Bengtsson & Agerfalk (2011)	How can IT serve as a change actant in sustainability innovation and what is the nature of its relation to other human and non-human actants?	Empirical (case study)	Governmental
Chan & Ma (2017)	How different CEO compensation forms influence the execution of IT-based environmental strategies	Empirical (survey and archival data)	Individuals & groups within organizations
Corbett (2013)	Do personal CMS in organizations help to promote ecologically responsible behaviors by employees? Which, if any, of the persuasive system design principles are most relevant to personal CMS deployed within organizations? How does the persuasion context of environmental sustainability influence the design of personal CMS used in organizations?	Empirical (case study)	Individuals & groups within organizations
Marett et al. (2013)	How important are personal benefits and institutional pressures for current end users when deciding to continue using sustainable information systems?	Empirical (survey)	Individuals & groups within organizations
Nishant et al. (2017)	How much do green IT announcements affect a) market value and b) share trading volume? Do shareholders react differently to different types of green IT announcements? Do shareholders view green IT announcements by innovative and non-innovative firms differently?	Empirical (event study)	Industrial & Alliances
Seidel et al. (2017)	What are appropriate design principles for IS for sensemaking (i.e., sensemaking support systems) in environmental sustainability transformations?	Empirical (design science research)	Organizational
Benitez-Amado & Walczuch (2012)	Does IT capability have a positive effect on the capability of proactive environmental strategy? Does IT capability influence firm performance by means of the capability of proactive environmental strategy?	Empirical (secondary data)	Organizational

Loeser et al. (2017)	How environmental orientation and strategy influence Green IS initiatives and whether Green IS initiatives yield organizational benefits in general?	Empirical (survey)	Organizational
Cooper & Molla (2016)	What is IS-environmental absorptive capacity? What influences IS environmental absorptive capacity? What is the value of developing IS-environmental absorptive capacity?	Empirical (case study)	Organizational
Hanelt et al. (2016)	What is the impact of supporting IS on the organizational performance of eco-innovations? What are the mechanisms through which this impact occurs? How do organizational factors influence the use of supporting IS?	Empirical (case study)	Organizational
Hedman & Henningssson (2016)	How do Green IS initiatives and organizational sustainability process influence each other?	Empirical (case study)	Organizational
Hu et al. (2016)	How firms decide whether to practice green IT, as conducted by Chen et al. in a similar setting, using finegrained analyzes and empirical testing at the organizational level?	Empirical (Survey)	Organizational
Butler (2011)	What features and functions of Green IS are required to support: (i) sense-making; (ii) decision making; and (iii) knowledge sharing/creating activities in response to signals from the institutional environment? How are the organizations studied using Green IS to support such activities?	Empirical (case study)	Organizational
Dao et al. (2011)	What is the role of IT resources and their integration with human and supply chain resources in helping firms develop sustainability capabilities that help firms deliver sustainable values and gain sustained competitive advantage?	Conceptual	Organizational
Bose & Luo (2011)	What framework can be used as a theoretical foundation for studying Green IT across different stages?	Conceptual	Organizational
Petrini & Pozzebon (2009)	How can the process of defining and monitoring socio-environmental indicators be integrated into the organizational strategy for sustainability?	Empirical (case study)	Organizational
Henfridsson & Lind (2014)	What is the process by which the micro-strategizing of actors from a variety of organizational sub-communities contribute to realize strategy contents as they use IS to implement a sustainability strategy?	Empirical (case study)	Organizational
Seidel et al. (2013)	How do information systems contribute to the implementation of sustainable work practices?	Empirical (case study)	Organizational
Tim et al. (2017)	How does the use of social media influence community-driven environmental sustainability?	Empirical (case study)	Societal
Han et al. (2020)	How do the three major actions in the knowledge reuse for innovation process affect the generativity of an innovation that addresses societal challenges?	Empirical (secondary data)	Societal
Rajão & Marcolino (2016)	How new users in developing countries use ICT to broadcast or render opaque particular self-images?	Empirical (interpretive methodology)	Societal
Watson et al. (2011)	How can four information drives (ubiquity, uniqueness, unison, and universality) be used to explain the tight coupling that is necessary between the physical and informational components of green projects to improve their usefulness?	Empirical (secondary data)	Societal
Loock et al. (2013)	To what extent goals and defaults lead to higher energy savings, implemented in the user interface of a web-based energy feedback platform?	Empirical (field experiment)	Societal

Table 5. Overview and categorization of main empirical and theoretical contributions to Green IS research in the leading IS literature

The results from this systematic literature survey confirm our initial assumption that immersive technologies have not yet been researched or applied as a Green IS in the leading IS literature. In our sample, the interest for Green IS and immersive technologies have appeared over the past decade, but only as two separate topics. However, the total of 31 papers on Green IS and

five papers on AR/VR is not an encouraging result. Considering that the AIS basket of top 8 IS journals should hold the world's leading IS knowledge, paradoxically there is a lack of research on Green IS, an absence of AR/VR applications for environmental sustainability, and only a few papers addressing environmental policy (Corbett & Mellouli, 2017; Bengtsson & Ågerfalk, 2011; Tim et al., 2017).

Environmental sustainability has become a topic of interest among IS community only in the last ten years. However, the number of papers is not growing, there are rather certain trends in publishing. Several years have marked a growing interest in Green IS research – 2011, 2016, and 2017. These trends might indicate that IS community is reactive to important ecological events, such as Paris Agreement (UNFCCC, 2015). Also, it may be that systematic literature surveys on Green IS motivated other researchers to investigate IS applications for environmental sustainability (Melville, 2010).

As seen from Table 5, most of the research on Green IS has been conducted at the organizational level. For example, these studies investigated businesses' Green IS initiatives (Hedman & Henningsson, 2016; Seidel et al., 2013), their use of Green IS to support sensemaking and decision-making activities (Seidel et al., 2018; Butler, 2011), and their sustainability strategies (Petrini & Pozzebon, 2009). Green transformations within organizations, businesses, and governments are unquestionably important; their role has been recognized as relevant in tackling environmental challenges (Elliot, 2011).

However, our sample consists of only five studies conducted at the societal level, addressing environmental issues at individual and collective levels. Individuals should not be ignored – not only do their actions have an enormous impact on the environment, but they have the power to pressure suppliers and governments in reducing their negative practices (Watson et al., 2010). Information and communication technologies can do much more than just help businesses achieve their green practices. Green IS can help individuals understand and relate to environmental issues, and their specific design can motivate them to take sustainable actions (Tim et al., 2017; Loock et al., 2013).

Undoubtedly, IS has a major role as a promotor of public awareness and engagement around environmental issues. In this study, we focus on under-researched phenomena – how IS could help individuals or groups in society in addressing environmental sustainability – and we highlight the need for more research on Green IS specific to societies locally, nationally, and

internationally at individual and collective levels (Elliot, 2011). For their ability to generate psychological mechanisms important for promoting PEBs, we suggest immersive technologies as the basis for building persuasive Green IS.

1.3.2. Immersive technologies in the leading Information Systems literature

Secondly, we present the primary studies dealing with immersive technologies in the leading IS literature. Typology of virtual environments is adopted from Innocenti (2017), who classified them according to the degree of users' immersion: (1) LIVE, low-immersive virtual environments experienced on a computer screen and (2) HIVE, high-immersive virtual environments, experienced by specialized head-mounted display (HMD) equipment or by entering a CAVE (a cube-shaped room in which the virtual content is projected onto the walls) (Innocenti, 2017). Our survey focuses on high-immersive virtual environments (HIVE), because we introduce the concept of highly immersive technologies (AR and VR) as stimulators of environmental behavior.

Table 6 presents the total of five papers addressing high immersive virtual environments (AR and/or VR) in the leading IS journals. Summary and categorization of main empirical and theoretical contributions to AR/VR (HIVE) research in IS literature are presented in the Table 7 (see Appendix 1.B for the list of references).

		Journal						
		EJIS	ISJ	ISR	JAIS	JIT	JMIS	MISQ
AR/VR	AR						1	
	VR			1	1		1	
	AR&VR						1	
	TOTAL			1	1		3	
		TOTAL						
								5

Table 6. Number of papers on AR/VR per journals per type of immersive technology

Besides HIVE, the second type of virtual environment is LIVE, which stands for low-immersive virtual environments experienced on a computer screen. Common examples are games and simulations such as the virtual world Second Life (Innocenti, 2017). Although this is not the focus of our research because immersive technologies fall into the HIVE category, we listed

them and categorized based on the topic of the paper. Most of these papers are related to virtual worlds Second Life, massively multiplayer online games (MMOG), or virtual shopping environments (see Appendix 1.C for details and references).

Reference	AR/VR	Research question	Methodology	Sample	Domain of application
Pfeiffer et al. (2020)	VR	Can eye movements be used to classify two search motives: goal-directed and exploratory search?	2 eye-tracking experiments in virtual (CAVE) and physical reality	29 participants (VR); 20 participants (physical)	Commerce
Gleasure & Feller (2016)	VR	Oculus VR's changing relationship with their backers on Kickstarter from August 2012 to April 2014	Grounded theory	2,202 comments, 53 webpages, 1,156 responses, the public profile for Oculus VR, 9,522 members profiles	VR industry
Peukert et al. (2019)	VR	How immersion influences adoption of highly immersive shopping environments?	Laboratory experiment (in highly immersive VR and low immersive computer screen)	257 participants	Commerce
Steffen et al. (2019)	AR & VR	Do users adopt virtual and augmented reality because they afford activities that are impossible or advantageous when compared to the activities afforded by physical reality?	Multimethod: Quantitative: 2 experimental surveys including hands-on experience with AR and VR / Qualitative: open-ended interview	Quantitative: 263 students + 204 participants from Amazon's Mechanical Turk / Qualitative: 18 professionals from different fields	users' acceptance / adoption of VR and AR
Biocca et al. (2007)	AR	How can an AR system successfully manage and guide visual attention to places in the environment where critical information or objects are present, even when they are not within the visual field?	Within-subjects experiment	14 students	Decision support & task completion

Table 7. Summary and categorization of main empirical and theoretical contributions to AR/VR (HIVE) research in the leading IS literature

Surprisingly, our literature search resulted in a total of only five papers dealing with HIVE among leading IS journals (Table 7), which demonstrates that knowledge of VR and AR in the IS discipline has been accumulated slowly. Four out of five papers were published in the last four years. This growing interest in immersive technologies among IS scholars could be due to the cost reduction of AR/VR equipment and its recent wide accessibility. Therefore, we expect that this trend will continue.

The dominant methodology in the papers on AR/VR in the leading IS literature is an experiment – researchers have recognized the potential immersive technologies could offer to improve laboratory experiments. However, supplementing quantitative with qualitative studies are recommended for such emerging concepts when their state of the art is still inconclusive (Venkatesh et al., 2013), as in the case of immersive technology in the context of environmental sustainability. Moreover, comparative research is suggested for the development of contextual theory in IS research (Avgerou, 2019). IS community should recognize the opportunity of this historical turn when immersive technologies have become widely accessible to the mass public, to investigate their potential in addressing societal challenges.

1.4. Filling the gap with insights from the behavioral literature

Since there is an absence of papers among leading IS literature addressing this issue, we discuss how to fill this gap by borrowing insights from other disciplines. Combining IS knowledge with Behavioral Science can improve research on environmental sustainability and provide practical solutions for incentivizing pro-environmental behaviors. In this subsection, we suggest how virtual experiences, built on behavioral insights, could serve for environmental policy evaluation and implementation.

1.4.1. Behavioral concepts integrated into virtual experiences for policy implementation

Insights from behavioral literature can improve IS research in building more efficient *behavioral information systems* (Goes, 2014), that could be used to improve public policy aiming for environmental sustainability. These insights, if integrated into virtual experiences

provided by immersive technologies, could serve as a policy tool that could boost citizens' environmental behavior and policy support. This approach could enhance environmental policy implementation for several reasons discussed below.

Virtual experiences have the potential to reduce psychological distance. By providing direct and rich sensory experiences, AR or VR might be effective in raising engagement around environmental issues that are spatially or temporally distant, such as pollution or ocean acidification (Fox et al., 2019; Ahn et al., 2016). Virtual experiences can improve the presentation of information (Steffen et al., 2019), past or future experiences can become present, and far-away places can become closer. In other words, virtual experiences might provide direct experiences needed to minimize the psychological distance (Trope & Liberman, 2010).

Presence generated through virtual experiences may influence risk perception. In addition to psychological distance, some studies reveal that presence can be manipulated through virtual experiences. The sensation of *being there* is an important psychological factor that can influence risk perception of environmental threats, such as forest fire or flood. Consequently, it can impact an individual's coping responses (Treuer et al., 2018; Zaalberg & Midden, 2013; Fiore et al., 2009). In traditional environmental campaigns, governments can supplement visual communication with immersive AR experiences, letting citizens *live* the consequences of an environmental threat through the lens of their smartphone camera.

AR campaigns could activate social norms. AR has recently been getting significant attention on social networks – digital platforms with the potential for encouraging green behavior (Malhotra et al., 2013). For its vivid and entertaining nature, AR campaigns on social networks could become viral, reducing the cost of fundraising campaigns and raising collective awareness by the means of social norms – a powerful lever that can influence behavior change (van der Linden et al., 2015). Therefore, mobile AR could serve as a powerful public policy tool for raising awareness of environmental issues and encouraging pro-environmental behavior.

1.4.2. Virtual experiences for policy evaluation in controlled settings

By *bringing the field in the lab*, immersive technologies could improve scientific research where human behavior is being investigated. Virtual environments could raise the internal validity of experiments by providing context and field cues needed for examining real decision-making (Innocenti, 2017). This is useful for policy evaluation studies, as a replacement for artifactual cues (textual and pictorial presentation) that are usually used in environmental valuations.

Virtual environments could provide citizens with realistic scenarios needed to understand and properly evaluate policy choices, lowering the choice error variance, left-right bias, and asymmetry between willingness to pay (WTP) and willingness to accept (WTA) (Olschewski et al., 2012; Matthews et al., 2017; Bateman et al., 2009). For example, governments can expose citizens to virtual simulations of environmental disaster such as forest fires, to test their willingness to pay for prevention policies (Fiore et al., 2009).

1.5. Concluding remarks

In order to find out the current state of the art, we systematically presented the leading IS knowledge dealing with immersive technologies as Green IS. Our results indicate that the field is still embryonic and emerging technologies such as AR and VR have not yet been scientifically investigated for such purposes in the leading IS literature. We proposed to fill this gap by borrowing insights from behavioral literature.

Future studies should extend the limited sample of this study with relevant papers outside of the AIS basket of 8 leading IS journals. Also, it would be interesting to investigate the early acceptance of such mode of environmental communication among end users, and to test the real impact of such immersive experiences on execution of pro-environmental behavior. This study paves the way for researchers and practitioners involved with environmental policy and encourages them to keep exploring the potential of immersive virtual experiences for encouraging individuals' sustainable practices.

2. Immersive virtual experiences affecting drivers of pro-environmental behavior: A systematic literature review⁶

While major global institutions constantly warn about the impact of human behavior on the environment (IPCC, 2021), the change we make is not sufficient. Environmental communicators often face a great challenge: first, environmental data are often too complex and abstract, and second, the change in behavior is required *now*, to contribute to something that will happen *in the future*. In this context, one type of technology may be especially useful. Thanks to its ability to provide engaging and sensory-rich virtual experiences, technologies such as augmented (AR) or virtual reality (VR) may affect users' cognitive and psychological factors and serve as a tool for promoting environmental behaviors (PEB⁷) (Fauville et al., 2020). This literature review aims at *examining the existing literature to identify key drivers of PEB that have been affected by immersive virtual experiences*. This study contributes to our understanding of the potentials (and limitations) of immersive storytelling⁸ for pro-environmental communication efforts and behavioral interventions, and can serve as a base for further design and development of digital artifacts serving this purpose.

2.1. Methods

In this systematic literature review, we gathered studies conducted in virtual environments that address human engagement with nature. The literature search followed strict guidelines and a logical procedure that ensures transparency and replicability (Linnenluecke, 2020; Templier & Paré, 2015). The search was conducted in the period February 2021 - August 2021 in the

⁶ This study was presented at the International Conference on Information Systems (ICIS) 2022, Pre-ICIS French AIM Workshop (Copenhagen, Denmark), and is published in the Journal of Behavioral Economics for Policy (JBEP).

⁷ We will use the term pro-environmental behavior (PEB) to describe any conscious behavior that intends to lower one's negative impact on the environment. For example, PEBs include lowering resource and energy consumption, reducing waste production, buying sustainable, local and organic products, or bringing reusable bags to the supermarket (Kollmuss & Agyeman, 2002; Schaeffer et al., 2018).

⁸ Immersive storytelling refers to a narration technique using immersive technologies (AR and VR) to provide sensory-rich experience in which users feel the sense of presence in a computer-generated environment. See example: Thomas et al., 2018

databases Scopus and Web of Science, by using keywords: “augmented reality” OR “virtual reality” OR “mixed reality” OR “extended reality” OR “virtual” OR “immersive technology” AND “pro-environmental behavior” OR “environmental sustainability” OR “climate change” OR “nature” OR “green”. See Figure 3 for detailed procedure of the literature search.

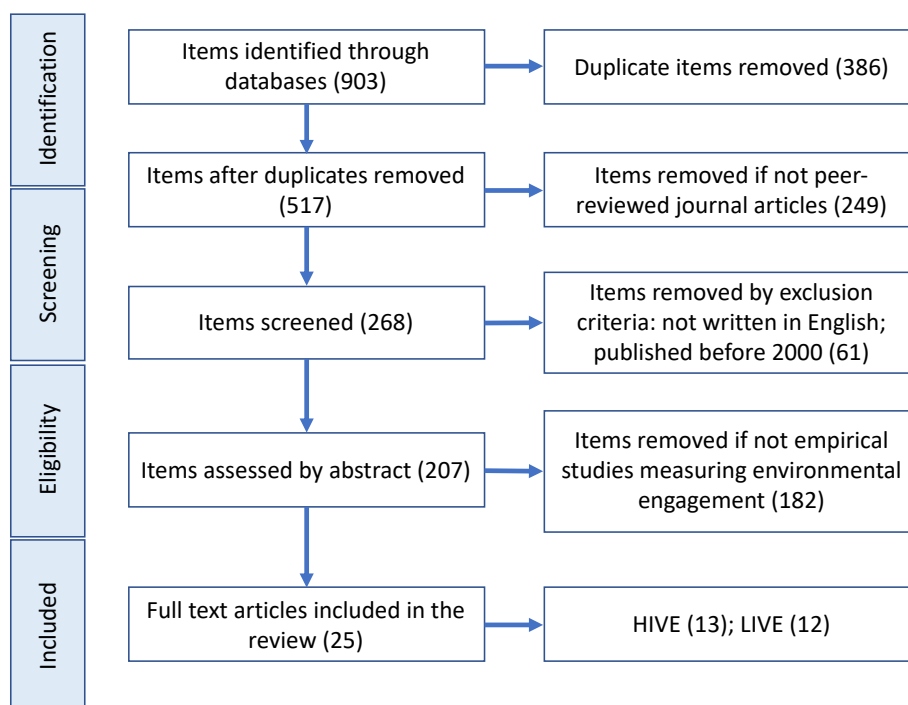


Figure 3. Literature search procedure

The initial search of the literature, based on the keywords and forward-backward search, gathered 903 records from diverse sources. After removing duplicates (386), 517 items were further refined by examining the article abstracts and using the following inclusion/exclusion criteria: (1) we included only peer-reviewed journal articles; (2) written in English; (3) published after 2000; (4) containing empirical studies measuring at least one of the three elements of environmental engagement – cognitive, affective or behavioral (Lorenzoni et al., 2007).

Also, we excluded studies that were conducted in virtual worlds such as Second Life, because participants’ virtual identities do not necessarily correspond to their true selves, and the fact that an experimenter cannot physically observe participants makes this challenge even more difficult to address (Harrison et al., 2011). Indeed, virtual worlds are often used as a playful

“escape from everyday reality”, and their artificial aspect could lead participants not to take the experiment seriously (Innocenti, 2017).

Our focus is on technology that provides highly immersive virtual environments (HIVE) — a type of environments that requires special equipment, such as smart AR glasses or head-mounted displays (HMD) for VR. However, we also included studies conducted in low-immersive virtual environments (LIVE) – which are based on flat computer screens (Innocenti, 2017) – to gain a deeper understanding of this phenomena⁹.

2.2. Results and discussion

2.2.1. General overview of collected studies

Over the past decade, we witness growing trends in the publication of experimental studies conducted in both low– and high–immersion virtual environments that address individuals’ engagement with environmental issues. However, as might be expected, high-immersive virtual experiences were not used in experimental studies until several years after low-immersive environments, due to the more advanced technology requirements. High-immersion experiments may become more common than low-immersion ones over time as immersive technologies become more accessible and available to the general public.

Finally, our literature search resulted in 25 papers (13 studies conducted in HIVE and 12 studies conducted in LIVE) from various disciplines, including computer science, environmental science, psychology, management. The following figure (Figure 4) shows the number of published experimental studies conducted in highly immersive (HIVE) and low-immersive (LIVE) virtual environments that address human engagement with environmental issues over the last 20 years.

⁹ For example, in the study by Ahn et al. (2014), a highly immersive VR is used; in the study by Fiore et al. (2009), participants observed a virtual content on the computer screen that is low-immersive VR.

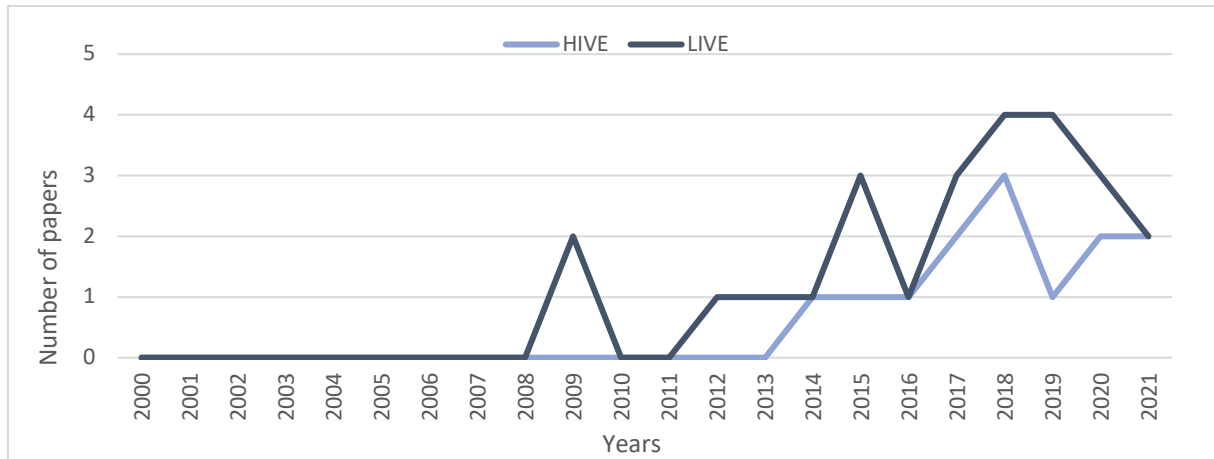


Figure 4. Trends of publishing experimental studies addressing human engagement with environmental issues by using highly immersive (HIVE) and low-immersive (LIVE) virtual environments over the past 20 years

Table 8 provides a general overview of the experimental studies conducted in virtual environments that address people’s engagement with environmental issues (either measured in cognition, affect or real behavior – see Lorenzoni et al., 2007), listed in alphabetical order. We intended to categorize studies results into positive/negative/neutral, however, results were often mixed and inconsistent (e.g. virtual experiences successfully impacted only one out of two variables etc.) Below is the list of information we collected about each study:

- **Type of virtual environment** (which technology was used: HIVE (AR/VR) or LIVE);
- **Topic addressed in the study;**
- **Nature of the main task of the experiment** (the main task of an experiment can test either real behavioral choices, such as monetary donation in the study by Nelson et al. (2020), or hypothetical stated preferences, such as in the study by Olschewski et al., (2012));
- **Treatment scenario** (summary of the content of the virtual experience);
- **Control treatment** (existence of a control treatment, or an experimental group that did not receive any treatment to compare the effect of a treatment with a baseline. For

example, in the Nelson et al. (2020) study, there is a control treatment, while in the Bailey et al. (2015) study, there is no control treatment);

- **Sample size;**
- **Incentive (for participating in the study)** (it is recommended that monetary incentives are incorporated to improve participants' performance on judgment and decision tasks and to increase control over preferences (Jacquemet & L'Haridon, 2018; Camerer & Hogarth, 1999; Hertwig & Ortmann, 2001));
- **Measuring environmental engagement** (environmental engagement is defined by three key components - cognitive (understanding and knowledge about a particular issue), affective (emotions, interest and concern about a particular issue) and behavioral (actual action in relation to a particular issue) (Lorenzoni et al., 2007). We are interested to know what type of environmental engagement was measured by each study).

Reference	Topic addressed	Type of virtual environment	Sample size	Incentives	Nature of the main task of the experiment	Treatment scenario	Control treatment	Measuring cognitive effect	Measuring emotional effect	Measuring behavioral effect
<i>Ahn et al., 2014</i>	Paper conservation	HIVE (VR)	Experiment 1 (47) and Experiment 2 (65) students	-	Real	Participants held a chain saw and cut a tree in a virtual forest for 2 minutes, after which the tree crashed down on the ground	No	Yes	Yes	Yes
<i>Ahn et al., 2015</i>	Environmental conservation	LIVE with haptic feedback	Convenience sample of 114 students	-	Real	In the virtual world, participants embodied a person who helps the tree grow by pressing a water pump, or cuts a tree with a chainsaw	Yes	No	Yes	Yes
<i>Ahn et al., 2016</i>	Connectedness with nature	HIVE (VR)	3 experiments: 27, 52, 126 students (sum 228)	-	Hypothetical	(1) participants got down on their hands and knees, and saw their cow avatar directly facing them as if looking into a mirror. Participants ate and drank water in the virtual pasture, and experienced the cow being hit by the virtual cattle. (2) participants virtually embodied a coral reef. They saw the net handle intersect their coral torso, experienced the arm breaking off from their virtual coral body and observed the effects of ocean acidification	No	No	Yes	No
<i>Bailey et al., 2015</i>	Water conservation	HIVE (VR)	70 students	Course credit	Real	Participants took a virtual shower and received a feedback about their energy used to heat the water	No	No	No	Yes
<i>Bateman et al., 2009</i>	Environmental damage prevention	LIVE	288 students	-	Hypothetical	Participants observed 3D visualization of different land use scenarios from aerial view	No	No	Yes	No
<i>Breves & Heber, 2019</i>	Commitment to the environment	HIVE (VR)	56 students and volunteers	Course credit for students and nothing for volunteers	Hypothetical	Participants viewed a 11-minutes long 360° documentary that captures a journey through the rainforest and is followed by a story of a local inhabitant who stresses the importance of nature for local community and the whole population	No	No	Yes	No
<i>Breves & Schramm, 2020</i>	Risk perception and psychological distance	HIVE (VR)	112 participants	some participants received money, some course credits, some nothing	Hypothetical	Participants saw an animated 360° nature video of a bee that explains and demonstrates negative consequences of mono-cropping in agriculture	No	No	Yes	No
<i>Chirico et al., 2020</i>	Plastic pollution	HIVE	The preliminary study: 172 students // Experiment: 60 participants	-	Hypothetical	The scenario captures a natural environment: spring garden with trees and flowers, blue and sunny sky. Then, an average plastic consumption was	No	Yes	Yes	No

						visualized either with numbers, or by 'mountains' of plastic bottles, or both				
<i>Fiore et al., 2009</i>	Environmental damage prevention	LIVE	45 students	5 \$ showup fee / initial credit 80 \$ / 90.68\$ average fee paid out	Real	Participants observed a virtual simulation of forest fires depending on various protective measures	No	No	Yes	Yes
<i>Fox et al., 2019</i>	Environmental pollution	LIVE	190 students	Course credit	Hypothetical	In a virtual 3D environment, participants guided their avatar in a kayak down a river surrounded by a forest. The scenario represented how the river would look like in future, due to pollution and illegal dumping	No	No	Yes	Yes (self-reported)
<i>Greussing, 2019</i>	Environmental news	LIVE	401 Austrian citizens	-	Hypothetical	Participants saw a short realistic news stories related to climate change	No	Yes	Yes	No
<i>Hsu et al., 2018</i>	Water conservation	HIVE (VR)	165 senior high school students	-	Hypothetical	Participants were placed in a virtual bathroom and received an accelerated feedback about water consumption during toilet flush and shower, in a form of 600ml water bottles	No	Yes	Yes	No
<i>Isley et al., 2017</i>	Sustainable consumption	HIVE (mobile AR)	126 people (random customers of a grocery store)	\$20 grocery gift card	Real	Participants used an AR smartphone application that provides information about grocery products	Yes	No	No	Yes
<i>Joerß et al., 2021</i>	Sustainable consumption	HIVE (mobile AR)	Prestudy: 261 + Main study: 120	-	Hypothetical	In a simulated shop, participants used AR application on a tablet device to access more information about products	No	No	Yes	No
<i>Markowitz et al., 2018</i>	Ocean acidification	HIVE (VR)	Study 1: 16 students; Study 2: 47 students; Study 3: 167 participants; Study 4: 47 students	class credit	Hypothetical	Participants dive into virtual underwater and engaged into marine species count activity, first in a healthy zone, and then in a unhealthy zone with high levels of acidity	No	Yes	Yes	No
<i>Matthews et al., 2017</i>	Environmental damage prevention	LIVE	1062 people recruited by internet advertising and agency	5\$	Hypothetical	Participants observed a virtual beach which landscape changed due to protective measure against coastal erosion	Yes	No	Yes	No
<i>Moore. & Yang, 2019</i>	Environmental serious games	LIVE	61 undergraduates + 293 online participants	research credit & \$0.75	Real	Participants played a game in which players work collaboratively to save the world from an incoming meteor while trying to maintain the ecosystem in the process	Yes	Yes	Yes	Yes
<i>Nelson et al., 2020</i>	Environmental fundraising	HIVE (VR)	1006 (students, citizens and tourists)	lottery with 10% chance to win 100,000 Indonesian Rupiah (IDR)	Real	Participants saw an immersive 5-minutes underwater film about coral reefs and the importance of protecting them	Yes	No	Yes	Yes

Oh et al., 2020	Environmental conservation	LIVE	76 students	course credit	Hypothetical	Participants saw a 360° video showing how natural resource has been damaged and depleted by recent climate change	No	No	Yes	No
Olschewski et al., 2012	Environmental damage prevention	LIVE	129 households	-	Hypothetical	Participants saw 3D landscape model representing avalanche protection measures in the mountains (trees and vegetation)	No	No	Yes	No
Prada et al., 2015	Environmental serious games	LIVE	20 subjects from University	-	Hypothetical	Participants played a virtual 3D game in which the players run a farm that produces food for a small village and learn about the environmental effects of different agriculture styles	No	Yes	No	No
Schaeffer et al., 2018	Sustainable consumption	HIVE (AR glasses)	12 (control) + 12 (web plugin) + 12 (AR)	-	Hypothetical	Participants used an AR prototype that displays ecological information of grocery products once the product's logotype is detected	Yes	No	Yes	No
Soliman et al., 2017	Connectedness with nature	HIVE (VR)	227 students	Partial course credit	Hypothetical and real	In a 4-min. video, participants either viewed a natural (forest, mountains, rivers, wildlife) or a built environment (bridges, skyscrapers, cars)	No	No	Yes	Yes
Treuer et al., 2018	Environmental damage prevention	LIVE	348 homeowners from four Southeast Florida	<10 \$	Hypothetical	Participants engaged into a realistic experience of a sea level rise thirty-five years into the future	No	No	Yes	No
Zaalberg & Midden, 2013	Environmental damage prevention	LIVE	55 citizens	yes but not indicated how much	Hypothetical	Virtual experience started with a short film explaining the cause and consequences of global climate change. Then, participants experienced a heavy rain, walked towards the top of the dike where they watched the river rising. The water then approached the participants, and in the end flooded the first floor of their residence	No	No	Yes	No

Table 8. Overview of collected studies

2.2.2. Drivers of pro-environmental behavior addressed in virtual environments

The following table (Table 9) shows the drivers of PEB that were addressed in virtual environments in selected studies, listed by alphabetical order. Due to diverse set of measures and terminology across the reviewed literature in various disciplines, we did a mapping of experimental variables to align them with the six identified drivers of PEB (see Appendix 2).

Reference	DRIVERS OF PEB						Real behavior
	<i>Beliefs</i>	<i>Concern and awareness</i>	<i>Connectedness to nature</i>	<i>Intention</i>	<i>Psychological distance</i>	<i>Risk perception</i>	
Ahn et al., 2014	x	x		x			x
Ahn et al., 2015	x			x			x
Ahn et al., 2016		x					
Bailey et al., 2015							x
Bateman et al., 2009				x			
Breves & Heber, 2019			x				
Breves & Schramm, 2021		x		x	x	x	
Chirico et al., 2020		x		x			
Fiore et al., 2009.				x			
Fox et al., 2019	x			x	x	x	
Greussing, 2019		x					
Hsu et al., 2018		x		x			
Isley et al., 2017							x
Joerß et al., 2021				x			
Markowitz et al., 2018		x		x			
Matthews et al., 2017				x			
Moore & Yang, 2019		x		x			x
Nelson et al., 2020		x					x
Oh et al., 2020	x			x			
Olschewski et al., 2012				x			
Prada et al., 2015		x					
Schaeffer et al., 2018				x			
Soliman et al., 2017			x				x
Treuer et al., 2018		x		x			
Zaalberg & Midden, 2013		x		x			

Table 9. PEB and its underlying drivers addressed in surveyed literature

The analysis of the collected literature revealed interesting conclusions regarding the potentials, as well as limitations of virtual experiences and immersive storytelling for promoting PEB. Although the surveyed sample is small and the literature in this domain is still in its infancy, some studies suggest that providing rich sensory experiences may affect people's cognitive and emotional information processing, and influence some of the drivers that are important predictors of PEB: (1) *beliefs that one's action have an impact* (such as self-efficacy and locus of control); (2) *environmental concern and awareness*; (3) *connectedness to nature*; (4) *behavioral intentions*; (5) *psychological distance*; (6) *risk perception* and eventually, real behavior. Below we discuss relevant findings of investigated studies related to each PEB driver.

Beliefs

Beliefs about how impactful one's actions are, such as locus of control and self-efficacy are important drivers associated with PEB. Internal locus of control, or an individual's perception that their own behavior can bring about change, also impacts perceived responsibility of the issue (Kollmuss & Agyeman, 2002). Moreover, research suggests that, when environmental messages elicit greater perceptions of self-efficacy (in other words, a degree to which individuals believe that they can influence the outcomes associated with environmental degradation), they are likely to lead to greater intentions for environmental behaviors – such as recycling, buying more sustainable products or promoting PEB to others (Huang, 2016; White et al., 2011). A few recent studies have investigated whether virtual experiences could impact some of those important drivers of PEB.

Two studies by Ahn et al. (2014) examined if virtual simulations of future negative environmental events could affect environmental locus of control and behavior. Before the experiment, experimenter read out loud information about the impact of paper consumption on deforestation, and then participants were randomly allocated either to one of three different conditions: immersive (in which participants engaged in tree trimming experience using VR headset and haptic devices); video (in which participants watched the video of tree trimming); and print condition (in which participants read a narrative about tree trimming and were asked to imagine it). Following the experimental treatments, participants were filling the survey when the experimenter also came to their table, knocked over a glass of water, and ask each participant to clean it with paper napkins. Real environmental behavior was measured by the

number of paper napkins participants used while cleaning the water from the table. Comparing to print description, virtual condition lead to 20% less paper consumption. However, the difference between internal environmental locus after virtual and text condition was not significant immediately following experimental treatments, although, one week after, the effect of immersive treatment on internal environmental locus of control and self-reported environmental behaviors were consistently strong, while the effect of print and video decreased. (Ahn et al., 2014).

Several other manipulations were included in a similar study by Ahn et al. (2015): interactivity (low/high) and framing (loss/gain). In the low interactivity condition, users interacted with a virtual content using regular computer mouse, whereas in the high interactivity condition, users interacted with virtual content using specialized equipment (haptic device). Framing conditions differ in a scenario: participants either grow, or cut a tree. The number of napkins used to clean the water which the experimenter spilled ostensibly by mistake, were counted afterwards. Also, environmental response efficacy was measured one week before the experiment, immediately after the experiment, and one week after the experiment. Briefly, any form of message received through virtual experience reduced real paper use by 25% compared to a control group. The greatest positive effect on environmental response efficacy and in turn, environmental behavioral intentions, had interactive and gain-framed environmental message of growing a tree. While high levels of environmental response efficacy after the gain virtual treatment persisted one week after the treatment, high interactivity led to greater self-reported environmental behavior than low interactivity condition, although it did not differ significantly between the framing conditions. Growing a tree in a virtual environment led to belief that one's action have an impact on the environment, however, the opposite behavior of cutting down a tree did not promote this belief (Ahn et al., 2015).

In a study by Oh et al. (2020), a lab experiment was conducted in order to investigate the effects of pro-environmental 360° videos on pro-environmental attitudes, self-efficacy and intentions. Four different videos for each condition represented how natural spots have been damaged due to climate change effects. Participants first filled pre-questionnaire, then they were assigned to one of two conditions (either viewing 360° videos, or unidirectional videos), and then filled the main questionnaire. Comparing to unidirectional videos, 360° videos were rated as significantly more interactive and fun, that led to higher intentions to actively promote green consumptions and policies. Environmental self-efficacy was significant predictor of participants' evaluations

of 360° content. However, 360° videos were not rated as more credible than unidirectional ones, neither it led to higher reduction intentions. To summarize – while 360° videos may be effective for getting users' attention, it may not be enough to raise the believability of the content. Note the limitations of the study: there was no control treatment in this study, and female participants were dominant in the sample (Oh et al., 2020).

Concern and awareness

Although the evidence on the relationship between environmental attitudes and actual behavior is inconsistent (Siegel et al., 2018; Kollmuss & Agyeman, 2002), some studies suggest that concern for the environment is associated with higher motivation to adopt PEBs. This could be reflected on a higher support for policies or acceptance of energy-saving measures at home or in transportation (Poortinga et al., 2004; Spence et al., 2012), as well as intention to buy environmentally sustainable products and vehicles (Rusyani et al., 2021). Some recent studies investigated the impact of virtual experiences on environmental awareness, concern and similar emotions. The results are mixed and suggest that immersion does not guarantee pro-environmental outcomes.

A study by Chirico et al. (2020) tested how different presentations of statistical data on plastic consumption affected participants' pro-environmental attitudes. First, a survey was conducted in order to find out about the average plastic consumption of students, and the collected data was used to create a visual simulation. In three experimental conditions consisting of a visualization and a narrative, statistical data on plastic consumption were presented in three different modalities: numerical, concrete ('mountains' of 3D plastic bottles), and mixed (combination of the first and second modality). In contrast to the numerical format, the concrete and mixed formats had a significantly higher impact on participants' emotions (such as disgust, fear and sadness), attitudes and risk awareness. Mixed format was more effective for persuasion towards pro-environmental behavioral intentions, although the difference between mixed and concrete format was not significant. Moreover, vivid mode of presenting information generated higher sense of presence in a virtual environment, which indicates how vividness is important for immersion. On the contrary, abstract numerical data representation in VR was not powerful enough in conveying pro-environmental messages. In other words, advanced technology may

not be enough to improve the effectiveness of environmental communication, because it also greatly depends on the content and the way the content is presented (Chirico et al., 2020).

Similarly, the study by Greussing (2019) investigated how immersion alters the understanding and evaluation of an environmental news story. In an online survey experiment, participants were either exposed to climate change related news story with a 360° image, still image, short video, or plain text. After the treatments, knowledge acquisition and perceived message credibility of the news were tested using quizzes and questionnaires. The results suggest that the mode of consuming news may not be related to its perceived credibility; namely, neither visual content in general, nor still photography, video, nor 360° photography significantly enhanced participants' perception of the credibility of the news. Moreover, knowledge gain was the highest in text condition, and the lowest in 360° photo condition. The results suggest that immersive photography may have distracted users as they reported significantly lower levels of knowledge gain after consuming a news text including a 360° photograph than news with text-only coverage (Greussing, 2019).

Another set of studies was focused on testing the impact of virtual games. For example, a study by Prada et al. (2015) examined whether a serious game called AgriVillage could increase engagement with environmental issues. The game involved running a farm that provided food to a village, while educating users about the negative environmental impacts of farming. Participants were asked to play the game, and evaluate it in a questionnaire afterwards. The results suggest that the game improved players' knowledge about agriculture and their awareness of the environmental impact of agriculture. However, note the limited external and internal validity of the study: the study sample was very small (20), there was no real control treatment (the evaluation results were compared to results of a pilot study) and while the game was in English, only 8 participants reported good levels of English (Prada et al., 2015).

Another study tested if virtual water conservation game may impact cognition, attitude and behavioral intention to conserve water. Participants were placed in a virtual bathroom and received accelerated feedback about water consumption during toilet flush and shower. Environmental attitudes were assessed before, after, and one month after the treatment. The results of the study suggest that vividness and personally relevant experience may significantly alter the cognition regarding water consumption and behavioral intention to conserve water. Vivid graphical representation in forms of bottles of water may have helped individuals to

comprehend the amount of water they consume on a daily basis. However, the overall attitude toward water usage was not significantly improved. Note that the study results were not compared to a baseline because there was no control condition (Hsu, 2018).

Finally, note that although individuals with strong pro-environmental attitudes and concerns are more likely to engage in PEB, environmental awareness may not be a sufficient adaptation; people sometimes report that they are aware of and interested in environmental issues, but they do not act accordingly. In other words, pro-environmental attitudes do not necessarily translate into pro-environmental behaviors (Poortinga et al., 2004; Kollmuss & Agyeman, 2002). This is sometimes due to other external factors and psychological barriers that mediate the relationship (Tam & Chan, 2017). Therefore, more effective interventions are needed than those focused only on increasing environmental concern.

Connectedness to nature

In addition to environmental concern and awareness, research shows that one's connection to nature may trigger positive attitudinal and behavioral responses (Clayton et al., 2014). People who exhibit high levels of nature connectedness report greater concern and perceived severity of ecological problems and tend to adopt PEBs (Nisbet et al., 2009). This connectedness may be achieved by encouraging individuals to take the perspective of nature (e.g. a bird) to induce empathy (Berenguer, 2007). Taking this into account, recent research has examined whether this connectedness with nature can be influenced by perspective-taking manipulations in virtual environments.

A study by Ahn et al. (2016) consisted of three experiments with the aim of investigating how an immersive environmental experience through the embodiment of animals (coral reef or a cow) in VR affects feelings of connectedness with nature, compared to viewing a non-immersive video of the same experience. To increase immersion in the VR treatment, besides visual stimuli, participants experienced spatial sound and haptic feedback. In the video treatment, each participant viewed a recording of a previous participant in VR treatment. Virtual experience of embodiment led to greater perception of spatial presence, body transfer, and connectedness with nature. Consequently, the body transfer led to greater involvement of the self with nature, resulting in less temporal distance from an environmental risk (ocean

acidification) and greater involvement with the issue. However, note that effect sizes reported in the study are small to moderate, so the experiment should be replicated with larger samples to draw concrete conclusions (Ahn et al., 2016).

That immersion could increase connection with nature is also evidenced by Breves & Heber's (2019) study. This study explored whether viewing nature videos in VR can increase connectedness to nature. In an experiment, participants watched a nature documentary in either a 360° format via a VR headset, or on a regular computer screen. The results suggest that immersive videos, comparing to regular videos of nature, lead to significantly stronger sense of presence and commitment to the nature. However, these results should not be taken for granted due to the small sample size (56), which was a consequence of as time-consuming one-to-one experiment procedures (Breves & Heber, 2019).

Despite smaller samples size, the results of studies summarized above suggest that immersive media could be more powerful than traditional media in promoting the feeling of connectedness with nature, which may be due to the perception of the contact to be similar to a direct nature experience.

Intention

The Theory of Planned Behavior teaches us that the intention to engage in a particular behavior is likely to lead to the actual performance of that behavior (Ajzen, 1991). Therefore, it is crucial to understand whether this important predictor of PEB can be influenced through virtual experiences. We present several studies that investigated the impact of virtual treatment to intentions to engage in PEBs.

Although VR technology is dominant in the context of environmental research, recent studies have suggested new ways in which AR could also be used to promote PEB. For example, several studies tested whether AR might be effective in providing real-time information and orienting consumers towards more sustainable shopping. Isley and colleagues (2017) reported insights from a field experiment conducted in a grocery store. During shopping, participants used a mobile AR application that was, in real time, overlaying products with a layer of relevant information (such as the product's carbon footprint), and were asked to choose a bottle of water and cereals. In comparison to a control group (that had the same shopping task but did not used

the application), the usage of the application lead to 22% reduction in carbon footprint for bottled water. However, in the case of cereals, AR did not significantly reduce carbon footprint, but instead led to choosing healthier (less fat and less sugary) cereals (Isley et al., 2017).

A similar study experimentally tested an AR recommendation application, this time in a simulated store. Using a tablet device, participants interacted with the AR application that provided them with additional sustainability information about the products. Consumers who used AR recommendation systems during their shopping are, in most cases, likely to choose a product that is according to the technology classified as sustainable. However, this did not happen with all the grocery categories: participants chose more sustainable coffee, cereals, and milk (relative importance of the sustainability rating compared to brand and flavor was approx. 40%), but on the contrary, participants chose less sustainable jam. However, note that the study did not compare results to a control group that did not use the application, but instead to the expected likelihood of randomly selecting a sustainable option (Joerß, 2021). Another similar study compared the effects of a regular web store, a web store with a plugin that provides ecological information about the products, and an AR prototype that displays ecological score of the products in a grocery store. It turned out that both plugin and an AR prototype lowered the selection of less eco-friendly products and increased the selection of more eco-friendly products, even at a higher price (Schaeffer et al., 2018). The results of these studies suggest that providing timely and easy-to-use information may affects shoppers' decisions at the time of purchase, however, preexisting preferences may sometimes be dominant.

On the other hand, a set of studies aimed at investigating if presenting information in visual forms – in contrast to conventional numerical format – can enhance the content evaluability in non-market valuation studies. Namely, in such experiments, participants are required to evaluate different choices, such as public goods. Usually, these choices are presented through numerical and static data. However, information presented in this format might be difficult to comprehend, and without proper understanding of the content, its poor evaluability might lead to anomalies, judgement errors and gain/loss asymmetry. To address the evaluability critique in choice experiments, tridimensional VR visualization is proposed as a solution. For example, in one study, participants had a chance to experience and view long-term consequences of their present choices related to wildfire prevention policy. After seeing virtual scenarios of fires that differ in prevention strategy, participants had to choose between policies and face the real monetary consequences of their choices. Virtual simulation lead to subjective beliefs that are

closer to actual risks (Fiore et al., 2009). Based on several similar studies it seems that VR visualizations could motivate people to take protective measures to escape the environmental threat (such as supporting higher taxes or moving out of the region) (Treuer et al., 2018; Zaalberg & Midden, 2013), but also significantly lower the judgement errors and asymmetry between willingness to pay (WTP) and willingness to accept (WTA) (Bateman et al., 2009; Olschewski et al., 2012). However, in some studies, the difference between the treatment and control group was not significant (Matthews et al., 2017).

Psychological distance

Research on human psychology informs us that perceived psychological distance from environmental problems, probably due to a lack of direct experience, can be a significant barrier to pro-environmental behavior (Lorenzoni et al., 2007; van der Linden et al, 2015). According to the Construal Level Theory (CLT), direct experiences create concrete and detailed mental construal that we perceive as psychologically closer. On the other hand, when we are not directly experiencing something, but thinking about it instead, these mental construals are abstract and psychologically distant (Trope & Liberman, 2010). If people feel psychologically distant from environmental risks, they are likely to perceive them also as less serious (Lorenzoni et al., 2007). Therefore, insights from environmental psychology suggest that communication efforts should aim at minimizing the psychological distance in order to promote PEB (van der Linden et al, 2015). Thanks to their possibility to place users into an immersive and vivid environments, immersive technologies are able to create a sense of presence and create an impression of being in a virtual environment. Some studies investigated whether this immersion could also impact the perception of psychological distance.

One study tested the impact of a serious game - a game with intention to educate and persuade users to perform a specific behavior - on environmental attitudes and behavior. In the game, participants were involved in an environmental clean-up action of a virtual river. Treatments varied in psychological distance (the river was either presented as close or distant in space and time) and interactivity (participant's action either had an impact on the environment, or the environment changed automatically). One day after the experiment, participants received an online post-test which assessed psychological distance, interactivity, risk perception, environmental self-efficacy, environmental policy support, and self-reported environmental

behaviors. They had one week to complete the questionnaire. Results suggest that the feeling of being psychologically close to the an environmental issue (polluted river) enhanced the perception of an environmental risk, which consequentially lead to more environmental behavior and support for environmental policies. Moreover, interactive game format resulted in more positive environmental outcomes: participants who impacted the game scenario with their actions reported greater levels of self-efficacy, and consequentially more environmental behavior (such as buying and installing environmentally friendly products) and higher support for environmental policies. However, in this game, the threat may have been *too easy to manage*, because the environment got cleaner in the end no matter what participants did. Note also that the study did not include a control treatment, and did not report how many days after the treatment each participant completed the questionnaire (Fox et al., 2019).

Insights from psychology suggests that perceived psychological distance may also guide our estimation of environmental risks (Uzzel, 2000), that is related to the assessment of the urgency and importance of environmental protection, which we discuss below.

Risk perception

As some studies suggest, perceptions of environmental risk may play an important mediating role in promoting PEB. For example, individuals who perceive a higher level of environmental risks may be more willing to change their lifestyle and habits to be more environmentally friendly (Zeng et al., 2020; Yoon et al., 2021). Due to psychological distance, people sometimes feel less responsible despite recognizing the problem as serious. In this context, direct experiences may help to heighten the risk perception (Akerlof et al., 2013; Uzzel, 2000). Because this approach may be too difficult, costly, or dangerous, researchers have investigated whether virtual simulations of risky events could be an efficient alternative.

In an experimental study by Breves & Schramm (2021) participants viewed a video explaining negative consequences of mono-cropping in agricultural practices. The experimental treatments varied in (1) immersiveness: (the participants either viewed a stimulus material using a VR headset, or a 360° video on a flat computer screen) and (2) level of construal - the video was either framed as taking place at proximal location (low level of construal), or distant location (high level of construal). Although the VR technology successfully created the sense of

presence, it was not successful in manipulating all the variables studies in the experiment. First, it reduced only the perceived temporal distance and hypotheticality, but did not significantly affect the spatial psychological distance. Second, presence achieved through the virtual environment increased the perceived severity of the environmental risk, even ten days after the experiment. Third, the spatial presence enhanced environmental behavioral intentions, but only if the problem was demonstrated as distant. Therefore, immersive videos were found to be a suitable tool for communicating distant environmental risks. Note that the study did not measure all dimensions of psychological distance and presence (e.g. social dimension), neither results were compared to a baseline because there was no control study. Note also that most of the study sample consisted of highly educated females that may have been influenced by external factors, such as ongoing environmental events (e.g. Fridays for Future) (Breves & Schramm, 2021).

However, even when an environmental problem is perceived as a serious threat, people tend not to prioritize it if they perceive it as a remote risk, that is, a risk that affects people and places far away in space and time. Therefore, communication efforts aimed at promoting PEBs should increase people's environmental concern and perception of risk, but also bring the problem psychologically closer and provide evidence, as people tend to rely on affect, emotion, and experiential processes rather than rational considerations when assessing risks (Leiserowitz, 2006).

The impact on real behavior

Finally, several studies from the surveyed sample tested the impact of virtual experiences on real behavior. Results are mixed and suggest limited potential of immersive experiences that needs further exploration. Note that PEB is a complex set of behaviors and these studies used diverse measures for assessing it (for example, while a study by Soliman et al., (2017) assessed PEB by participants expressing interest in the campus sustainability plan, a study by Ahn et al. (2015) measured if participants aimed at conserving the paper while cleaning water from the table with napkins).

On the one hand, a set of studies suggest positive impact of virtual experiences on PEB. Nelson and her colleagues (2020) tested the impact of immersive virtual underwater diving on people's

generosity to donate money to an ocean conservation charity. In a field experiment, participants watched a short immersive 360° omnidirectional film about coral reefs. Experimental treatments varied in the level of immersion (low or high) and message framing (positive or negative). Participants were incentivized by a ten percent chance to win 100.000 Indonesian Rupiah in a lottery, and were asked how much would they donate to the marine conservation charity, in case of a victory. Overall, comparing to text, video - and above all, 360° video - induced higher willingness to donate. However, for each sample, different strategy was more effective, varying in framing of the messages. Namely, for those unfamiliar with VR technology, such experience may be overwhelming. Also, VR can cause limited capacity to process other information – in case there is audio input at the same time, users may find it difficult to focus on a visual content, so it might work better with subtitles (Nelson et al., 2020).

Bailey et al. (2015) measured the water temperature during participants' handwashing, after being receiving a vivid feedback in VR about the energy used to heat the water for the shower. Besides visual stimuli, they were exposed to spatial sound and haptic feedback. The experiment consisted of four treatments. In each treatment, participants read and listened to a narrative related to energy consumption, and energy use was presented as pieces of coal. The treatments varied in the level of personalization (first-person perspective or third-person perspective) and vividness (using avatars and haptic feedback or providing textual messages on a virtual billboard). Following the experiment, the real amount and the temperature of water was measured while participants washed their hands. The treatment successfully led to a decrease in water temperature, however, the same did not happen for the amount of water used to wash hands (Bailey et al., 2015).

A set of studies from the Stanford's Virtual-Human Interaction Lab (VHIL) inform us how virtual experiences of nature degradation may positively impact PEB. In studies that varied in the level of immersion (participants either virtually cut the tree, or read about it and were asked to imagine it) and framing (participants either cut, or grow a tree), virtual condition lead to a significant decrease in paper consumption, and the effect of the treatment on internal environmental locus of control and self-reported environmental behaviors stayed consistently strong after one week. The biggest positive effect on environmental response efficacy and in turn, environmental behavioral intentions had interactive and gain-framed environmental message of growing a tree (Ahn et al., 2014; Ahn et al., 2015).

On the other hand, in a study by Soliman et al. (2017), viewing nature videos via immersive technology increased the feeling of connectedness with nature, but the treatment was not strong enough to lead to PEB, which was measured in post-treatment choices (choosing a hard copy of debriefing, signing up for a sustainability newsletter, and downloading a campus sustainability plan (Soliman et al., 2017). Furthermore, in an experimental study by Moore & Yang (2019), participants played (or watched a video of) a pro-environmental game with the goal to save the world from an incoming meteor while trying to maintain the ecosystem in the process. The researchers measured PEB by two post-game observations: choosing a plastic cup and recycling or not a bottle. While neither of two measured behaviors did not significantly differ across conditions, participants who watched a video trailer of the game were significantly more likely to refuse a drink (Moore & Yang, 2019). To conclude, based on these few studies, we observe mixed support of the potential of immersive storytelling for impacting PEB, and more research is needed to get deeper understanding of this phenomena.

2.3. Implications, limitations, and future directions

This chapter surveys peer-reviewed articles and systematically summarizes their empirical insights about using immersive technologies to promote PEB. The present literature review has important implications for practitioners and researchers. We point out to the biggest strengths as well as challenges of immersive storytelling, needed to direct communication strategies, create behavioral interventions, and guide further research projects.

Most importantly, data from the collected studies suggest that immersive virtual experiences can influence some psychological factors important for environmental engagement, such as beliefs (e.g. environmental self-efficacy and locus of control), environmental concern and awareness, connectedness to nature, behavioral intentions, psychological distance, and risk perception. In some cases, however, virtual experiences were counter-effective in promoting PEB as they distracted users from obtaining relevant information (Greussing, 2019). One of the biggest strengths of immersive storytelling is their ability to generate the feeling of presence, which is suitable especially for those who are not able to vividly imagine future scenarios. *The more vivid, the more believable*: if the simulation in a virtual environment seems sufficiently realistic, participants may treat these experiences as if they really happened to them and may

therefore generate the sense of presence (Fiore et al., 2009). However, we should be careful with immersion into shocking events: researchers suggest that a virtual event should not be too threatening, otherwise it could result in '*running away*' and dismissing the threat. Therefore, the level of threat should be manageable, rather than paralyzing (Fox et al., 2019).

Despite their potential, immersive behavioral interventions poses some risks and challenges that mostly arise in their implementation challenge. Namely, in order for a virtual experience to have an impact, people must want to experience it in a natural settings (Fox et al., 2019). However, not only AR and VR technologies are novel and not yet fully adopted by masses, but communicators should be aware of technical requirements of immersive experiences. This includes AR or VR-supporting equipment, (often) stable internet connection, and safe and big enough surrounding environment in which users can interact with virtual experiences. Furthermore, VR experiences may be tricky to implement in a social environment (e.g. classroom) because although a user wearing a VR headset does not see the real world, real world sees him, and others may find it funny or weird (Markowitz et al., 2018).

This study has several limitations. First, we advise to take this analysis with caution due to small effect sizes of most of the surveyed studies. Most of the studies did not measure real behavior (but rather intentions of hypothetical behavior), did not include a control treatment, or did not incentivize participants for participation. Therefore, to make conclusions with confidence, more research is needed. Furthermore, our literature sample consisting of 25 paper is very small. We are aware that the application of virtual environments for addressing PEB is a very novel topic, and perhaps including the conference paper would provide more insights into this emerging field. Also, we focused on empirical and experimental papers, but conceptual or qualitative papers should not be neglected as they would help us in understanding the potential or adoption of immersive technologies and storytelling. Finally, the heterogeneity of surveyed papers posed a great challenge for analysis. It took a great deal of time to analyze and synthesize data from studies that investigated diverse set of measures applying different methods, and communicated results using different terminology. However, we believe these rich datasets will serve our community to better understand the possibilities of AR and VR for enhancing environmental communication.

Despite listed challenges and limited empirical support, we believe that immersive communication and storytelling offers great potential to enhance traditional environmental

communication. Let us take an example of communicating a growing environmental problem: plastic pollution. In addition to images and videos, future campaigns could be supplemented with immersive pro-environmental AR experiences. Any user who comes across such a campaign could ‘live’ the consequences of plastic pollution. Such an immediate experience could bring users psychologically closer to the problem of plastic pollution and perhaps increase their motivation to choose greener behavior. Future studies should test how such AR experiences affect PEB, in controlled laboratory settings.

On the other hand, immersive virtual experiences can complement experiments (or replicate field experiments¹⁰) in the lab (Innocenti, 2017), that test environmental behavior, risk preferences, and decision-making. Because of their ability to create a sense of presence, virtual environments can provide the realistic context (spatial and temporal cues) that participants need to properly evaluate non-market goods and their associated risks, especially when they are spatially or temporally distant in reality (Treuer et al., 2018; Zaalberg & Midden, 2013).

2.5. Concluding remarks

We analyzed peer-reviewed empirical studies conducted in low- and high-immersive virtual environments. We found that virtual experiences are able to increase certain drivers that are important for promoting PEB, namely: concern, connectedness to nature, intention, psychological distance, and risk perception. However, we also observed that immersive experiences may not guarantee positive outcomes, as they may distract users while absorbing information.

Although immersive technology is still in the early stages of mass adoption, we encourage researchers to recognize this turning point as AR and VR become widely accessible, and to explore the potential for immersive virtual experiences to change behavior for the greater good. This study paves the way for future research on the potential of immersive technologies for creating effective pro-environmental interventions aiming to promote PEB.

¹⁰ For field experiments in economics see List & Price (2016)

3. Theoretical justification of design principles

In this thesis, our aim is to design an AR-based artifact that promotes individuals' PEB. Following DSR approach, before we enter into the design process, we theoretically ground the artifact's design principles in kernel theories and provide justificatory knowledge for the artifact's design (Gregor & Hevner, 2013). In DSR, kernel theory stands for any descriptive knowledge that informs artifact construction and explains (at least partially) *why design works* (Gregor & Hevner, 2013).

In sum, we consider three interdependent aspects of the artifact: information (which message is communicated and how), social (which social relationships may be impacted by an artifact), and technology aspect (what are the material and other properties of the artifact, such as hardware and software) (De Leoz & Petter, 2018; Lee et al., 2015). Each aspect of the artifact's design – information, social, and technology – is governed by a kernel theory, which is explained in the following subsections. In accordance with Gregor et al. (2020), we specify design principles by defining these information: (1) *aim, implementer and user*; (2) *context*; (3) *mechanisms* and (4) *rationale*. Later, we translate these design principles into specific design requirements of the artifact (see Subsection 3.3 of Chapter 2).

3.1. Construal Level Theory to capture the information aspect of the artifact

Information on environmental issues is often consumed in abstract and analytical form as text messages, photos, videos, social media posts, etc. However, recent research challenges traditional communication media and demonstrates that environmental issues, when directly experienced, are more likely to engage people than while displayed through standard formats (van der Linden et al., 2015). For example, personal experiences with extreme weather events such as flooding are likely to influence a person's risk perception and intentions associated with climate change (van der Linden, 2014; Akerlof et al., 2013).

The influence of experienced situations on our cognitive processes may be explained by Construal Level Theory (CLT) - a theory of perceived psychological distance and its mental construals. Namely, according to CLT, people create different mental representations for

different events depending on how far they are from the *here* and *now*. When someone experiences something directly, their mental construal is detailed, concrete, and psychologically closer. In contrast, when someone only thinks about or imagines something, their mental construal is less detailed, more abstract, and psychologically more distant. An object can be distant in four interrelated dimensions – temporal, spatial, social, and hypothetical. This influences one’s estimation of when, where, for whom, and whether an event occurs at all (Trope & Liberman, 2010).

Consistent with the literature on psychological distance, we can therefore conclude that environmental information is better translated into vivid personal experiences and presented in a way that reduces perceived psychological distance and makes plastic pollution immediate, local, real, and relevant to information recipients (van der Linden et al., 2015). Direct experiences of environmental degradation therefore have the potential to clarify people’s perceptions of the problem. Since such events are usually in the future, it is necessary to speed up the process of environmental degradation and demonstrate its consequences in the form of accelerated experiential feedback (Hsu et al., 2018). Recent studies suggest that immersive virtual experiences could provide a solution: when virtual stimuli integrate enough reality, they can create a sense of presence and elicit cognitive, emotional, and behavioral responses as in real life (Miller et al., 2019; Chirico & Gaggioli, 2019; Morina et al., 2015). With this in line, we define the initial design principle of psychological distance (Table 10).

Design principle title	Initial design principle of psychological distance
Aim, implementer and user	<i>In order to raise the perceived seriousness of environmental issues by individuals</i>
Context	<i>in pro-environmental communication interventions</i>
Mechanisms	<i>the environmental issues should be directly presented at familiar and relevant places</i>
Rationale	<i>because direct, personally relevant experiences are likely to bring environmental issues psychologically closer</i>

Table 10. Initial design principle of psychological distance

3.2. Social Influence Theory to capture the social aspect of the artifact

In addition to the technical components of the artifact, we also consider potential social impacts that may result from its design or implementation (Qureshi et al., 2021; Lee et al., 2015). The importance of considering social dimensions when designing an artifact is increasingly shared by the IS researchers (Qureshi et al., 2021; De Leoz & Petter, 2018). People are social beings and the social environment in which they live is likely to influence their behavior and decision-making. In other words, social norms are often used as triggers for pro-environmental behavior (van der Linden et al., 2015; Farrow et al., 2017)¹¹.

According to Social Influence Theory, people's attitudes and behavior are under social influence through three main processes: compliance (people adopt a behavior because they expect a positive response from others), identification (a person behaves in a certain way to establish or maintain a beneficial relationship with others), and internalization (a person adopts a behavior because it is consistent with his or her value system and its content is intrinsically rewarding) (Kelman, 1958). Hence, digital means of environmental communication may have some advantages over traditional means: thanks to the rapid development of the Internet, mobile devices, and social media, people today can be socially connected anytime, anywhere, and with anyone, opening up avenues for social influence. Social media platforms have the ability to quickly spread content through networks of connected users who engage with the content by sharing, liking, and commenting. This increased engagement can boost visibility of the shared content, which is an added value of social-media based campaigns.

In line with this theoretical framework, social aspects of the artifact could be assessed at two levels:

- *between users (human-human interactions)* – the artifact should enable communication and interaction between people. The artifact could be integrated into a system already in use, such as a social network or other multi-user platform where users can easily share content with each other. A strong evidence from research and practice suggests that social networks may be a tool of social influence and can be therefore used to

¹¹ For example, hotel guests are likely to reuse their towels if they receive information that most other guests do the same (Goldstein et al., 2008).

promote collective environmental movements (Tim et al., 2017; Vasey, 2021; Armstrong, 2010).

- *between users and the artifact (human-machine interactions)* – the material dimensions of the artifact could enable social relationships between users and the artifact itself. One of the best-known examples of emotional relationships with computers is probably the Tamagotchi, a pocket device that acted as a virtual pet (Fogg, 2003). Today, thanks to advances in artificial intelligence, graphical interfaces, and natural language processing, people have begun to form social relationships with artificial beings as well (Skjuve et al., 2021). Recent studies suggest that people treat virtual entities (e.g., virtual humans or animals) integrated into AR similarly to real beings (Miller et al., 2019; Norouzi et al. 2022)¹².

The former level enables indirect persuasion, where people use the computer system to persuade others (computer-mediated persuasion). For example, if an artifact allows users to observe other users engaging in a particular behavior (e.g., sharing environmental pledges), it may increase the likelihood that a person will engage in a particular behavior. The latter level enables direct persuasion, where computer systems are used to persuade a user directly (computer-human persuasion). For example, if an artifact puts users in a situation where they should help endangered creatures due to an environmental problem, it can exploit the natural willingness of humans to cooperate and help (Oinas-Kukkonen & Harjumaa, 2009). Social influence between users and artificially created social influence can pave the way towards pro-environmental behaviors and form the initial design principle of social influence (Table 11).

Design principle title	Initial design principle of social influence
Aim, implementer and user	<i>In order to encourage individuals' PEB</i>
Context	<i>in digital environment</i>
Mechanisms	<i>the artifact should enable social interactions between (1) users and (2) users and the artifact</i>
Rationale	<i>because social interactions can influence behavior</i>

Table 11. Initial design principle of social influence

¹² In one experiment, participants avoided sitting on a chair occupied by a virtual agent in AR (Miller et al., 2019).

3.3. Theory of Persuasive Technology to capture the technology aspect of the artifact

At the technological level, the design principle is inspired by the Theory Of Persuasive Technology (Fogg, 2003) and persuasive system design (Oinas-Kukkonen & Harjumaa, 2009). Persuasion, defined as “an attempt to achieve voluntary change of attitudes or behavior, or both, without using coercion or deception” (Fogg, 2003, p. 15), can be achieved with technology. The term persuasive technology describes “any interactive computing system designed with the intention to change people’s attitudes or behaviors” (Fogg, 2003, p. 1).

Interactive technologies, then, can influence behavior in different ways depending on the role they play, as explained by the ‘functional triad’: computers can be used as a tool, as a medium, and as a social actor-or as a combination of all three roles. When a computer is used as a tool – to increase efficiency – it can be persuasive by simplifying behavior or providing services that guide behavior. A computer can be used as a medium that provides experiences. A computer can also be a social actor, as people often treat computers like people and build relationships with them. By engaging users in social interactions, these systems can drive desired behaviors (Fogg, 2003).

In any case, an interactive system provides some level of feedback (e.g., verbal or visual) to users that guides them to behave in a certain way. In the context of environmental sustainability, a system should use simulations to link cause and effect of users’ behavior (Oinas-Kukkonen & Harjumaa, 2009), thereby enhancing individuals’ perceived self-efficacy – an important force for promoting PEB (Ahn et al., 2014; Ahn et al., 2015). Theoretical base for constructing persuasive systems led us to define the initial design principle of interaction, presented below (Table 12).

Design principle title	Initial design principle of interaction
Aim, implementer and user	<i>In order for an immersive system to be effective</i>
Context	<i>in attempts to promote PEB</i>
Mechanisms	<i>the artifact should provide interactive simulations</i>
Rationale	<i>because interactive computer simulations are efficient in changing people’s attitudes or behaviors</i>

Table 12. Initial design principle of interaction

3.4. Summary of initial design principles

In the following table (Table 13), we summarize the main theoretical arguments that guided the development of the artifact's design principles. The design of the artifact, i.e., its information, social, and technology aspects (De Leoz & Petter, 2018), was influenced by three kernel theories: Construal Level Theory (Trope & Liberman, 2010), Social Influence Theory (Kelman, 1958), and the Theory Of Persuasive Technology (Fogg, 2003).

Design aspect	Kernel theory	Design principles
Information	<i>Construal level theory (Trope & Liberman, 2010)</i>	In order to raise the perceived seriousness of environmental issues by individuals in pro-environmental communication interventions, the environmental issues should be directly presented at familiar and relevant places, because direct, personally relevant experiences are likely to bring environmental issues psychologically closer
Social	<i>Social influence theory (Kelman, 1958)</i>	In order to encourage individuals' PEB in digital environment, the artifact should enable social interactions between (1) users and (2) users and the artifact, because social interactions guide behavior
Technology	<i>Theory of persuasive technology (Fogg, 2003)</i>	In order for an immersive system to be effective in attempts to promote PEB, the artifact should provide interactive simulations, because interactive computer simulations are efficient in changing people's attitudes or behaviors

Table 13. Overview of kernel theories and design principles of the green AR artifact

Defining the theoretical background for this project and reviewing relevant studies in other disciplines have allowed us to better understand the potential of AR technology in motivating individuals to adopt pro-environmental behavior. We now move to the second chapter of the Part One, in which we introduce the methodological approach and procedures used to design, develop, and evaluate the green AR artifact.

CHAPTER TWO:

METHODOLOGY

The purpose of this chapter is to detail the methodological approach adopted for this doctoral project. Specifically, I will present the research design and empirical techniques used in this thesis to investigate potential of AR in motivating individuals to engage in pro-environmental behaviors. The mixed-methods approach generated knowledge on an important field problem and helped to fill the gap in the Green IS field, which still lacks relevant studies (Elliot & Webster, 2017). This chapter consists of four sections.

First, I introduce and justify the research approach – the Design Science Research (DSR) methodology (Hevner et al., 2004), which has yielded insightful prescriptive knowledge about the design, development, and impact of green AR artifacts. After developing a testable prototype of the artifact, we used insights from Behavioral Science to test the utility of the artifact (its actual impact on pro-environmental behavior), and supplement the thesis contributions with descriptive knowledge (Hevner & Chatterjee, 2010).

Second, I describe in detail the research design – consulted guidelines (Henver et al., 2004) and steps (Peffer et al., 2008) taken to achieve the intended research outcomes. I express my expectations regarding theoretical and practical contributions and justify why I also address the social implications of the green AR artifact.

Third, I introduce the artifact, its functionalities, design, and potential use. I explain the derivation of design requirements, present activities that led to the first prototype of the green AR artifact, and justify the technical decisions that influenced its development.

Finally, I explain the value of the mixed methods approach used to evaluate the artifact: qualitative methods (focus groups, semi-structured interviews) and quantitative methods (laboratory and laboratory-in-the-field experiment). I also explain the sampling procedure and justify the selection of participants in the empirical studies.

1. Research approach and epistemology

1.1. Design Science Research methodology

This research addresses a contextual field problem (Pascal et al., 2013; Van Aken, 2005) – the challenge of motivating individuals to adopt PEB to address the global plastic pollution crisis. To achieve the objectives of this research, we rely on the Design Science Research (DSR) methodology. In this subsection, we justify our research approach by first explaining what design is and then introducing the DSR methodology as a valuable approach to answering our research questions.

Design - the art of creating applicable solutions to problems - has become a valuable research method in many disciplines. Unlike the natural and social sciences – whose goal is to help understand reality – design science, as conceptualized by Simon (1996), is a problem-oriented research approach that calls for the creation of innovative, effective, and purposeful solutions to solve real-world problems (Simon, 1996; Hevner et al., 2004).

Design Science, however, is more than just design. It is also more than just a method or just an artifact. It is a continuous process that spans many disciplines and consists of numerous iterations of evaluations, in which feedback on the usefulness of an artifact for solving the problem being addressed is critical to its improvement (Hevner et al., 2004; Markus et al. 2002; Baskerville, 2008).

DSR has become a popular and accepted approach among IS scholars, as evidenced by editorial letters and invitations from major IS journals encouraging IS scholars to engage with DSR (March & Storey, 2008; Goes, 2014; Baskerville, 2008; Peffers et al., 2018). In the IS discipline, the DSR approach involves a rigorous process of creating and evaluating new IT artifacts to solve an identified problem (Hevner et al., 2004; March & Smith, 1995).

DSR is seen as a way for academics to engage in projects that have impact outside of academia (Gregor et al. 2020). In this sense, IS researchers can apply the DSR approach (Hevner et al., 2004) to develop novel technological solutions to environmental sustainability problems, referred to in the literature as Green Information Systems (Green IS) (Brendel et al., 2018, Melville, 2010). Research on Green IS aims to generate knowledge about how digital technology and information systems can be used to influence environmentally sustainable behavior at the individual, organizational, and societal levels (Elliot, 2011).

Although interest in IT solutions for environmental sustainability has emerged among IS scholars (Melville 2010), the diversity of publications at the intersection of DSR and Green IS is still limited (Brendel et al., 2018). Therefore, in this thesis, we aim to generate new Green IS knowledge and contribute to the field with new empirical and theoretical insights. However, besides the design itself, it is also useful to investigate whether the artifact is capable of addressing a specific real-world problem. Therefore, it is proposed to complement design knowledge with Behavioral Science methods to test the utility of design artifacts (Hevner & Chatterjee, 2010), as discussed in the next subsection.

1.2. Borrowing insights from Behavioral Science to investigate the artifact's utility

Behavioral Science and Design Science are two distinct but complementary and interdependent methodological approaches that are recognized as fundamental to the IS discipline. While Behavioral Science has its roots in the natural sciences and aims to explain and predict human behavior and find out *what is true*, Design Science has its roots in engineering and the sciences of the artificial (Simon, 1996) and aims to create innovative artifacts and find out *what is effective* (Hevner et al., 2004).

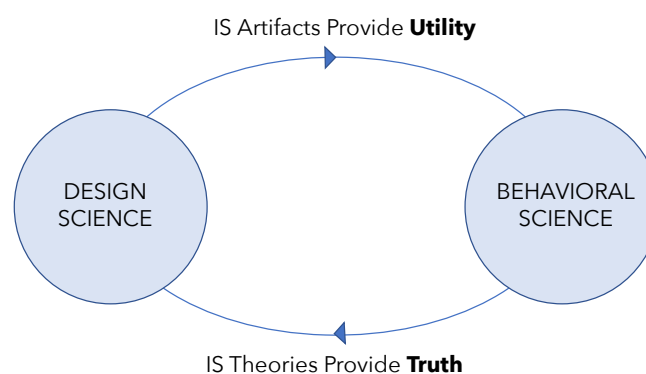


Figure 5. Complementarity of Design Science and Behavioral Science research approaches, as explained by Hevner & Chatterjee (2010)

Design Science and Behavioral Science are inextricably linked and together form a complementary research cycle (see Figure 5) that is necessary to produce truth (justified theory)

and utility (effective artifacts) (Hevner & Chatterjee, 2010). In other words, while Behavioral Science often explains causal relationships and answers *whether X is the cause of Y*, Design Science is more concerned with answering *how X can be developed to solve Y* (Thuan et al., 2019).

One of the most important activities in a DSR process is evaluation of the artifact's utility, i.e., testing how well the artifact is able to solve a real-world problem (Hevner et al., 2004). To this end, we chose a mixed methods approach (Venkatesh et al., 2013): in addition to qualitative studies to evaluate the design and implementation of the green AR artifact, we used insights and methods from Behavioral Science to test its utility (Hevner & Chatterjee, 2010). More specifically, we conducted a controlled experiment to test whether the artifact is able to promote individuals' pro-environmental behavior.

Indeed, economic experiments help us understand and predict the behavior of decision makers under certain circumstances (Jacquemet & L'Haridon, 2018). For example, experiments in environmental economics aim to understand what drives collective and individual behavior that affects the environment and address issues such as air and water pollution, climate change, or natural resource depletion (Jacquemet & L'Haridon, 2018, Sturm & Weimann, 2006).

In this study, we attempted to *bring the field into the lab* by conducting an experiment in an immersive virtual environment: we used AR to simulate a real-world context and test the utility of the artifact in this simulated environment (for the study, see Chapter 4). Thanks to the mixed-methods approach, we were able to generate knowledge in the area where it is still lacking: immersive technologies and their use to address environmental sustainability challenges. These choices reflect our epistemological positioning, which is explained in the next subsection.

1.3. Justifying epistemological positioning

In any research inquiry, researchers use specific methods to answer one or more research questions. The choice of methods is critical because it affects the outcome of a research project. Equally important is the choice of epistemological perspective, which influences how knowledge is gathered and generated. The epistemological perspective adopted by the research reflects how the researcher views the world (Guba & Lincoln, 1994). In other words,

epistemology could be metaphorically explained as glasses because our view of the world is influenced by the type of glasses we wear.

By definition, an epistemological framework is “a set of basic beliefs (or metaphysics) that deals with ultimate or first principles. It represents a worldview that defines, for its holder, the nature of the world, the individual’s place in it, and the range of possible relationships to that world and its parts, as, for example, cosmologies and theologies do” (Guba & Lincoln, 1994, p. 107). Some epistemological frameworks are consistently used in the field of Information Systems, Organization and Management research, namely: positivism, interpretivism, constructivism, and critical realism (Avenier & Thomas, 2015).

The positivist approach assumes that there is an objective world that is independent of the researcher. Researchers who conduct research within this framework usually choose methods that can be used to generate testable hypotheses. On the other side, there is interpretivism, which states that knowledge about reality is contextual and subjective and arises through social situations. Similarly, there is constructivism, which holds that knowledge emerges through experiences in the interaction between investigator and participant. Finally, there is critical realism, which takes a strongly realist ontological approach. It is based on the idea that the world is independent of our knowledge, but that this knowledge is relative, i.e., socially and historically constructed (Avenier & Thomas, 2015; Guba & Lincoln, 1994).

In answering the two research questions that guided this PhD project, it was obvious that a strict epistemological positioning could inevitably lead to limitations. Indeed, the methodological choices went beyond the limits of a single epistemological framework, as it was necessary to adopt a mixed methods approach: on the one hand, the exploratory techniques necessary to gain insight into the design and use of the artifact generated context-dependent knowledge; on the other hand, addressing the question of the artifact’s utility called for a hypothesis-testing.

However, the choice of a mixed methods approach adds important value to this work and contributes to the validity and complementarity of new findings. When the goal is to investigate a novel phenomenon for which current research is fragmented, inconclusive, and ambiguous, mixed methods approach contributes to development of novel theoretical perspectives (Venkatesh et al., 2013).

Furthermore, in contrast to Mode 1 knowledge production (which is purely academic and monodisciplinary), this design project, which combines two complementary perspectives (science-based and human-centred design¹³), generates Mode 2 context-specific scientific and practical knowledge, which is more multidisciplinary and focused on solving complex and relevant field problems (Van Aken, 2005; Pascal et al., 2013). Considering that there is a lack of existing theoretical contributions in the field of Green IS that could address a particular field problem of promoting individuals' PEB (see Section 1 of Chapter 1), we believe that Mode 2 knowledge production is relevant and needed to generate knowledge in this emerging domain, which justifies the choice of adopted methodology. In the next section, we detail the research steps carried out to achieve the intended research outcomes – producing relevant, contextual field knowledge.

2. Research design and intended research outcomes

2.1. Overview of guidelines, procedures and outcomes

This research project followed well established steps (Peppers et al., 2008) and guidelines (Henver et al., 2004) for conducting a DSR study, that resulted in specific outcomes. The following figure (Figure 6) presents a research design schema, and summarizes the key steps taken that led to important research outcomes.

13 While science-based design is based on academic research and focuses on the development of explanatory and prescriptive knowledge to solve a specific field problem, human-centred design implies the active participation of users in the design process and provides understanding of a specific phenomenon. The combination of science-based and human-centered design leads to the co-creation of new knowledge (Pascal et al., 2013).

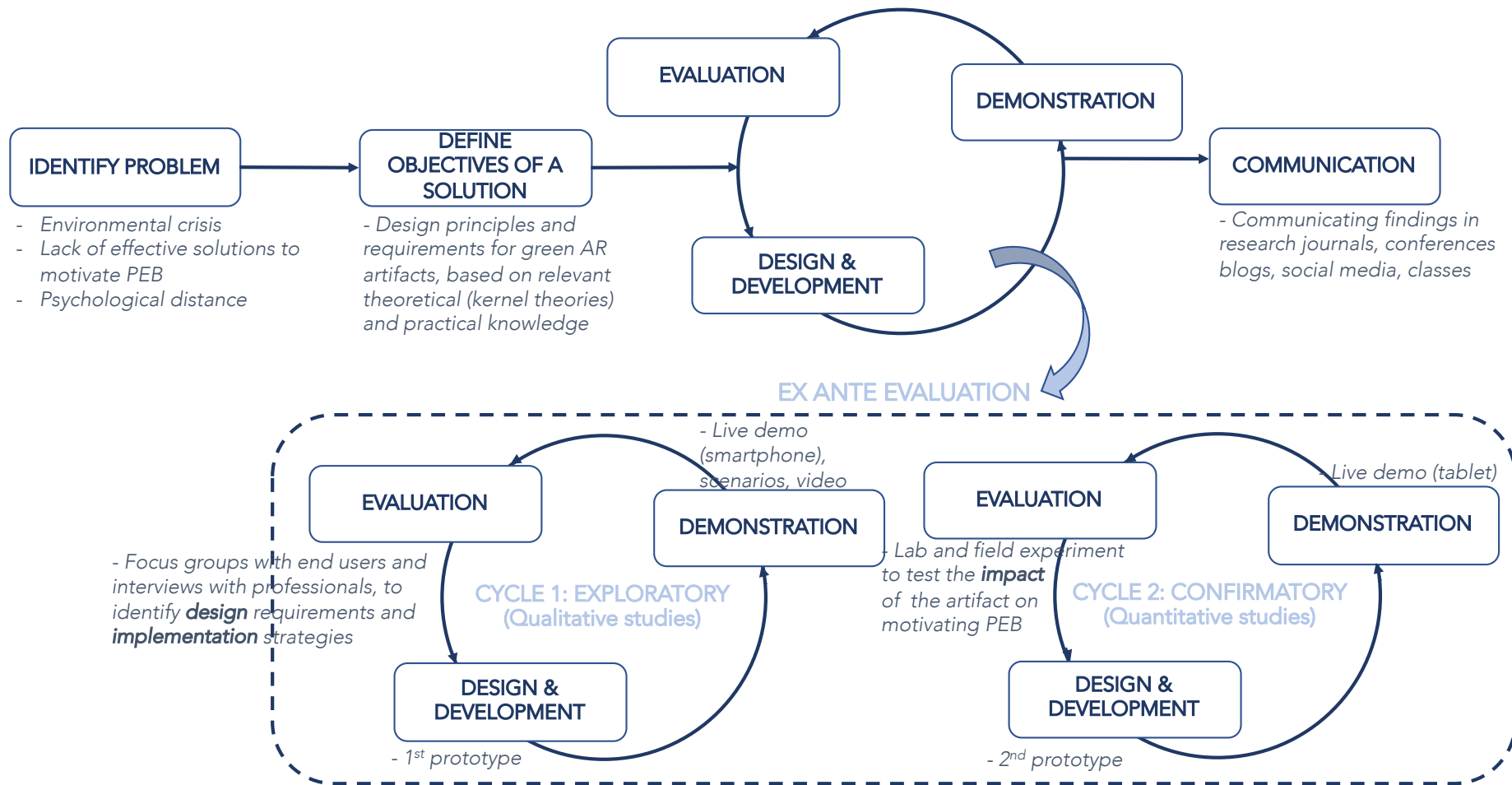


Figure 6. Research design schema (steps and outcomes), following Peffers et al. (2008)

Initially, we **identified the problem** (the global environmental crisis of plastic pollution and the challenge of promoting pro-environmental behaviors) and the motivation for the project. To fully understand the problem and the importance of solving it, we reviewed the literature and empirical sources on environmental communication and its challenges (see General Introduction) and defined how our research could contribute to solving this problem.

Next, we **defined objectives of a solution** by analyzing peer-reviewed publications from IS and other disciplines (as presented in Chapter 1). After reviewing the literature, we found a lack of studies on the role of immersive technologies in promoting pro-environmental behaviors. Therefore, we consulted three kernel theories to derive initial design principles, that we used to design our artifact. These theories guided the design for each of the three aspects of the artifact: information, social and technology aspects (Section 3 in Chapter 1).

Then we conducted **two design-demonstration-evaluation iterations (cycles)**. The first cycle consisted of three qualitative studies, and the second cycle consisted of two quantitative studies).

In each cycle, we **designed and developed the artifact**. In collaboration with external developers, we instantiated a low-fidelity prototype (described in Section 3 of Chapter 2), that was used in evaluation activities. Each evaluation cycle informed the further artifact's design.

The next step in the cycles was to **create demonstration materials** that were used to evaluate the artifact. We demonstrated the utility of the artifact using scenarios, videos, and real-time on-site demonstrations. Each of the demonstration materials is discussed in more detail in the empirical studies in Chapter 3 and Chapter 4.

Finally, in each cycle, the artifact was **evaluated (*ex ante*¹⁴ evaluation)** with different types of users to investigate its potential to solve the addressed problem. To evaluate the artifact from different perspectives, we conducted qualitative (focus groups and interviews) and quantitative (experimental) methods (see Chapter 3 and Chapter 4 for empirical studies). In this phase, we alternated back and forth between steps three, four, and five as each evaluation activity influenced further design of the artifact.

¹⁴ *Ex ante* refers to the evaluation in the phase before the artifact was implemented in practice (Sonnenberg & vom Brocke, 2012).

At the end of each cycle, **the research findings of each empirical study were communicated** to academics and other relevant audiences. This included presentations at IS conferences and workshops, submissions to relevant journals, incorporating findings into teaching materials, writing articles for the local press, and covering our work on social media platforms (see Table 2 in the General Introduction for the list of publications).

For each step in our research process, we applied a set of guidelines (G) (Henver et al., 2004). In step 1, we applied G2 (problem relevance) and G4 (research contributions); in step 2, we applied G6 (design as a search process); in step 3, we applied G1 (design as artifact) and G4 (research contributions); in step 4, we applied G1 (design as artifact and G3 (design evaluation); in step 5, we applied G3 (design evaluation) and G4 (research contributions); finally, in step 6, we applied G7 (communication of research). In all research steps, we made sure to apply G5 (research rigor). The following figure (Figure 7) summarizes the steps, guidelines, and outcomes of this PhD project.

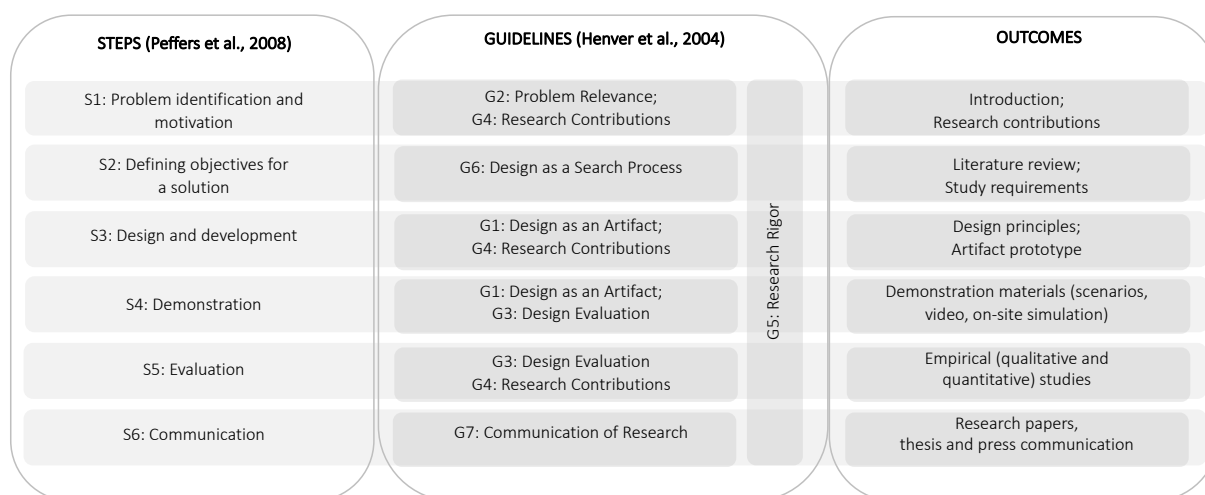


Figure 7. Summary of the research steps, guidelines, and outcomes

2.2. Theoretical and practical contributions of Design Science Research projects

DSR can make theoretical and practical contributions. A theory is a form of knowledge consisting of a set of statements that describe, explain, or predict relationships between constructs. There are five types of theories in IS: (1) theory for analysis, (2) theory for

explaining, (3) theory for predicting, (4) theory for explaining and predicting, and (5) theory for design and action. An outcome of DRS is a design theory-prescriptive knowledge for design and action that explains *how to do something* (Gregor, 2006). The theoretical contribution of this thesis is detailed in Subsection 4.1 of the General Discussion.

An important theory for DSR is a kernel theory – any descriptive theory used during the construction of an artifact to explain the rationale for a particular design (Gregor & Hevner, 2013; Gregor, 2006). We used three kernel theories, and each of them influenced one of the aspects of artifact design, namely information, social, and technology aspects (De Leoz & Petter, 2018). The set of kernel theories that formed the basis for the artifact design are presented in Chapter 1, Section 3.

In addition to the knowledge contribution, the practical component of a DSR study is an artifact – a conceptual or tangible object that people have created to solve a real-world problem (Simon, 1996; Hevner et al., 2004). An artifact can take four different forms: constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations (systems that are prototyped or implemented in practice) (Hevner et al., 2004; March & Smith, 1995). The output of this DSR project is an instantiation – an artifact based on AR technology, in its early conceptual stage, accompanied by guidelines for its further development and implementation strategy, presented in Section 3 of the General Discussion.

2.3. Considering social impacts of an artifact

Design Science focuses mainly on the technical aspects of an artifact. However, to fully understand the practical contribution of the artifact, it is important to also consider its social impact. Although the true impact cannot be defined until the artifact is fully implemented in a social setting, considering the social aspects in the design process helps researchers define other qualities that go beyond traditional utility evaluation (De Leoz & Petter, 2018).

During the DSR process, we followed guidelines for incorporating social components into an IT artifact (De Leoz & Petter, 2018). First, the design of the artifact was informed by the literature on social influence (Kelman, 1958) (see Subsection 3.2 in Chapter 1). Then, in evaluating the artifact, we confronted participants with hypothetical social situations and asked

them to evaluate the potential social impact of the artifact (e.g., how would the artifact be used and what would be the social consequences if integrated into social media platforms) (see Chapter 3 for results of empirical studies).

Our goal was to consider each of the three design aspects of the artifact (information, social, and technology aspect) (De Leoz & Petter, 2018). Therefore, we translated the initial design principles into specific design requirements, and communicated these specifications to an external AR developer. The detail of artifact's design, concept, and intended use is explained in the next section.

3. Artifact description¹⁵

3.1. Pre-development investigation

Following the recent trends of leading IT companies such as Google, Apple, Microsoft, and Meta, we have turned to new types of media formats that set new standards for communication, entertainment, and social interaction (Kelly, 2022; Morse & Stein, 2022). The real-life story that inspired this project was the redesign of Berlin's Museum of Natural History in VR and an immersive 360° VR video about the dinosaur Giraffatitan created by Google Arts & Culture. Using a VR headset, museum visitors experienced the full-size dinosaur virtually '*brought to life*' (Google Arts & Culture, 2016). Motivated by the idea that we can use immersive media to recreate real-world experiences, our goal was to create an artifact that could simulate risk experiences with environmental threats.

In deciding between the two most popular immersive technologies – VR and AR, we gave preference to AR due to its practicality (unlike VR, no additional equipment is required), mass accessibility (most smartphones on the market today support AR (Farshid et al., 2018)), and popularity (major social media platforms report millions of users interacting with AR through their services (Meta, 2019)).

15 This study was presented at AIM PRE-ECIS2023 Paper Development Workshop, 2022 (online) and was conditionally accepted at the European Conference on Information Systems (ECIS) 2023 (Kristiansand, Norway) in February 2023.

Before starting with design, we analyzed relevant academic and empirical sources to define the state of the art and analyze similar artifacts (Hevner et al., 2004; Gregor & Hevner, 2013) (see Section 1 and Section 2 in Chapter 1). Although such applications are still in their infancy, there are a growing number of examples that demonstrate the potential of immersive storytelling. Global leaders in environmental communications are using augmented and virtual reality to raise awareness and educate the public about social issues. For example, UN uses AR to raise awareness about plastic pollution with immersive face camera effects (UNEP, 2021a; Vasey, 2021), and VR to put users in the shoes of a refugee (UNVR, 2015).

The academic literature on AR/VR to address environmental sustainability challenges is sparse. A growing number of studies on the effects of AR/VR on human behavior comes from the Virtual Human Interaction Lab (VHIL) at Stanford University. As far as we know, there is no academic work that proposes to simulate environmental problems through AR experiences. Therefore, this study aims to fill this gap by developing a testable tool that can be used to gain new insights. We have not found an artifact on the market with the specifications needed for our study – a system that uses AR as a means to simulate the consequences of environmental threats to marine animals. Therefore, we took the next pre-development phase: we have defined initial design principles that will guide the development of the system.

Our design was guided by three kernel theories (more on these in Section 3 of Chapter 1), each of which influenced one of the three design aspects: information, social, and technology aspects (De Leoz & Petter, 2018). The information aspect of the artifact was influenced by Construal Level Theory, which emphasizes the importance of experience in the perception of psychological distance (Trope & Liberman, 2010; van der Linden et al., 2015). Social Influence Theory, which states that human behavior is strongly influenced by social norms (Kelman, 1958), served as a guide for the social dimension of the artifact. Third, Persuasive Technology Theory (Fogg, 2003) was an inspiration for defining the technological aspect of the artifact, which aims to influence behavior without coercion. Next, we needed to familiarize ourselves with the technical specifications of AR systems in order to understand how AR works.

3.2. Understanding augmented reality

In 1995, Milgram and colleagues defined the reality-virtuality continuum (see Figure 8), which defines a large class of immersive displays that the authors refer to as mixed reality (MR). It

ranges from fully real environments (consisting of real physical elements that can be observed either directly or indirectly) to fully virtual environments (a computer-generated environment that can be observed via screens or immersive technologies) (Milgram et al., 1995).

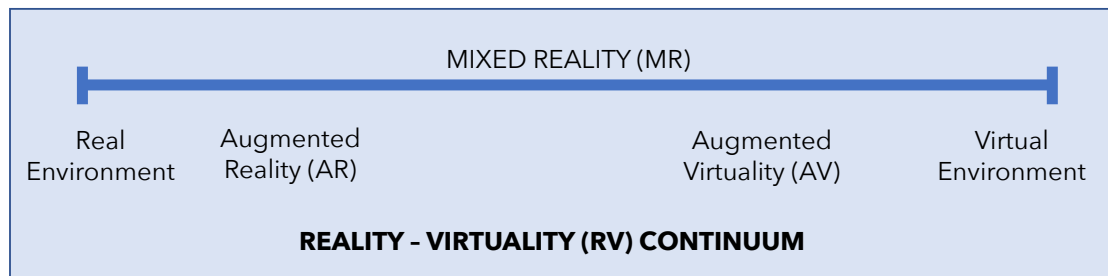


Figure 8. Reality-Virtuality Continuum (adopted from Milgram et al., 1995)

AR is a variant of virtual reality (VR), with one key difference: while VR fully immerses the user into a synthetically simulated environment and replaces reality, AR augments reality by superimposing virtual objects over the real world (Azuma, 1997). There is also a difference in hardware: while VR requires a headset, AR can be used without a headset. AR can be defined as any system that (1) combines real and virtual elements, (2) is interactive in real time, and (3) is captured in three dimensions (Azuma, 1997). While people consume a book by reading, a movie by watching, or music by listening, people consume AR by experiencing (Craig, 2013). AR relies on computer vision, an area of artificial intelligence that enables computers to construct a meaningful understanding of the physical world (Ballard & Brown, 1982). The combination of different technologies is required to bring digital content into visual perception (Kipper & Rampolla, 2012):

- **Displays** – AR system requires display technologies which can create an impression of merging of the real and the virtual world (Craig, 2013). There are three main types of displays used in AR: (1) Head Mounted Displays (HMD); (2) handheld displays, such as smartphone; and (3) spatial displays, which project digital content directly onto physical objects (Carmigniani et al., 2010).
- **Input devices** – besides sensors that register user's movements, sensors for collecting user input information are buttons, touchscreens, keyboards, phone, gloves, wristband, and others (Craig, 2013; Carmigniani et al., 2010).

- **Tracking devices** – the tracking method varies depending on the AR system, but also depends on the environment in which AR is used. Some of the most common tracking sensors are: camera, a sensor needed for computer vision; Global Positioning System (GPS), a satellite-based navigation system; gyroscope, a sensor that reports orientation; compass, a sensor that reports the direction a user is pointing; and accelerometer, a sensor that reports direction and changes in movements (Craig, 2013).
- **Computer** – any AR system requires a processor that can coordinate sensory input information and execute the task of the AR program (Craig, 2013). In other words, the AR system requires a computer with a powerful central processing unit (CPU) and a sufficient amount of memory capacity (Carmigniani et al., 2010).

An AR experience begins with recognition – a process in which device’s hardware and software components determine where and how reality will be augmented (See Figure 9 for an example of an AR process: recognition of a pattern followed by augmentation of a digital object). In the process of understanding the surrounding environment, devices rely on one of these recognition methods:

- pattern (objects are augmented in AR after detecting a simple shape or mark),
- outline (objects are augmented in AR after detecting a body part such as hands or face),
- location (objects are augmented in AR based on detailed location information), or
- surface (objects are augmented in AR after detecting a specific surface, such as screens, floors, or walls) (Kipper & Rampolla, 2012).

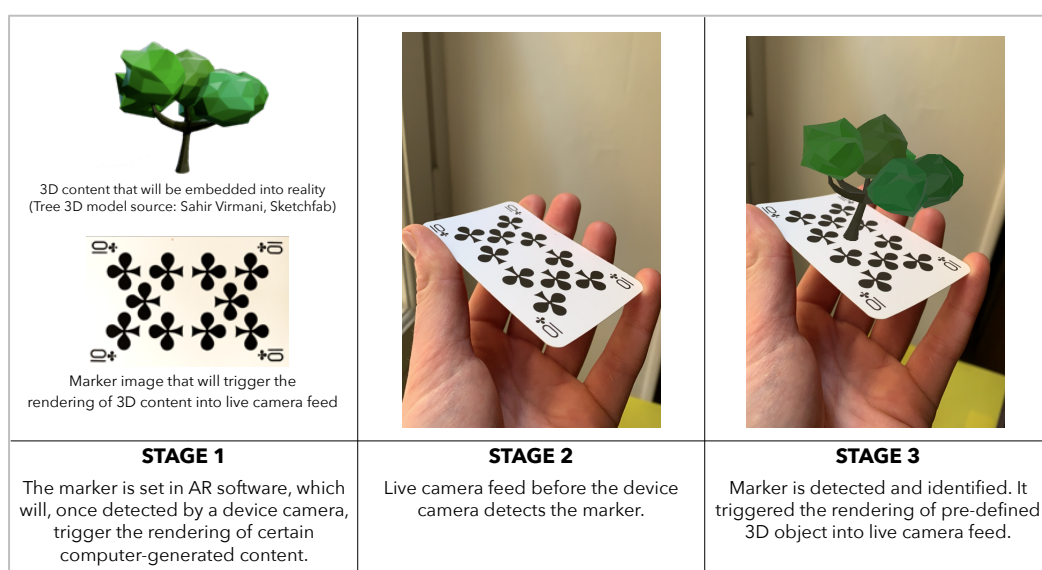


Figure 9. An example of a marker-based AR

In recent years, we have seen tremendous advances in reality-enhancing systems. Some even say that this could be the next big step in IT innovations (Cipresso et al., 2018). Certain events may have contributed to the mass adoption of AR and public interest, such as the release of the AR software toolkit AR Toolkit in 1999 (Carmigniani et al., 2010), investments by tech giants like Microsoft, Meta, and Google (Kelly, 2022), and the emergence of low-cost VR/AR equipment in the market (Castelvecchi, 2016). AR has been used in innovative and useful ways and has a wide range of applications in military, entertainment, education, navigation, art, tourism, medicine, etc. (Azuma, 1997; Kipper & Rampolla, 2012; Carmigniani et al., 2010).

Recently, mobile-based AR is undoubtedly growing in popularity (Farshid et al., 2018; Statista, 2022). One of the reasons for the mass acceptance of mobile AR is certainly the social networks. Popular platforms like Snapchat and Instagram offer their users the ability to experience AR through their camera feed and edit their content by overlaying digital content on top of real-world environments. The result: more than a billion users engage with AR on Facebook, Messenger, and Instagram (Meta, 2019).

Finally, AR developers must decide in advance on a platform for which to design. For example, AR experiences can be developed as a stand-alone mobile application or integrated with another existing platform, such as a social media platform. They also need to decide on the hardware, choosing between a mobile AR and a glasses-based AR. Considering practicality, availability, budget constraints, and usability, we decided to develop a mobile AR system accessible to a mass audience. However, prior to development, we had to map the previously defined kernel construct to the specific design requirements of the artifact, as explained in the next subsection.

3.3. Defining design requirements

To ensure transparency and rigor in our design process, we followed a framework for logical reasoning of transporting kernel theories into design principles and requirements of IT artifacts (Kuechler & Vaishnavi, 2012). In the following table (Table 14), we present the mapping of kernel constructs to design principles and requirements.

The table consists of:

- *Kernel constructs* (explanatory statements from kernel theories);
- *Design principles* (prescriptive statements about the design of the artifact); and
- *Design requirements* (detailed steps that must be taken to integrate the kernel constructs into the design of the artifact).

Kernel constructs	Mapping	Design principles	Mapping	Design requirements
Direct experience with an object or event reduces the perceived psychological distance associated with it (Trope & Liberman, 2010)	→	In order to raise the perceived seriousness of environmental issues by individuals in pro-environmental communication interventions, the environmental issues should be directly presented at familiar and relevant places because direct, personally relevant experiences are likely to bring environmental issues psychologically closer	→	<ul style="list-style-type: none"> - The artifact should enable the communication of environmental issues through immersive AR experiences - The artifact should allow AR content to be experienced anywhere in the user's environment
People's attitudes and behavior are under social influence (Kelman, 1958)	→	In order to encourage individuals' PEB in digital environment, the artifact should enable social interactions between (1) users and (2) users and the artifact, because social interactions guide behavior	→	<ul style="list-style-type: none"> - The artifact should be integrated into a multi-user platform - The platform should enable sharing of content among users - The artifact should include scenes of animals in danger to evoke empathy with the virtual creatures
Interactive technologies can influence behavior (Fogg, 2003)	→	In order for an immersive system to be effective in attempts to promote PEB, the artifact should provide interactive simulations, because interactive computer simulations are efficient in changing people's attitudes or behaviors	→	<ul style="list-style-type: none"> - The content of the artifact should be interactive and respond to the actions of the users

Table 14. Mapping kernel constructs with design principles and requirements

Mapping kernel constructs to design principles and requirements helped us define detailed design specifications, which we later sent to an external AR developer. In the next section, we explain the concept of using AR to communicate about environmental issues and explain how the artifact can be used in practice.

3.4. Conceptualization and potential use

We introduce the concept of *living* impactful events of environmental degradation through mobile AR experiences. Experiential mode of presenting information should make usually static environmental communication more dynamic and vivid. Instead of consuming environmental stories in the form of text, images, or video, one can interact with content in a form of digital holograms superimposed over real world, as AR places tridimensional digital objects into one's immediate surrounding.

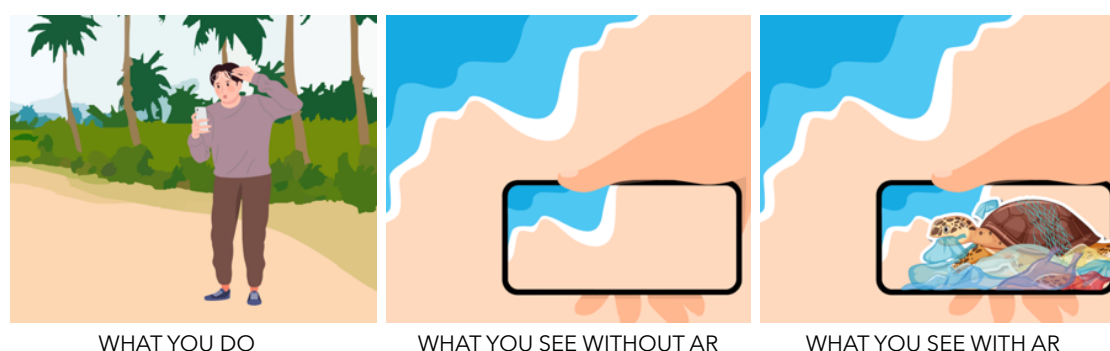


Figure 10. The concept of experiencing environmental issues through mobile AR

We have developed a prototype of an artifact that uses mobile AR technology to provide direct experience of environmental risks. The artifact augments one's reality by overlaying digital elements on top of the real world (as illustrated in Figure 10). What is normally seen through the device's camera is enriched with three-dimensional content that makes an illusion of the presence of digital objects in real life.

In these narratives we have chosen to address one of the fastest growing problems, the problem of plastic pollution (UNEP, 2021b). This problem is characterized by its temporal and spatial discrepancy: while citizens pollute the environment through excessive consumption and improper disposal of plastic products, those who suffer the consequences are mainly people from developing countries and species of marine life. Therefore, we assume that direct confrontation with the destructive side effects of plastic pollution could influence people's awareness, concern, and resulting behavior.

Here is an example of how the artifact can be used in a pro-environmental communication campaign. First, let's define two types of users: (1) communicators (mediators) - those who launch a campaign - and (2) the public (end users) - those who consume the campaign but also create the campaign content - as shown in Figure 11. To interact with campaign content, end users need a device that supports AR and a stable internet connection. Mediators (e.g., an NGO or a government) use the AR artifact as a tool to reach end users. But the campaign does not end there: once mediators reach end users, they also provide them with a tool to record unique AR-enhanced video content they can share with other users to expand the campaign's reach.

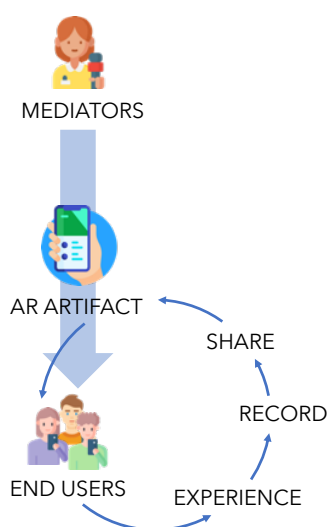


Figure 11. Conceptual diagram: AR intervention in a campaign

Using such an artifact for environmental communication offers three main advantages compared to other media formats. First advantage is vividness. Compared to static photographs and more dynamic video content, AR offers interactive immersive experiences that can create a sense of presence or *being there* (Innocenti, 2017). Such vivid and interactive experiences could be remarkable for users and motivate them to change behavior (Ahn et al., 2014).

The second advantage is personalization. Each AR experience is unique and personalized because it simultaneously connects virtual content to the user's immediate environment. For example, the same content from AR may have a different effect on a user when experienced indoors or outdoors. This offers new opportunities for tailored pro-environment communication that can be more effective than impersonal public communication (van der Linden et al., 2015).

The third advantage is the social component. Namely, AR experiences can be integrated into a multi-user platform such as social networking application, which then enable the experience and sharing of content with others in a social setting. This opens doors for influence through social norms, an important lever for influencing behavior (van der Linden et al., 2015; Farrow et al., 2017). However, we recognize that the current state of the artifact may not be attractive enough to be used and shared by users. Therefore, design and development should aim to create not only a useful end product, but also an attractive and socially acceptable one.

While moving from the conceptual to development phase, we realized a potential problem; since AR is still an emerging technology, it would be difficult to explain this concept to newcomers (users who are not yet familiar with the technology) with mere words, graphics, and pictures. Therefore, in order to proceed with the research activities, we had to develop a simple prototype that explains the concept of using AR for environmental communication. We guide through the development process in the next subsection.

3.5. From the concept to the first prototype

There was a methodological challenge to overcome in this project: AR-based artifacts are difficult to demonstrate and therefore evaluate in their conceptual phase without an actual AR system. Indeed, AR is an interactive system that overlays the real world with 3D digital content in real time (Azuma, 1997). Thus, unlike traditional media such as photos or videos, which are consumed by viewing, AR is consumed by experiencing. Therefore, in order to conduct an empirical study, we needed an AR prototype already in the first design cycle.

After translating the initial design principles into a set of detailed design guidelines and specifications (see Subsection 3.3 in Chapter 2), we proceeded to the development. The goal of the first prototype was not to develop an actual mobile application, but rather to illustrate the concept of using AR to communicate about environmental issues, which would help end users understand the purpose of the artifact. Therefore, the first prototype took the form of a simple mobile AR experience that showed a common anecdotal evidence of plastic pollution: a sea turtle caught in a disposable plastic waste such as a plastic bag and a bottle.

To create the desired AR experience, we needed two professional services: (1) an artist to create a 3D model of a turtle tangled in a plastic garbage, and (2) a developer who will integrate the

3D model into an AR experience. For the first service, we contacted an independent 3D artist through an online freelance portal. For the second service, I spent several weeks studying AR design and development. In fact, due to budget constraints, I had to attend continuing education courses to acquire technical knowledge and create an initial prototype of an AR artifact.

The simplified timeline of creating the prototype is shown in Figure 12: (1) first, I imported the 3D model into the AR software; (2) second, I created the AR scene, set real-world markers triggering the AR experience, and defined interactions between objects; (3) third, I exported the final project to a server, which was then (4) accessible through a mobile application.

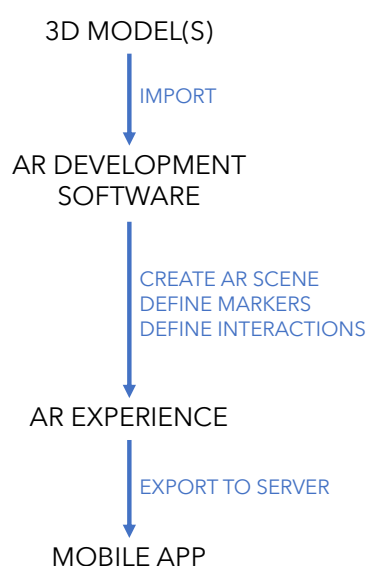


Figure 12. The process of creating an AR experience

For practical purposes, I created a simple AR experience in Meta's open source platform for creating AR camera filters for Facebook and Instagram called Spark AR Studio (now: Meta Spark). This does not mean that the final artifact will necessarily take the form of a camera filter; however, the optimal form will be determined based on user feedback as the project progresses. I set a simple marker (the image of a turtle printed on a paper) as a real-world trigger that, once detected by a device, would be obscured by a virtual 3D object (Figure 13).

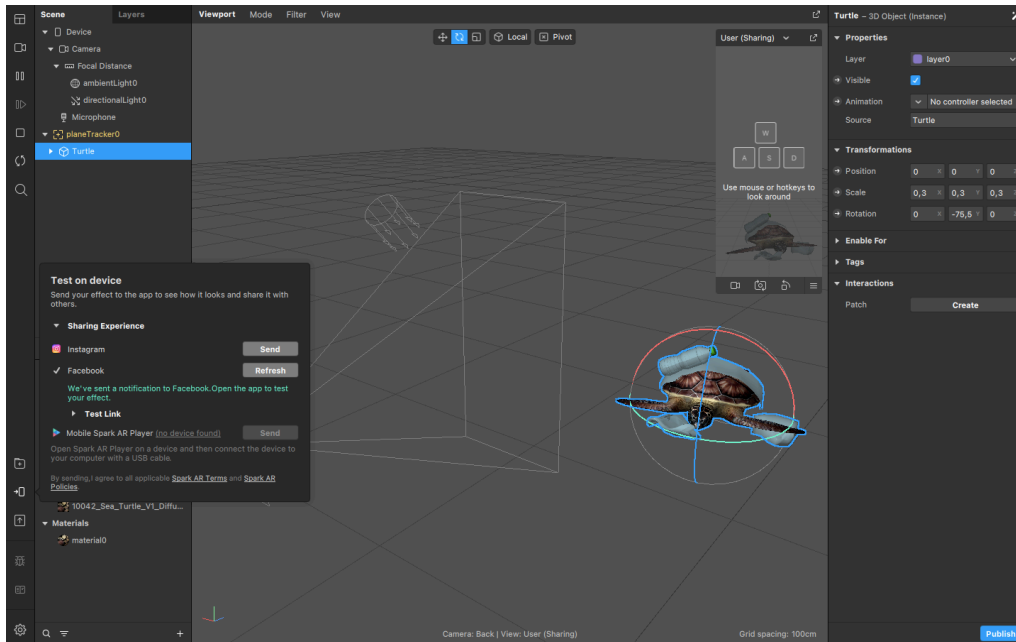


Figure 13. Setting an AR scene in Spark AR Studio (now: Meta Spark)

The AR experience was then exported to a Facebook's server and it was available as a camera filter in Facebook's mobile application. Next, we had to prepare the equipment needed for the demonstration: (1) an AR-supporting device; (2) the Facebook mobile application installed on the device; and (3) a stable internet connection. To experience the AR scene, one simply needs to open the camera feed on Facebook platform and select the camera effect. Once the device's camera understands the environment and detects the predefined real marker, it projects the 3D virtual object of a turtle overlaying the real environment onto the device's screen (Figure 14).



Figure 14. Merging real and digital: digital turtle superimposed over real beach

The following figure (Figure 15) illustrates the use of the first prototype of the artifact in practice. A person using the artifact sees a digital hologram in AR through the lenses of the device's camera. The right image shows how the artifact is used: one simply has to point a smartphone at the real surface on which one wants to augment virtual objects. The image in the middle shows what a user sees in a normal camera feed (without AR), while the image on the right shows what a user sees in a camera feed with AR. Note that while we took the images at the beach, the artifact can be used anywhere. This is an advantage of the system, but also a potential drawback, if the overall AR experience would appear unrealistic (e.g., if a sea creature appears in a user's bedroom).

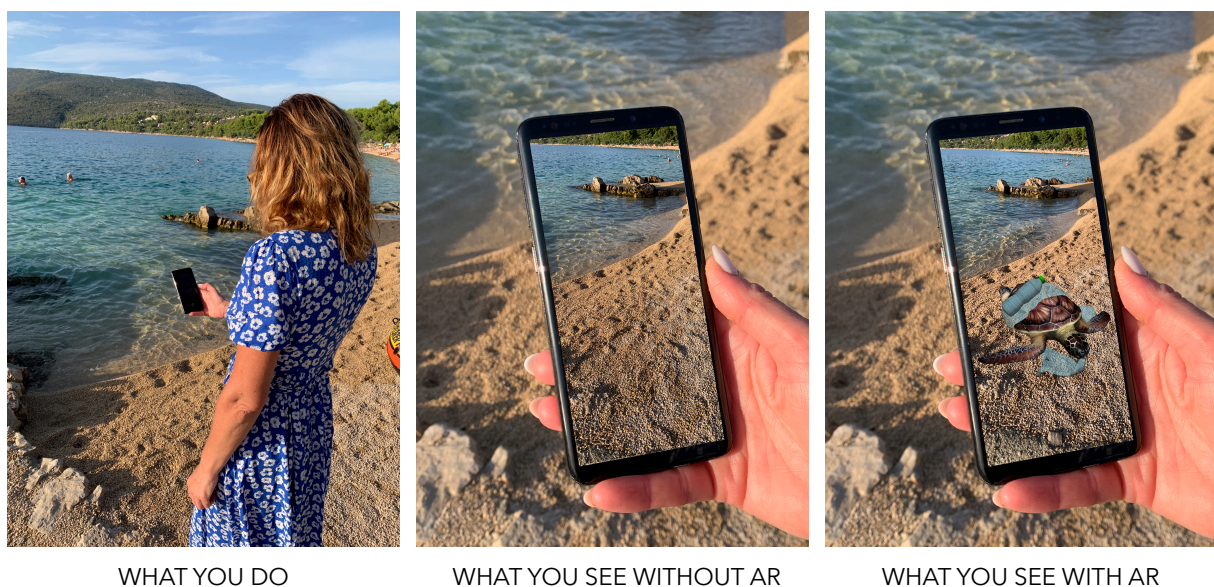


Figure 15. The first prototype: demonstration of use

Once we created the prototype that demonstrated the purpose of the artifact, we moved on to its evaluation. The assessment activities informed the design of the artifact. In each design cycle, the design of the artifact was adjusted according to the design guidelines we had received in a previous evaluation, and the updated version was used in further evaluation activities. In the next section, we explain how, why, and with whom we evaluated the artifact to assess its ability to solve a real-world problem.

4. Artifact evaluation: Mixed methods approach

The crucial activity of a DSR study is the evaluation of the artifact, which aims to obtain feedback on its utility, quality, and efficacy, and to improve its design (Hevner et al., 2004). To evaluate our artifact from multiple perspectives, we used mixed methods – a research approach that combines qualitative and quantitative methods in a research inquiry (Venkatesh et al., 2013; Teddlie & Tashakkori, 2009) and provides an opportunity to take a comprehensive look at a IS phenomenon for which existing knowledge is inconclusive. Such comprehensive data collection is otherwise more difficult or impossible when only qualitative or only quantitative methods are used (Venkatesh et al., 2013; Jokonya, 2016).

The main advantage of the mixed methods approach is the ability to simultaneously answer confirmatory and exploratory research questions (Teddlie and Tashakkori, 2009). We recognize that this method can present challenges as it is time consuming, requires extensive data analysis skills, and typically requires more space to report findings (Pascal et al., 2018). However, choosing a mixed methods approach was appropriate for answering the research questions: with this approach, we achieved complementarity and completeness of data needed to develop and test theory (Venkatesh et al., 2016). Our goal with our empirical studies was to:

- (1) Receive detailed feedback on the information, technical, and social aspects of the artifact's design;
- (2) Define a way to implement the artifact in practice;
- (3) Test the utility of the artifact, namely, its ability to reduce psychological distance and promote individuals' pro-environmental behavior;
- (4) Investigate user intentions to use the artifact.

A researcher can use different methods to evaluate the artifact. Hevner et al. (2004) created a taxonomy of evaluation methods divided into five categories: (1) observational methods, including case studies and field studies; (2) analytical methods, including static analysis, architectural analysis, optimization, and dynamic analysis; (3) experimental methods, such as controlled experiments, simulations, or expert evaluations; (4) testing methods, including functional (black box) and structural (white box) testing; and (5) descriptive methods, which use informed arguments or scenarios (Hevner et al., 2004).

In this project we have used experimental and descriptive methods. More specifically, we evaluated the artifact through focus groups, questionnaires, interviews, and a controlled laboratory experiment, and demonstrated its utility through scenarios. We used these methods sequentially, meaning that the results of one study influenced the other (Venkatesh et al., 2013). The research rigor in the combination of qualitative and quantitative methods produced comprehensive and informative results.

We also combined data from two perspectives, namely from two different types of users. As explained in the Subsection 3.4 in this Chapter, there are communicators – professional users (such as environmental communicators, non-profit organizations, and government agencies), who act as mediators; and end users, to whom professionals direct their communication campaigns. The following table (Table 15) explains the evaluation activities, their purpose, and the sample that participated in the evaluation of the artifact.

	Research method	Purpose	Sample	Addressed research question
QUALITATIVE	<i>Focus groups</i>	getting in-depth feedback on the artifact's design (information, technical and social aspect); defining a way to implement the artifact in practice	End users of the artifact	RQ1
	<i>Interviews</i>	getting in-depth feedback on the artifact's design (information, technical and social aspect); defining a way to implement the artifact in practice	Mediators (Professional subjects from the domain of environmental communication)	RQ1
QUANTITATIVE	<i>Laboratory experiment</i>	testing the utility of the artifact (is it able to minimize the perceived psychological distance and promote individual pro-environmental behavior)	End users of the artifact	RQ2

Table 15. Overview of evaluation activities

The empirical data collection methods corresponded to artifact's evaluation objectives, and are discussed in the following two subsections.

4.1. Qualitative approach: Exploratory investigation

The qualitative part of the evaluation was exploratory and was conducted using two different data collection methods and two different samples: (1) focus groups were conducted with participants representing typical end users of new media, and (2) individual interviews were conducted with environmental communication professionals.

The choice of qualitative research method in this case is consistent with the objectives of the study. Namely, we wanted to gain a deeper understanding of end users' and professionals' perceptions of information, social, and technology aspects of the AR artifact's design, and to determine what factors might influence the success of the implementation strategy in practice.

The data were recorded and then transcribed by an independent person. The data analysis phase involved several coding cycles until the data were transformed into a more comprehensive theoretical model. Guidelines were followed to ensure scientific rigor and credibility (Gioia et al., 2013). Detailed methodological procedures for qualitative studies can be found in Chapter 3, more specifically in Subsections 1.1, 2.1, and 3.1.

4.2. Quantitative approach: Confirmatory investigation

The quantitative part of the evaluation was confirmatory and provided insights into two important and measurable elements: the impact of the artifact on (1) psychological distance and (2) individual pro-environmental behavior, measured in voluntary donations to an environmental organization. In this case, we chose to measure real-world choices and include larger samples, so collecting quantitative data was more appropriate.

To answer the second research question, we conducted two controlled experimental studies in which we measured individuals' environmental awareness, psychological distance, and pro-environmental behavior after interacting with a short AR experience. We measured actual behavior by the generosity in donating money to an environmental organization. The details of the experimental design can be found in Chapter 4, Subsections 1.2 and 1.3.

PART TWO:

DESIGN CYCLES:

SCENARIOS OF USE AND

EXPERIMENTATION

CHAPTER THREE:

EXPLORATORY STUDIES

This chapter assembles empirical studies conducted in the first design cycle, with the goal of answering exploratory research question: “*How can a green AR artifact for promoting pro-environmental behavior be designed, evaluated, and implemented in practice?*” To answer this question, we conducted several qualitative studies with different types of users of the artifact (end users and mediators). This chapter consists of three sections, each containing an empirical study that produced insightful and rich findings. These findings were communicated to academic community through a journal publication and scientific conferences.

Initially, we started with a pilot focus group with end users. The purpose of the study was to evaluate the early opinions on AR in environmental communication. Although the study sample was small (seven participants), the results were informative and the study was helpful to determine whether our focus group guide comprehensively covered all the topics we wanted to address.

The second section presents the qualitative study with end users. Following the pilot study from the first section, we slightly refined the artifact’s design and the focus group guide, and conducted another six focus groups with end users in two different countries (in France and Croatia). The aim of the second study was to evaluate the AR artifact in its conceptual phase, and to obtain feedback from end users on the design and potential use of the artifact. The rich empirical data, analyzed according to rigorous guidelines (Gioia et al., 2013), led to a grounded theory model (Strauss & Corbin, 1990) and development of concrete practical guidelines for implementing green AR artifacts in practice.

Third, we reached out to environmental communication professionals to supplement our findings from the mediators’ perspective. We conducted semi-structured interviews with nine experts: marketing manager at an oceanographic museum, nonprofit organization founder, AR/VR developers and designers, researchers, and policy advisors. Following the same guidelines for conducting qualitative studies (Gioia et al., 2013), the results of the study were then used to refine the initial design principles, suggest ways to expand the artifact, and define strategies for its potential practical implementation.

1. Gathering early opinions on the use of augmented reality in environmental communication: Pilot focus group with end users¹⁶

If people could experience firsthand what plastic pollution is doing to marine life, such an experience could influence their awareness, risk perception, and pro-environmental behavior. We developed a prototype of a system that uses AR to superimpose a three-dimensional digital object of a sea turtle caught in plastic waste over real world. The goal of this pilot study is *to investigate the early adoption of this type of environmental communication* among potential end users and to analyze individuals' opinions, viewpoints, and beliefs regarding campaigns promoting pro-environmental behavior. Moreover, with this pilot study, we want to evaluate if our focus group guide comprehensively encompasses all the topics we would like to address.

1.1. Methods

With the aim of investigating the early adoption of AR as a means of environmental communication among potential end users, a qualitative study was conducted using the focus group method (Sutton & Arnold, 2013). The research was conducted under controlled conditions at the end of January 2020 at the premises of the Faculty of Economics and Business in Rijeka, Croatia. All participants signed a consent form to participate in the study.

The sample consisted of seven second-year Master students who, according to their age characteristics, belong to Generation Y (those born between 1981 and 1996). The reason for selecting such a sample is that they were born and raised in the “digital age” and are therefore potential early adopters of such innovations (Rogers, 1962). At the time of the study, all participants indicated that they considered themselves to be moderately familiar with new technologies. Detailed socio-demographic data on the participants can be found in the following table (Table 16).

¹⁶ This study is published in Croatian journal *Ekonomski pregled* (eng. Economic review), and was presented at the conference IEEE VR 2023 (Shanghai, China) (a poster co-authored with Daniel Pimentel and Kay Vasey).

#	Age (years)	Sex (m/f)	Year of study	Familiarity with new technologies (1 – 5)*	Have experienced augmented reality (yes/no)
1.	23	M	2nd year of Master	3	YES
2.	23	F	2nd year of Master	3	YES
3.	24	F	2nd year of Master	3	YES
4.	24	F	2nd year of Master	3	YES
5.	23	F	2nd year of Master	3	YES
6.	24	F	2nd year of Master	3	YES
7.	25	F	2nd year of Master	3	YES

*1 – I am not familiar at all; 5 – I am extremely familiar

Table 16. Socio-demographic data about participants

For research purposes, we have developed a simplified prototype of an artifact that allows users to observe the consequences of plastic pollution in AR. By looking at the screen of the mobile device, the real world is augmented in real time by a three-dimensional model of a sea turtle caught in plastic waste (Figure 16 - right). The system is programmed so that a projection of a turtle appears on the screen when the device's camera detects a specific marker in the real world (Figure 16 - left). The system was developed using opensource software for creating Facebook AR camera effects called SparkAR (now: MetaSpark) and is available on the social networking platform Facebook as a camera effect. During the focus group, participants had the opportunity to personally experience the described AR content using the device iPhone X.



Figure 16. Screen capture of the AR experience during the focus group: process of marker recognition (left) and projection of a digital 3D object on the real world in real time (right)

The questions posed to the focus group participants were aimed at achieving the objective of the study. The scientific framework of the work that influenced the composition of the focus

group guide was exploratory, but also partially inspired in part by the Technology Acceptance Model - TAM (Davis, 1989) (see Appendix 3 for a complete focus group guide). The categories of questions discussed in the focus group were as follows:

- Participants' opinions on environmental conservation campaigns;
- Participants' opinions on factors influencing the performance of pro-environmental behaviors;
- Participants' opinions on AR as an environmental communication tool.

1.2. Results and discussion

1.2.1. Participants' opinions on environmental conservation campaigns

In the very introduction of the discussion, the participants were asked to state their views on environmental protection campaigns: how did they learn about the problem of plastic pollution, through which media did this information reach them, and what kind of campaigns have an impact on the formation of their awareness of the problem.

Participants get informed about environmental problems mainly through social networks (Facebook, Instagram) and through domestic and foreign media, and they have also heard about plastic pollution from famous people. Participants also noticed that some stores started to promote the reduction of the consumption of plastic products, by canceling the sale of single-use plastic bags or by awarding additional points for loyalty programs to those customers who refuse a plastic bag when shopping.

- *Participant no. 3: Well, mostly everything is generally circulating on social media, Instagram right now... famous people... for example, Formula 1 drivers, Lewis Hamilton talks about it a lot, Leonardo DiCaprio...*
- *Participant no. 5: In Kaufland¹⁷, too, they abolished those plastic bags. And that whole campaign 'we are environmentally conscious'...*

Between two plastic pollution awareness campaigns, one showing a plastic bag floating in the ocean and the other showing a sea turtle trapped in a plastic bag, all participants concluded that

¹⁷ Kaufland is a German hypermarket chain that has its shops in Croatia.

campaigns showing animals in danger were more appropriate. They cite compassion for another living creature as the reason. Moreover, they are already used to seeing a plastic bag in the ocean, so visuals containing such scenes do not catch their attention. The participants believe that negative scenes such as the consequences of plastic pollution for animals are shocking and attractive, worth attention and are likely to be shared on social networks.

1.2.2. Participants' opinions on factors influencing the performance of pro-environmental behaviors

During the discussion, participants commented on what influences their decisions to engage in pro-environmental behaviors. The following is a summary of participants' opinions on the influencing factors.

(A) Motivating factors

Animals that elicit empathy. Participants believe that animals, especially when they are in danger, evoke empathy in people. As examples, they cite plastic pollution awareness campaigns that use scenes of dolphins, sea turtles, or whales, and reports of fires in Australia with photos of koalas in danger.

- *Participant no. 3: Because it is a living being.*
- *Participant no. 6: Yes, and then it's more emotional.*
- *Participant no. 6: We are all weak for animals.*

When asked which animals they thought would be appropriate to evoke empathy, participants made several suggestions: a dolphin, seahorse, or other animal that gives the impression of being helpless; but also whales, so that people understand that even such a large and strong animal can be endangered due to environmental problems; and the fish we eat, so that people understand that microplastics pose an indirect threat to us, i.e., to the entire food chain.

Personal relevance. Participants believe that it is important to show people plastic pollution in a familiar place they have an emotional attachment to (e.g., their favorite beach) in order to bring them closer to the problem psychologically and so that they can understand it.

- *Participant no. 3: I think it would work exactly... to show something that we are connected to. People are emotional beings. And they always fall for that particular emotion.*

Attractive and shocking scenes. Participants believe that the easiest way to process information and remember details is by visualizing it. When it comes to ‘ugly’ or disturbing scenes, participants claim that such scenes are desired in campaigns. They describe them as realistic, interesting, and worthy of attention. As examples of successful and disturbing campaigns that people like to follow and share on social networks, they cite scenes of animals in distress, scenes of Notre Dame Cathedral burning in Paris¹⁸, and disturbing reports of the pandemic caused by the virus COVID-19.

- *Participant no. 3: Well, people like it, in general.*
- *Participant no. 5: Because it is realistic.*
- *Participant no. 5: If everyone is watching, she is watching, I will be watching too.*
- *Participant no. 1: They will be curious.*

Social norms. Participants’ views confirm that social norms influence behavior - if society accepts certain patterns of behavior, individuals will be reluctant to do the opposite because everyone is trying to ‘fit in’. However, while some participants believe that it is possible to influence adults to change behavior, some participants disagree. They believe that, in addition to close people, famous people on social networks – known as influencers – have great power to influence others. However, they point out that it is important to choose such people carefully so that their lifestyle is consistent with what they promote. While some participants believe that society as a whole must put pressure on individuals, others agree that the actions of individuals can also be very motivating.

- *Participant no. 4: I think it should be done through social media and through influencers, famous people who are followed by a lot of people. Because, like ‘great, he’s doing it, now I’ll do it too’. Maybe that way...*

18 <https://www.bbc.com/news/world-europe-47941794>

- *Participant no. 4: Stupid example, but blogger, Ema Luketin. She made everyone buy metal straws. And she constantly promoted metal straws. And then they started (...) ‘Great, she has it, I have to be like her’.*

Rewards and punishments. According to participants, rewards and punishments are also effective ways to encourage pro-environmental behavior. While they cite financial fees for improper waste separation as examples of punishments, rewards can also be symbolic, such as loyalty points in stores for refusing to buy a plastic bag.

- *Participant no. 3: I think people should even be rewarded if they recycle something. That way they would be even more motivated (...)*
- *Participant no. 5: You don’t even have to get money, but something... just enough to make you feel like you’ve done something.*

(B) Demotivating factors

Waste management system. During the discussion, insight was also gained into participants’ views on the factors that present barriers to implementing pro-environmental behaviors. One of the most important factors is the waste management system, which participants felt was not working as it should. Frustration, disappointment, and distrust - participants blame the waste management system for failing to separate waste. They sarcastically joke describing how all their efforts are in vain because they often witness waste from different containers being transferred to the same, larger container.

- *Participant no. 1: And again we have an interesting situation: they force us to recycle and then a truck comes and - everything into the same bin!*
- *Participant no. 4: I tried to recycle everything for two months. I bought those bins for waste separation at IKEA, until I was drinking a coffee and saw a container that merges the waste from all three containers into one.*
- *Participant no. 5: Yes. Because you are trying, you want to change something and you invest time and everything in it and then he comes and, just like that, “all in one” (laughs).*

Price. When deciding which product to buy, participants admit that price plays an important role. Indeed, between a disposable plastic bag, which costs 1 HRK¹⁹, and a biodegradable bag, which costs 4 HRK, participants prefer to choose the cheaper or the free bag. They name two proposals as a solution: to lower the price of a biodegradable bag below the price of a single-use plastic bag, or to abolish the possibility of buying a single-use plastic bag and, instead, to provide only biodegradable bags to choose from - no matter what the price.

- *Participant no. 4: I think they should really lower the prices, because I see the same thing, in Plodine²⁰, that biodegradable bag costs 4 HRK. And this (plastic) one is 1 kuna. So they should swap it...*
- *Participant no. 3: More expensive production.*
- *Participant no. 4: Well, I know it is, but then let's cancel these! Let them only have biodegradable ones. 4 HRK - 4 HRK. Okay.*

Contradiction. One of the themes that elicited strong reactions from participants relates to campaigns or actions that participants see as contradictory. For example, participants do not see the point of eliminating the sale of single-use plastic bags in stores, since most of the products they buy on a daily basis are packaged in single-use plastics anyway. In addition, participants believe that it is pointless to promote the reduction of one environmental problem (plastic pollution) while creating another (destruction of natural resources such as forests - due to the need for paper packaging). They conclude that environmental conservation campaigns should not be promoted through the printed press and do not see the solution in replacing disposable plastic bags with paper bags.

- *Participant no. 5: And in Kaufland, they have now abolished those plastic bags. And that whole campaign 'We are environmentally conscious' and then you come to the fruit department and people tear those plastic bags like crazy... (laughs) just so they don't need to buy this (reusable) bag.*
- *Participant no. 3: Again, it does not make sense to me... First there was a story that forests should not be cut down for paper... Then they started to produce plastic... Well,*

19 HRK (Croatian Kuna) was the currency of Croatia until December 2022. Last exchange rate: 1 HRK=0.1327 €
20 Plodine is a Croatian supermarket chain.

plastic was great, and now we are back to that paper again, so we will destroy forests again. We are spinning around non-stop, there is no moving forward at all, in my opinion.

Wrong senders of messages. Participants find it frustrating and demotivating when the message to protect the environment comes from a person whose lifestyle is significantly different from what they promote. As examples, they cite celebrities who promote environmental protection and own luxury cars or private planes, companies that claim to be environmentally conscious but print a lot of paper, or countries that claim to be ecological but are actually among the biggest polluters. They also referred to the young Swedish activist Greta Thunberg and condemned the media that exploit her health situation to promote environmental protection. On the other hand, participants expressed their dissatisfaction that unknown people who do good for the environment rarely make it to the media.

- *Participant no. 3: (...) for Lewis Hamilton, who talks about plastic pollution, atmospheric pollution, ozone destruction, and the man has a collection of 15 sports cars, a private yacht and a private plane.*
- *Participant no. 3: So the girl (Greta Thunberg) is flying with a plane and she's talking about pollution. Well, I would kill her. It frustrates me so much, it's unbelievable (anger). And DiCaprio, I admire him as an actor, great, his work, but dude, you're really going to talk about pollution?! You sail on a 50-meter yacht, you fly with a private 'jet'. And then, one person has planted about a million trees in the last two years. Alone, takes seedlings, also some 'influencer', 'youtuber'. Nobody talks about him, at all!*
- *Participant no. 1: Yes, and there is a guy, he's 23 years old, a young scientist... He found ... he actually made some kind of machine that helps animals in the polluted ocean. Not a word about him anywhere, and Greta is everywhere (anger).*

Misrepresentations. Participants indicate that people do not find it easy to be comfortable with unrealistic depictions: even when scenes are disturbing, they believe that these scenes should be as realistic as possible. The choice of animals in campaigns is also important: if the purpose of the campaign is to evoke sympathy, predators (such as sharks) are seen as the wrong choice.

- *Participant no. 5: Maybe a stronger reaction is needed for them to react. Because if I see bad graphics...*
- *Participant no. 1: You can't relate to it.*

1.2.3. Participants' opinions on augmented reality as an environmental communication tool

All participants were familiarized with the meaning of the term augmented reality and asked to describe their experience with it. The participants are fascinated by this technology; they describe it as a powerful tool which makes it easy to forget which reality you are actually in. However, participants also expressed concern that large corporations might realize its potential and misuse it to reach the human subconscious.

- *Participant no. 7: Great. I like it. I think it's a bit 'scary' how something can be done like that... technology has advanced so much... that virtual reality is really becoming a reality...*
- *Participant no. 4: Yes, again, they can play with our minds and show false images...*
- *Moderator: So you are afraid that someone could manipulate you with that, since they have power?*
- *Participant no. 4: Yes... Yes.*
- *Participant no. 5: You completely forget where you are, what you are, all those graphics around you, it just pulls you into it. So, it's really thought-provoking...*
- *Participant no. 4: Well, it's great if they don't use it negatively. Especially large companies, to actually change consciousness so that they can make money.*
- *Participant no. 6: I agree.*

During the discussion, participants had the opportunity to personally test the prototype of the green AR artifact projecting the consequences of plastic pollution onto a sea turtle, and then commented on their experiences. The first moments were marked by the strong reactions of the participants – almost as one would expect in a real encounter with an injured animal.

- *Participant no. 2: Oh, poor thing!*

After a few minutes of looking at the AR projection, the subjects returned to their seats. After receiving information about the idea and use of environmental experiences in AR, they were asked to express their views and opinions. All participants were positive about the described concept and felt that there should be more such projects. They also pointed out the financial benefits by comparing the cost of the AR experience with the real-life experience of visiting polluted places. Participants also commented on the potential of this technology to enhance educational processes through visual memory and experiential learning. Although the scene they saw is unpleasant, 'ugly', or even disturbing, participants believe that people enjoy seeing ugly scenes and describe them as realistic and interesting. They concluded that the mentioned concept has the potential to become viral and popular on social networks.

- *Participant no. 6: And they would probably talk about it, so thinking would be encouraged.*
- *Participant no. 5: Yes.*
- *Moderator: Do you think someone could record it and share it on social networks?*
- *Participant no. 6: Yes.*
- *Participant no. 5: Yes.*
- *Participant no. 7: Anyway, very good idea. Surely for this time... for this digital age, something like that would have a much better effect on people. We should certainly work on such things more.*

Participants also agree that this type of content could raise awareness about plastic pollution, especially if people experience it in a familiar place, because then they can make a personal connection to the problem. One of the participants mentioned an idea for an application in the tourism sector: a tour and sightseeing with a guide who tells a narrative about the pollution, and the whole experience is enriched with AR projections at specific locations in the city.

However, some drawbacks of AR should be noted. Although they were enthusiastic about the proposed concept, the participants believe that the scenes should be even more realistic to achieve the desired effect of empathy. In addition, participants confirm that awareness of a problem does not necessarily lead to the application of a particular behavior. Participants are aware of the problem and acknowledge that they need guidance on next steps - what they can do to help reduce plastic pollution.

- *Participant no. 2: (...) we need to look at some solution. What after you watch that video? Maybe, how to direct people...*
- *Moderator: Give them some advice?*
- *Participant no. 2: Yes, yes. Something concrete. Because I get sad wherever I see it - on my beach or on another, it will affect me. Like from Australia - I'm not there, but it's hard for me. So, we need some kind of concrete proposal - how to take some measures, in what way... I don't know...*

1.2.4. Summary of the main results

Summarizing the main results, we can conclude that the early opinions of end users suggest that AR has the potential to become an effective communication tool, but AR campaigns should be curated carefully, taking into account the visual fidelity and credibility, to avoid possible counter effects. Institutions could integrate this form of communication into their campaigns conducted to build public support for stronger environmental policies. However, raising user awareness alone is not enough to change behavior. Therefore, environmental interventions should include three phases:

- (1) first, an awareness-rising campaign should be implemented, aiming to raise risk perception of an environmental problem;
- (2) then, once the individuals are motivated, an informational campaign should follow, that educates them about the next steps they can take;
- (3) once sensitized, motivated, and informed, individuals will be willing to support a campaign focused on reducing contextual barriers, which may include changing environmental policies, improving waste management systems, and collectively orientate society in a *green* direction.

1.3. Limitations of the study and further steps

The objective of this exploratory study was to investigate and understand the early opinions of end users on the concept of using AR in environmental communication. For this purpose, we conducted a focus group with 9 participants who represent typical potential end users of such system. Although this type of research method is very demanding in terms of time and analysis, its limitation is usually smaller samples compared to quantitative research methods.

Thus, the limiting factor of this research is the small sample of participants which makes it difficult to generalize the results of the research to the wider population. Future research approaches include qualitative research with a larger sample, quantitative research to validate the results, and an experiment to examine how such AR experiences influence the implementation of pro-environmental behaviors. To measure the success of this type of communication intervention, it is also necessary to investigate the extent to which AR can create a sense of the apparent presence of virtual objects.

Research on the acceptance of AR in environmental communication is very sparse, as is the application of the technology itself for the environmental sustainability purposes. Therefore, this study is an extremely useful basis for future research in this area, as well as for environmental policymakers, non-profit organizations, and other stakeholders interested in improving environmental communication.

1.4. Concluding remarks

Plastic pollution is a growing global problem that impacts all parts of our ecosystem and is mainly caused by human behavior - excessive consumption and improper disposal of plastic waste. The temporal and spatial gap between the causes and consequences of pollution makes environmental communication a major challenge, and there is a need for a method that psychologically minimizes this gap. To this end, virtual simulations of environmental problems using AR technology are proposed. Apart from the fact that such experiences may influence the user's emotions and risk perception, the popularity of AR on social networks offers the possibility of reducing campaign costs and engaging individuals in public dialogue.

This study is the first investigation into the early adoption of AR technology in environmental communication. To meet the objective of the study, a focus group was conducted with potential end users. The research findings suggest that AR, as an alternative form of pro-environmental communication, has the potential to enhance traditional forms of environmental communication, and that its acceptance in environmental campaigns can be realized if end-user biases are eliminated. This is because although participants support this form of communication because it is attractive, simple, and helps them identify with and understand the problem, at the same time they are aware of its potential to manipulate human subconsciousness, so there is a fear of abuse by large corporations. Therefore, it is important to include credible content in the

campaign and engage subjects whose lifestyle does not appear to be in conflict with the main message.

Situational factors – such as the price and availability of products and the quality of the waste management system – play an important role in decision-making. Therefore, in parallel with communication efforts, it is important to reduce contextual barriers as much as possible and make it easier for users to implement pro-environmental behaviors. It should be noted that due to the small sample, it is not possible to generalize the research findings to the broader population, but this work serve as a useful basis for future research.

2. Augmented reality for promoting pro-environmental behavior: Evaluation through a qualitative study with end users²¹

The human-induced environmental crisis increases the vulnerability of human and natural systems and leads to a multiplication of frequent and severe extreme events such as droughts, floods, and heat waves (IPCC, 2022). Aiming to tackle the challenge of motivating individuals' pro-environmental behavior, in this study, we propose a novel type of Green IS (Elliot, 2011) – an artifact that demonstrates the consequences of plastic pollution through AR experiences. We prototyped a system that, by using a smartphone, augments tridimensional digital holograms of real-sized animals fighting with plastic litter in real-time into users' immediate surroundings.

Our objective is to investigate how such an artifact should be designed and implemented in practice. For this purpose, we developed a prototype of the proposed Green IS, and evaluated it with participants that represent typical end users. Our study is guided by the following research question: *How to design and implement AR artifacts to induce pro-environmental behavioral change?*

²¹ This study was presented at the 2nd GREDEG PhD Workshop 2022 (Sophia Antipolis, France) and at European Conference on Information Systems (ECIS) 2022 (Timisoara, Romania)

To address this research question, we conducted a Design Science Research (DSR) study (Hevner et al., 2004; Gregor & Hevner, 2013). Following guidelines that ensure scientific rigor and credibility (Gioia et al., 2013), we inductively analyzed data collected from six focus groups, during which we introduced and demonstrated the prototype of the artifact to focus group participants to obtain their feedback. This approach resulted in novel findings on emerging phenomena and helped identify the design, development and evaluation requirements of a green AR artifact, as well as contributing to the development of new IS knowledge.

This study responds to an urgent call for research on Green IS (Elliot & Webster, 2017), and makes three contributions: methodological, theoretical, and practical. First, we provide an example of the DSR evaluation strategy in the design of (1) an artifact with an environmental dimension and (2) an AR artifact in its conceptual phase. Second, inductive analysis of our data led to a grounded theory model that informs the design and implementation of a green AR artifact, which generated the theory type IV (Theory for Explaining and Predicting) and the V (Theory for Design and Action) (Gregor, 2006). Third, the practical implications for policy makers, communication experts, and environmental organizations include specific guidelines for implementing AR-based behavior change interventions for promoting pro-environmental behavior in practice (Mirsch et al., 2018). We hope that this study can also contribute to the understanding of how a broader class of behavior-changing artifacts might be designed, evaluated and applied in practice.

2.1. Methods

This study presents one iteration of a design process of a DSR project (Hevner et al., 2004; Gregor & Hevner, 2013) in which the aim was to design and evaluate a novel IT artifact with an environmental impact (Seidel et al., 2018). The outcome of a DSR study should be an artifact in the form of a construct, a model, a method, or an instantiation, that is intended to solve a relevant real-world problem (Hevner et al., 2004). In this subsection, we explain the methodological approach adopted for the study.

2.1.1. Research approach

During the study process, we followed guidelines for conducting and reporting qualitative research that ensure research rigor, rely on data, lead to development of new concepts, and

generate a grounded theory (Glaser & Strauss, 1967; Strauss & Corbin, 1990; Gioia et al., 2013). We followed steps (Peppers et al., 2008) and guidelines to meet the requirements of an effective DSR study (Henver et al., 2004), as presented in Figure 17.

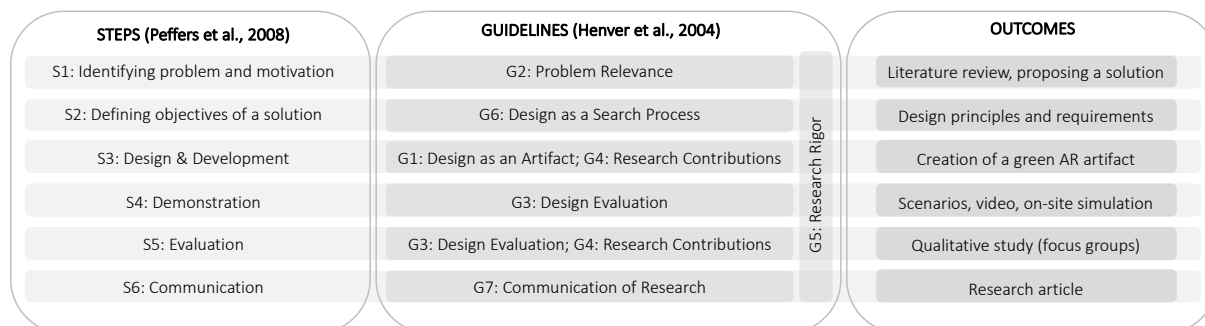


Figure 17. Our DSR research approach

Besides design itself, evidence-based artifact evaluation is a crucial step of the DSR process (Hevner et al., 2004). The evaluation pathway was established based on a Framework for Evaluation in Design (FEDS), and it combines two strategies: The Human Risk & Effectiveness evaluation strategy and The Technical Risk & Efficacy evaluation strategy. In both strategies, the dominant paradigm implies artificial evaluation using simulations and scenarios, with the intention of determining whether the artifact is technically adequate, and whether it is likely to provide usefulness and fitness in real situations and over the longer period of time (Venable et al., 2018).

2.1.2. Evaluation

Guided by our research question, we evaluated the artifact through six focus groups with end users. Focus groups are especially suitable for investigating novel technologies, where theoretical background is still limited. Although time-consuming and challenging, this approach often generates new ideas and concepts, and results in the greater understanding of an emerging phenomenon (Sutton & Arnold, 2013; Morgan, 1988).

For the purposes of our research, we split focus group discussion in two parts. In the first part, we aimed to understand which environmental communication approach and campaign elements work best in general. In the second part, we evaluated the design of the artifact and investigated its utility in a hypothetical field use through on-site simulation and scenarios. Additionally, in

order to increase the robustness of our findings, we accessed participants' opinions in a more anonymous manner through two short questionnaires conducted before and after each focus group discussions.

Focus groups were conducted in university's facilities, in controlled conditions, in the period between September and December 2020, among master's student²² at two European universities. Our sample (N=73, Female=56, Average age= 22.7 years) represents typical social networks users – people between 18 and 29 years old (Pew Research Center, 2021). On average, participants indicated moderate to high level of concern about plastic pollution (M 5.41/7), and moderate familiarity with AR technology (M 3.41/7). Six focus groups resulted in 5 hours of recordings and 111 pages of transcription. Sessions ranged between 60 and 90 minutes in length, and were recorded using a voice recorder or a smartphone. All participants signed a written consent to participate in the study.

The discussion aimed at obtaining participants' feedback on the artifact, specifically, its social, information and technology aspects (De Leoz & Petter, 2018). Since the artifact was being evaluated in the context of promoting pro-environmental behavior, we also inspected participants' 'green' attitudes and investigated whether there were any contextual barriers that would possibly impact the effectiveness of the artifact and its adoption. The artifact was introduced with a scenario, a one-minute video²³ and an on-site demonstration using a smartphone iPhone X (focus group settings are displayed in Figure 18, right image). Informed by the previously conducted pilot study (Section 1 of Chapter 3), we defined the focus group guide (available in the Appendix 4.A).

2.2. Artifact description

Built on predefined design principles (Section 3 of Chapter 1), and refined after the previous study (Buljat, 2023), we introduce a novel green AR-based IT artifact – a mobile application that demonstrates consequences of plastic pollution through AR experiences, which can be consumed through the lenses of mobile device such as smartphone or tablet. Here are the three reasons why we choose the smartphone as a device for the AR experience: (1) because mobile-

²²Although we cannot generalize our results to all population of social networks users, results from many studies that used students as a sample are robust and informative (Frechette, 2011).

²³ Video available at: https://www.youtube.com/shorts/E1-M_KbvFLM

based AR is more democratized than AR glasses (Statista, 2001); (2) because mobile phones are giving suggestions at the opportunistic moments (Fogg, 2003) and (3) make green content *available at everybody's fingertips* (Pitt et al., 2011).

The experiences consist of various examples of anecdotal scenes of plastic pollution crisis: real-sized tridimensional models of the most endangered animals suffering from plastic pollution: a seal, a sea turtle, a bird, a dolphin and a whale (Senko et al., 2020), presented in a form of a digital tridimensional hologram in user's immediate surrounding.

There was a methodological challenge to overcome in this study. Especially in the early design phase, it is difficult to show and evaluate an AR artifact with other media such as photo or video because AR needs to be experienced in real-time. Therefore, for the purpose of this study, we built the artifact's prototype in the open source software Spark AR. The AR scene depicts a seal caught in plastic garbage and trying to escape from it. In the current version, users cannot influence the outcome of the scenario. The animated 10-second scene of a moving three-dimensional object plays in an infinite loop.

The following figure (Figure 18) demonstrates the artifact's AR scenes in different environments.



Figure 18. Examples of AR scenes of a seal suffering from plastic pollution

The purpose of the artifact is to enhance traditional environmental communication by supplementing it with engaging, immersive and sensory-rich media forms. Not only is such experience more engaging than photo or video, but recent wide adoption of AR camera effects on social networks enables easy sharing among its users, which could lead to campaign virality (Vasey, 2021). In fact, a campaign creator does not create the final product – the final product is created by users themselves, and each experience is unique and personalized.

The experiences can be available in three different forms:

- (1) as a camera effect on social networks such as Facebook, Instagram, Snapchat, TikTok;
- (2) as a smartphone application;
- (3) as an interactive service integrated into a website, that is accessible through an internet browser that supports AR.

2.3. Results and discussion

Focus group recordings were transcribed by an independent person, and, if necessary, translated into English. In order to ensure anonymity, pseudonyms are used in place of participants' names. At this stage, 3 major themes and 24 sub-themes emerged after coding transcription (see Appendix 4.B for the Codebook). The first-order thematic analysis revealed key elements of a successful environmental campaigns, internal and external factors that influence pro-environmental behaviors, and technical and design requirements of an AR artifact.

Since there is very little existing research about AR as a pro-environmental communication tool, we let the data speak for itself and built a theory from the ground up (Strauss & Corbin, 1990). The insights from the study also informs kernel theories on which the artifact's design was built, which is the theoretical contribution of the study. Next, we applied a more systematic inductive approach in order to move from specific observations to broad generalizations, and to draw conclusions from the collected data (Gioia et al., 2013).

The figure below (Figure 19) summarizes the second-order analysis, and graphically represents the process of transforming the raw data into more abstract themes and aggregate dimensions (Gioia et al., 2013).

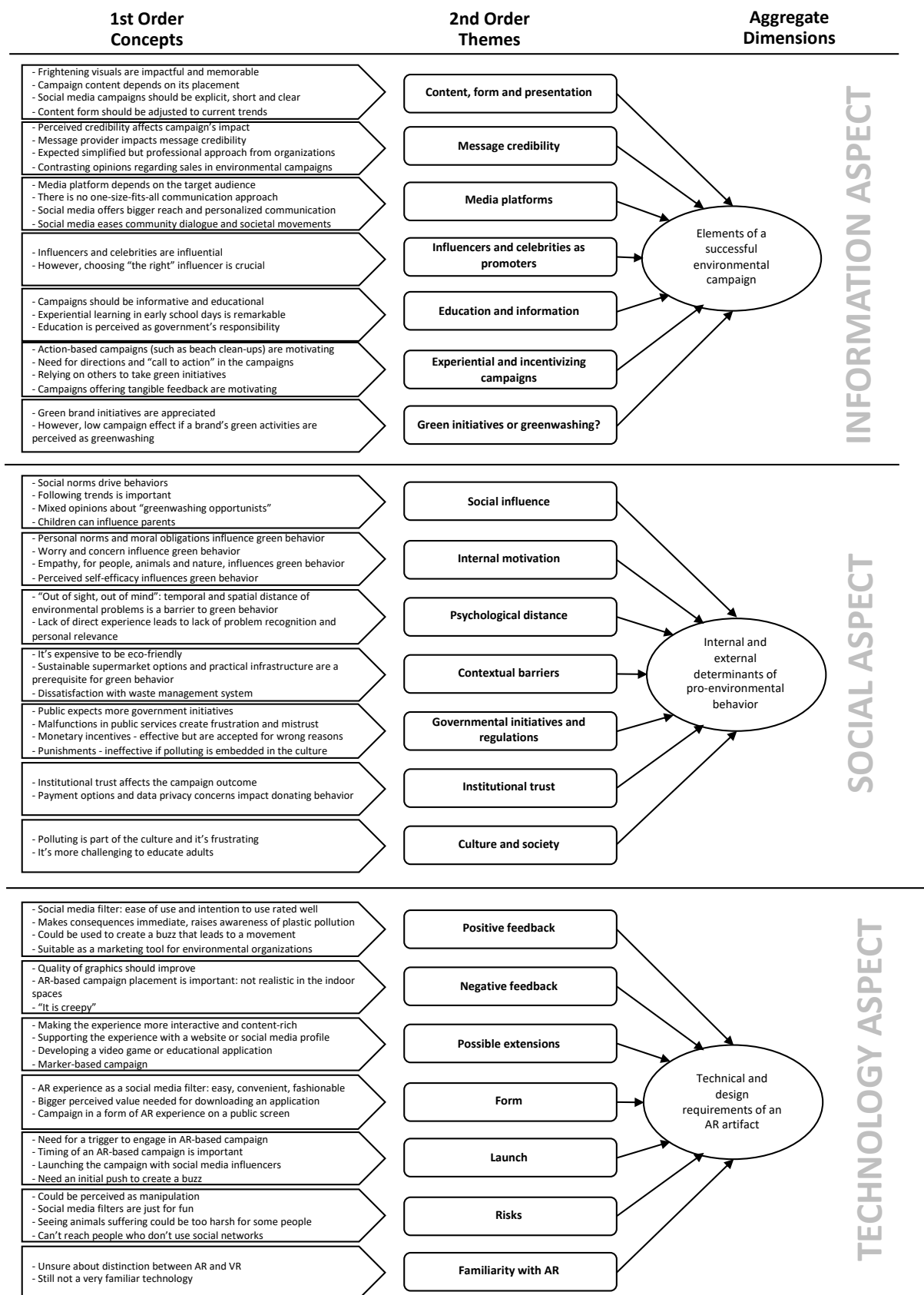


Figure 19. Data structure

After analysis of our findings, we used the static data structure to generate a dynamic inductive data-driven grounded theory model (Strauss & Corbin, 1990) which represents interrelations between emergent concepts of the phenomenon (Gioia et al., 2013). The model represents the process of introducing AR-based pro-environmental behavior-changing artifacts (Figure 20).

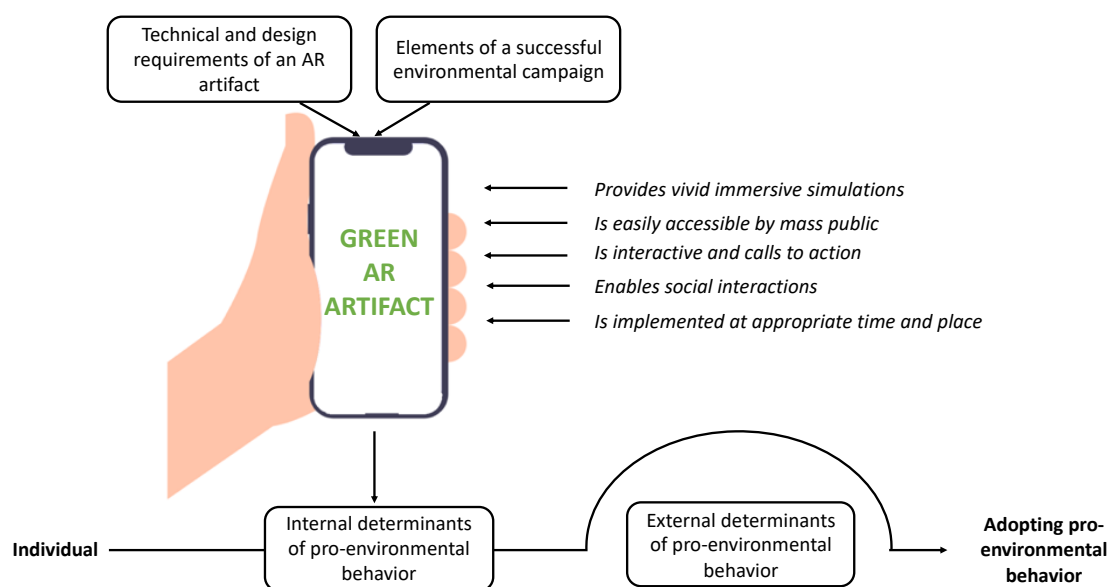


Figure 20. Theoretical model: The process of introducing AR-based pro-environmental behavior-changing artifacts

Our findings suggest that green AR artifacts have a potential to enhance traditional pro-environmental behavior-changing interventions, especially if they are immersive, interactive, accessible to a wide audience, enable social interactions, encourage users to take concrete actions, and are launched at the right time and place so that users can easily consume AR content. By optimizing the technical and design requirements of an AR artifact and incorporating effective elements for a successful environmental campaign, such strategically designed AR-based pro-environmental behavior-changing artifacts may affect individuals' internal determinants of pro-environmental behavior that lead to action. However, the outcome of a campaign may also depend on external factors (e.g., contextual, cultural, and social barriers) that must be overcome to achieve the adoption of pro-environmental behavior. Below, we elaborate on the findings.

First, the form of an AR artifact is important. The acceptance of the artifact is likely to be the highest in the form of a social media camera effect, as in UNEP's campaign #CleanSeas

(UNEP, 2019). Comparing to a stand-alone application or an AR experience within a website, this form is the easiest to use, but also attractive, engaging, and capable of becoming viral and creating a ‘buzz’. In order to be attractive for users, a stand-alone mobile application should provide more added value to users (entertainment or education).

- *FG1 P1: “It’s very easy to use, everyone can do it, that’s the capacity, well, the big advantage is the ease of use...”*
- *FG1 P3: “This is really the advantage, it’s the hyper-practical side, the practicality, that’s the advantage.”*
- *Moderator: “And if you see this from some kind of environmental agency, or UN for Environment... this type of filter, would it make you curious to see who is behind it? Would you click? Would it catch your attention?”*
- *FG4 P2: “I think yes.”*
- *FG4 P7: “Yes, I think it would because it’s not usual to see those kinds of things on social media, so...”*

In order to be convincing and cause social reaction and empathy, the simulation has to be realistic. The biggest criticisms of the artifact were the quality of graphics of the tridimensional model, and also the context of use: participants find it weird to see an animal in the classroom. Thus, some campaigns may require marker-based AR experiences, which limit the exposure only to locations where the augmentation of the models makes more sense (for example, limiting a campaign featuring sea animals to seaside locations).

However, a campaign’s outcome greatly depends on other elements as well, such as content and media platform. Although metaphorical visuals may better suit mass campaigns, it seems that shocking and negative imagery makes a pro-environmental campaign attractive and memorable, causing emotions that lead to engagement with issues and a personal connection, as stated in Leiserowitz (2006). Explicit, short and visual content may be more effective than textual, especially when there is a need to explain and present complex environmental data to lay people (Corner et al., 2018).

- *FG3 P2: “(...) I think it’s very important to have an emotional impact, yes, that’s the main reason of marketing campaigns, to trigger something in you, and develop a need in you, but this (impact on animals) is kind of harsh to some people.”*

- FG3 P1: *“Yes, but this is the point.”*
- FG3 P8: *“Yes, I think that is the point because this is the harsh reality.”*
- FG3 P1: *“Yes.”*
- FG3 P8: *“You can collect the plastic in the field. When people see that, yeah, we can collect it. But you cannot bring animals back after they die! Like, this is the worst consequence, not the pollution in a field, you know...”*
- FG3 P4: *“I think this has more effect, compared to the other. Because this clearly... When somebody sees this, they would be like “Oh my God, I’m not going to do this. I’m not going to pollute the environment. I’ll keep the plastics somewhere.” So, this actually brings out the reality.”*

Furthermore, it is important to follow communication principles and trends relevant to target audience (Steg & Vlek, 2009). Social media may be the most suitable platform for green AR campaigns, as it can contribute to collective green movements (Ballew et al., 2015; Vasey, 2021). Not only it can use customized communication and reach more people than traditional media, but it may serve as a powerful weapon to gather similar individuals and put pressure on brands and corporations to act in a more eco-responsible way, as seen in a campaign by Greenpeace (2010).

- FG3 P1: *“As she said, different target groups. That’s why advertising on social media and generally on computers where everything is strictly personalized, to me, it’s easier than putting it on the buildings. On a building, everybody from 0 to 99 years, they can see it. So you don’t know who is going to see it, you cannot customize it. It has to be for everyone. On social media it’s personalized to you – because you accept cookies, you agree with this, you agree with that, you give all your information, they know everything about you, they know if this picture, or that picture is going to work for you.”*

When a campaign is designed, attention should be put into planning its launch. AR campaigns may require a call-to-action (e.g. a poster or a social media post) as an invitation for users to join the experience. AR campaigns are specific because users cannot simply be exposed to them, they have to decide to engage with them. Therefore, a campaign creator must pay

attention to the appropriate time and place when users may be able to engage with it. For example, a billboard on the highway wouldn't work in this case.

Although providing information is a crucial part of a campaign, it is often not enough (Kollmuss & Agyeman, 2002). Therefore, it is expected that governments and environmental organizations will supplement informational campaigns with experiential activities such as beach clean-ups, as well as directives for further steps. In addition, virtual experiences should be frequently updated with new features, if long-term artifact use is desired.

Also, since credibility determines the success of a persuasion attempt (Fogg, 2003), message providers – preferably social media influencers or celebrities – should be carefully selected, so that their lifestyle reflects the values of the campaign. Environmental organizations should think twice before selling a product, as well as brands who claim to be green without clear evidence; the campaign may be counter-effective if the public perceive it as greenwashing.

A strategically designed environmental campaign enriched with convincing AR experiences may lead to individuals adopting green behavior by affecting their internal determinants, namely: perceived social and personal norms, moral obligations, worry and concern, and psychological distance. This is in line with previous studies (Steg & Vlek, 2009; Wang et al., 2018; McDonald et al., 2014). For example, immersive AR experiences may replace real experiences needed for individuals to personally relate to them and get psychologically closer (Carmi & Kimhi, 2015; Spence et al., 2012).

- FG2 P3: *“(...) I think the first barrier is what you were saying earlier, you said ‘yes but without an iceberg we die’, but in reality I don’t realize it, you know what I mean? In fact, since I don’t have an iceberg near me and my life does not depend on an iceberg at the moment, you know, in fact it makes it hard for me to feel concerned because I’ve been hearing about pollution since I was little but in reality my daily life does not change, you know, and I think that’s the barrier, it’s that as long as I don’t feel the impact I have trouble feeling concerned, really committed.”*
- FG2 P9: *“(...) well it’s a bit philosophical but generally when we don’t feel that our life is in danger, well, we don’t feel that we ourselves are going to die if tomorrow there’s still plastic, well that’s not necessarily going to push us to act, whereas if we really saw the impact in our daily life, well, I think that we’d move more for sure...”*

Finally, such behavior-changing intervention may work if individuals' way is clear of all the contextual barriers (Steg & Vlek, 2009). For example, mistrust in government and the waste management system may discourage motivated individuals who want to recycle, and few supermarket options may be the reason why some people overconsume plastics, although they would rather not. Moreover, there are certain polluting habits 'embedded' in the culture that may be difficult to change.

The following table (Table 17) shows the final evaluation of the artifact, i.e., participants' intention to use it and perceived utility²⁴. Participants are most likely to interact with such AR experiences through the services they already use, such as social networks (M 5/7), while downloading an application to their smartphone is obviously not an option (M 2,3/7), unless it brings additional benefits to users (such as entertainment or education). Most importantly, the green AR artifact is generally well rated for its main purpose: to make users more concerned about the plastic pollution problem (M 4,49/7).

Focus group ID	Intentions to use					Perceived utility
	<i>I would use this system again, if it was available as a free app from the App Store.</i>	<i>I would use this system again, if it was available as Facebook/Instagram camera filter.</i>	<i>I would use this system again, if it was available on a website in internet browser.</i>	<i>I would record my AR experience to share it on my social media.</i>	<i>I would recommend this app to my friend.</i>	<i>I would say that this app made me more concerned about plastic pollution.</i>
FG1	1,8 (1,26)	5,4 (1,72)	2,2 (1,47)	4,93 (2,19)	4,26 (2,43)	4,13 (2,03)
FG2	1,67 (0,9)	4,33 (2,32)	1,73 (1,16)	2,87 (2,2)	3,4 (2,06)	4 (2,04)
FG3	2,78 (0,97)	5 (1,87)	2,56 (1,81)	3,67 (1,66)	4,22 (1,92)	4 (2,06)
FG4	2,18 (1,25)	3,18 (2,09)	1,91 (1,04)	2,27 (1,35)	2,73 (1,49)	3,73 (1,42)
FG5	4 (1,48)	5,75 (2,05)	4 (1,71)	5,17 (1,40)	5,67 (1,23)	6,08 (1,24)
FG6	1,73 (0,9)	6,18 (1,47)	4,73 (1,79)	4,82 (1,83)	5 (1,61)	5 (1,34)
Σ	2,3 (1,38)	5 (2,12)	2,84 (1,88)	3,99 (2,1)	4,2 (2,04)	4,49 (1,86)

Table 17. Average marks of participants' evaluation of the artifact

Based on this discussion, we developed a 6-step guide for implementing green AR-based artifacts for promoting behavior change (Figure 21). For an intervention to be effective: (1) contextual barriers should be minimized; (2) AR experiences should be based on effective design principles (realistic, informative but emotional AR experiences that, by visualizing the problem, reduce the psychological distance); (3) AR experiences should be embedded in a form that is acceptable and easily accessible by mass public; (4) influential and credible subjects should be hired for its launch; (5) spreading the word on social networks should lead to the

24 Participants declared their answers on the scale from 1 ("I strongly disagree") to 7 ("I strongly agree"); in the brackets are standard deviations

‘buzz’, which is important for activating social pressure, that may finally lead to pro-environmental behavior being adopted. Finally, (6) if an artifact is to be used in the long term, frequent updates in its design are needed.

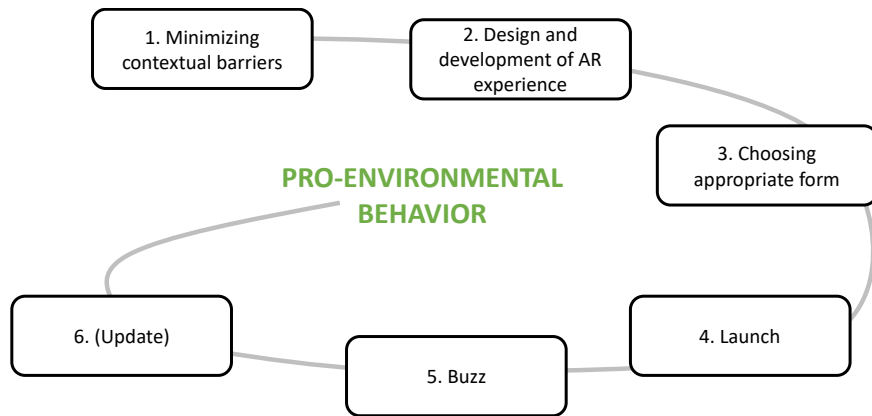


Figure 21. Implementing green AR artifacts in behavior-changing interventions

2.4. Concluding remarks

Due to the abstractness and the gap between today’s behavior and future outcomes, communicating about environmental issues is often challenging. Aiming to find out how to design and implement AR-based artifacts for promoting pro-environmental behavioral, we applied a DSR approach in which we designed and evaluated an artifact that demonstrates the consequences of plastic pollution in AR.

The findings of six focus groups with end users indicate that AR technology has a great potential to enhance traditional environmental communication, especially if it is vivid, interactive, engaging, and realistic. End users are most likely to consume it through the services they already use such as social networks, which enable social interactions important for motivating behavior change. However, although it may offer a fertile ground for collective green movements, it seems that technology alone is not enough to change individuals’ pro-environmental behavior, as this behavior also depends on other internal (such as personal norms and concern) and external (such as contextual and cultural barriers) factors which need to be taken into consideration.

We also realize that the context might have influenced the evaluation of the artifact (since it simulated the consequences of plastic pollution on the sea animals, it may have appeared

unrealistic on the classroom floor), so another focus group settings (outdoor environment) could result in richer findings. Therefore, we can conclude that researchers should be careful about choosing the environment when evaluating an AR artifact.

This study has certain limitations, one of them being the difficulty of generalizing conclusions to a larger population. Moreover, in this study we tested the artifact's utility through self-declarative statements. Therefore, conducting a controlled laboratory study might lead to more comprehensive conclusions about the artifact's real influence on pro-environmental behavior. It would be also interesting to evaluate the artifact from other groups of end users, as well as from the suppliers' side, namely, from various subjects who could be interested in using this media in their communication such as governments or nonprofit organizations. Therefore, we propose a set of three research questions that could guide future studies: (1) (How) does AR impact pro-environmental behavior? (2) Are AR experiences able to create a sense of presence? (3) Do professionals support including AR in green campaigns?

There are three major contributions made by this study: methodological, theoretical and practical. Firstly, we provided an example for implementation of appropriate DSR evaluation strategy when designing (1) an artifact with environmental dimension and (2) an AR-based artifact in its conception phase.

Secondly, our grounded theory model built from inductive analysis of the collected data contributes to the research on Green IS, and provides theoretical support for designing an AR-based artifacts for promoting pro-environmental behavior.

Thirdly, we provide concrete guidelines for implementing green AR-based behavior-changing artifacts, useful for subjects involved in environmental communication (policy-makers and environmental communicators). Although our study focuses on digitally promoting environmental behavior, these findings could be useful in other domains, for example, in the context of health and pro-social behavior.

3. AR for environmental communication: Evaluating the artifact with professionals from the domain of environmental communication²⁵

Significant changes in environmental behavior appear to be the only effective solution to reduce biodiversity loss, minimize pollution, and prevent the destructive effects of climate change (Antusch & Yan, 2022). Despite this diversity of environmental threats, environmental communication often fails to enhance pro-environmental behaviors, especially in the case of information-based campaigns (Kollmuss & Agyeman, 2002). This is mainly due to the grand challenges in communicating about environmental issues, as they are subject to a temporal and spatial mismatch between their causes and consequences, which makes them psychologically distant (van der Linden et al., 2015; Trope & Liberman, 2010). To address this gap, this article aims to design (and evaluate) an IS artifact based on augmented reality (AR) to promote pro-environmental behavior.

This study aims to propose a novel technological solution to improve environmental communication and is guided by the following research question: *How to design and implement a green AR artifact that visualizes the consequences of plastic pollution and aims to promote individual pro-environmental behavior?*

The research question is addressed through theoretical and empirical work: first, the initial design (prototype) of the artifact results from the formulation of design principles grounded in the concepts of three kernel theories. Second, to capture practical knowledge and expertise, the artifact (instantiation) is evaluated by a range of experts from the domain of environmental communication. More precisely, we conducted 9 semi-structured interviews with the objective to: (1) evaluate the design of the artifact (i.e., its information, social, and technology aspect), and (2) define a way to implement the artifact in practice.

Although this study focuses on green mobile AR systems for promoting pro-environmental behaviors (e.g., donating, cleaning up the oceans, recycling, reducing consumption) at an individual level in the context of plastic pollution, it could be applicable at a more abstract level

²⁵ This study, co-written with Lise Arena, was presented at the International Conference on Information Systems (ICIS) 2022, Pre-ICIS SIGGreen Workshop (Copenhagen, Denmark), and was conditionally accepted to the journal Communication of the Association for Information Systems (CAIS) in December 2022.

to similar artifacts for motivating behavior change in a similar context (situations where a user needs to visualize future risks).

In line with the call for IS community to establish a AIS Sustainability Task Force in 2019 (Watson et al. 2021), we apply a Design Science Research (DSR) approach (Hevner et al., 2004; Gregor & Hevner, 2013) to introduce a novel Green IS (Elliot, 2011) that stimulates pro-environmental behavior at the individual level. The artifact simulates the destructive side effects of plastic pollution in the form of vivid, immersive AR simulations and can therefore serve as a tool for behavior-changing interventions.

Following strict guidelines for qualitative research (Gioia et al., 2013), analysis of empirical data leads to new theoretical developments and refines design principles for a green AR artifact. This research also provides guidelines for implementing such an artifact in practice. Overall, our contribution can be assessed at both theoretical and practical levels. First, the theoretical results contribute to the field of green information systems (Green IS) (Gholami et al., 2016; Elliot, 2011; Elliot & Webster, 2017), but can also inform design and development processes of similar artifacts that aim to change behavior and address societal problems. Second, we believe that the artifact and guidelines for its implementation in practice could be useful to various actors in the domain of environmental communication and/or education, such as policymakers, communicators, environmental organizations, and educational institutions.

3.1. Methods

In line with the research question outlined above, we now present the general research approach, artifact design method, and data collection techniques that lead to the conceptualization of the green IS artifact.

3.1.1. Research Design

This study presents one iteration of a DSR project (Hevner et al., 2004), used to design, develop, and evaluate a novel green IS artifact. We followed the steps and guidelines for conducting a rigorous DSR study (Gregor & Hevner, 2013; Peffers et al., 2008) and analyzing qualitative data (Gioia et al., 2013) leading to theoretical developments and practical contributions.

Consistent with the methodological framework used in design science approaches, this study follows six steps (Peffer et al., 2008):

- Step 1: *Problem identification and motivation* (identifying a real-world problem that the artifact should address);
- Step 2: *Defining objectives of a solution* (defining initial design principles of the artifact, inspired by three kernel theories, that explain why the artifact could solve the addressed problem);
- Steps 3: *Design and development* (translating kernel concepts into design principles and requirements, and actual design and development process);
- Step 4: *Demonstration* (describing the design and functionalities of the artifact, presenting scenarios and other materials to demonstrate the artifact's ability in solving the addressed problem);
- Step 5: *Evaluation* (assessing the feedback on the artifact's functionality in solving the addressed problem);
- Step 6: *Communication* (dissemination of research findings among the IS audience).

3.1.2. Artifact Description

Consistent with the theoretical findings from the previous design cycle (Buljat, 2022) and guided by the design principles (Section 3 of Chapter 1), we sent design instructions to an external developer. The artifact was developed by an AR/VR development studio to our detailed specifications using Unity, a cross-platform software known for developing video games and 3D virtual environments. The artifact serves as a tool to present narratives about environmental issues in the form of vivid, interactive and realistic simulations in AR. Rather than viewing a photo or video on a flat 2D screen, the artifact enables consumption of content in the form of interactive three-dimensional digital holograms that are embedded in and merge with the real world in real time. The following figure shows examples of AR scenes (Figure 22).



Figure 22. Examples of scenes provided by the artifact

The artifact takes the form of a mobile application²⁶ that can be installed on a mobile device (smartphone or tablet) using Android operating system. Once the application is opened, the user immediately sees the camera recording, which is simultaneously recorded by the device. The AR experience begins when the system detects the flat surface, where clicking on the screen enlarges the AR objects. The AR experience consists of short scenes simulating the consequences of plastic pollution for five of the most affected marine animals²⁷.

The artifact enables social interactions between (1) users and (2) users and the artifact. Firstly, such an experience can be integrated into a multi-user platform (e.g., in the form of AR camera filter on social networks such as Instagram, TikTok, or Snapchat) that allows users to easily access, modify, record, and share AR content. In this way, such a system can serve as a tool to generate unique and personalized content and create social media movements. Secondly, the

26 During the development phase, we were confronted with many technical design decisions (e.g., which AR platform to build for, which hardware to choose, which operating system, or whether the experience should be marker-based or markerless) Our decisions were based on practicality and availability. For example, we chose mobile AR because it is accessible to a wider audience.

27 The scenes were inspired by anecdotal evidences, and the choice of animals was based on scientific evidence about the effects of plastic pollution on marine fauna (Senko et al., 2020).

artifact visualizes animals in danger due to the plastic pollution crisis, aiming to evoke emotional and social responses from users.

To present the artifact to our participants, we used direct and indirect demonstrations. When possible (when an interview was conducted in person), we presented the artifact through a live, on-site demonstration using the Samsung Galaxy Tab S5e tablet. Otherwise (if the interview was conducted via videoconference), we showed the mobile device screen via video stream while the artifact was being used. We also created additional materials to demonstrate the artifact (scenarios and a video²⁸).

3.2. Artifact evaluation

3.2.1. Sample and procedures

The empirical data collected mainly feed into step 5 of the research design. Evaluation is indeed central to any DSR approach, as it determines whether the artifact is capable of solving the intended real-world problems (Hevner et al., 2004). To this end, the artifact is evaluated using professional expertise. Specifically, we conducted semi-structured individual interviews to capture practical knowledge from a variety of environmental communication stakeholders (see Figure 23). To ensure diversity among interviewees, these experts belong to three different sectors: Non-profit organizations, public sector, and private sector.

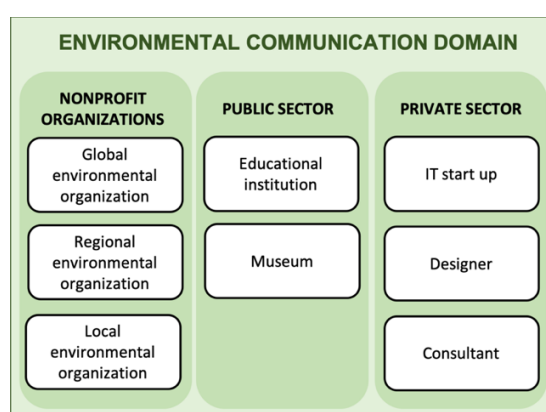


Figure 23. Interview sample – Interviewees' sectors of activity

28 The video is available at https://youtu.be/cZz0ox_mrSI

Interviews were conducted between September 2021 and May 2022. Due to the COVID-19 pandemic and geographic distance, we conducted the interviews by videoconference when it was not possible to conduct it in person. In total, our sample consisted of nine experts. A detailed description of the participants in the sample can be found in the following table (Table 18)²⁹. All participants signed a consent form for participating in the research.

Pseudonym	Sex	Country	Job title	Type of organization	Duration (min.)	Online / in person
Interviewee_1	F	Monaco	Marketing manager	Oceanographic museum and foundation	122	In person
Interviewee_2	F	France	Founder & president	Environmental NGO	69	In person
Interviewee_3	M	France	CEO	AR&VR agency	30	In person
Interviewee_4	M	France	3D artist & developer	AR&VR agency	29	In person
Interviewee_5	M	Poland	CEO	VR&AR agency	45	Online
Interviewee_6	F	Spain	UX designer and consultant	Design, UX, learning experience design	50	Online
Interviewee_7	F	Singapore	CEO	AR/VR agency and foundation/incubator	28	Online
Interviewee_8	F	Poland	University professor and researcher	Science & education / Field of research: VR, UX, speech recognition	89	Online
Interviewee_9	F	United States	Urban policy consultant and researcher	Environment, sport, policy	42	Online

Table 18. Interview sample overview

After a general introduction of the interviewee and his or her work, the interview guide focuses on eliciting the expert's opinion about the informational and social structures of environmental campaigns, as well as feedback on the artifact and its implementation in practice. Depending on the interviewee's expertise and profession, the interviewee naturally provided more in-depth information on specific topics. The artifact was presented using a scenario, a video, and, if the interview was conducted on-site, a live demonstration using a tablet device. The full interview guide can be found in Appendix 5.A.

²⁹ We recruited experts belonging to the same domain but not interconnected to ensure the objectivity of the results. We also intentionally recruited diverse experts with different profiles and roles to avoid redundancy in the answers and to cover multiple perspectives of the various stakeholders of the environmental communication domain. Despite the diversity of their profiles, all the interviewees have in common that they regularly create campaigns to raise awareness of environmental issues and aim to promote public pro-environmental behavior and declare an interest in new tools/trends/technologies. All participants signed a consent form for participating in the research. The integrality of written transcriptions is available on demand.

3.2.2. Collected Data

A total of 504 minutes of the interviews were recorded using a voice recorder or smartphone. The written transcripts consist of 165 pages of text. The transcribed data were then analyzed following strict guidelines to maximize research rigor and validity of findings (Gioia et al., 2013). Inductive analysis of the collected data resulted in a grounded theory model (Strauss & Corbin, 1990).

The first level analysis resulted in 3 major themes and 25 codes. The full codebook, along with relevant quotations can be found in Appendix 5.B. The second-level analysis resulted in the following figure (Figure 24), which depicts the first-order concept, second-order themes, and aggregate dimensions that emerged from the data. A discussion of each of the themes follows. The aggregate dimensions reflect the three aspects of the artifact and the design principles. Each aggregate dimension is discussed in turn in the following subsections. The second-order themes are again explained in detail to provide sufficient content for evaluating the artifact and refining the design principles for a next design cycle.

Overall, data inform two parts of analysis. The first one can be considered as relevant (especially for the ergonomics of the solution and a potential implementation); yet slightly peripheral to our objective to refine design principles. Then, the second part of analysis appears more central as data directly inform the refinement of initial design principles. Both parts are exposed in the data structure, but the data relevant to the second part has been colored in grey.

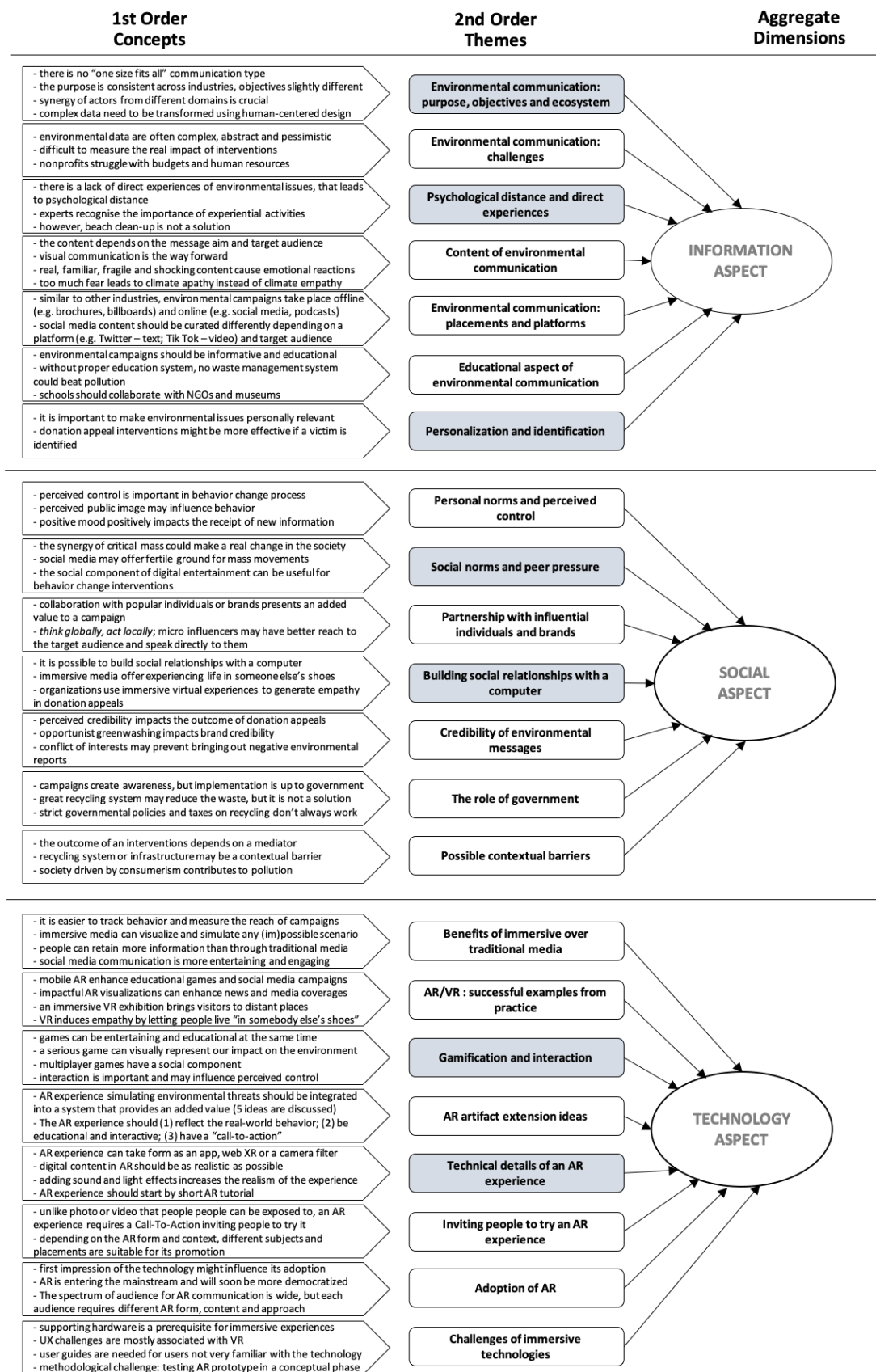


Figure 24. Data structure

3.2.3. Information aspect of the artifact

The first part of analysis include data that inform the potential improvement of the solution, as well as some potential implementation ideas). Among them, one can refer to:

Environmental communication: Challenges - Environmental communication can be tricky and challenging. First, the complex and abstract nature of environmental data makes it difficult for lay people (especially younger audiences) to absorb and understand its content. Environmental data are usually in the form of long brochures and complex statistics, so there is a need to put them into a more understandable, readable, and user-friendly form. Also, people do not like negative news. A smaller non-governmental organization went through difficult times at the very beginning of its creation because it started with a shocking documentary about the massacre of whales. After realizing that such an approach was “too political” and could negatively impact their reputation, they toned down their communication strategy. Another challenge is the difficulty of measuring the actual impact of interventions on people’s concern, awareness, or behavior. While large environmental organizations are powerful in attracting mass attention or targeting member states, they are not necessarily good at targeting individuals and tracking their behavior change. The last challenge is financial and mainly affects smaller associations or the private sector. Most NGOs rely on fundraising, but current practices are not sufficient to generate enough funds for organizations to fully utilize their capacity and have enough staff to carry out all desired activities.

Environmental communication: Content - The content of campaigns depends on the goal of the message and the target audience³⁰. Overall, respondents agree that visual communication is the way forward because it helps people understand environmental issues. People feel emotionally engaged when they see something real, familiar, fragile and shocking. Therefore, campaigns that aim to raise awareness about plastic pollution should include single-use plastic waste that people use every day (like a Coke bottle, sunscreen, or a balloon)³¹. The suffering of an animal can be particularly emotional and touching. But if it can have a direct impact, the experience should not end on a negative note, as people may avoid it due to guilt. Too much

30 For example, since museums are generally family-friendly, they avoid negative or fearful imagery in campaigns. Instead, they focus on charismatic species (such as whales or dolphins), but carefully selected because visitors perceive it as a “promise” that they will see these species in the museum.

31 For example, one of the viral social media posts included a photo of a seahorse holding a cotton bud, or a turtle wrapped in a six-pack packaging ring.

fear can lead to climate apathy instead of climate empathy. An example of a balanced intervention is a narrative that begins as a beautiful experience (as it should be) and then ends in the not-so-beautiful reality of thousands of pieces of plastic floating in the ocean. Shocking images can be very effective for a short time. However, if a long-term impact is desired, a less invasive and more subtle marketing material should be used.

Environmental communication: Placements and platforms - As in other areas, environmental communication and behavior change activities take place both offline and online. Examples of offline campaigns include billboards and posters, radio, conferences, presentations, stands, documentaries, brochures, and reports. Examples of online campaigns: podcasts, social media (Linkedin, Facebook, Instagram, Twitter, Tik Tok), engaging posts, stories, videos, websites, Google/internet ads. One of the most common misconceptions is that a publication can be used on different social media platforms. In fact, a campaign might get a better result if the same story is told in different ways - it should be tailored to each social media platform, but also to a specific audience. For example, Twitter is used by older generations and requires short sentences, while TikTok is dominated by Generation Z and requires short and descriptive video montages.

Educational aspect of environmental communication - Environmental communication should be informative and educational, focusing on informing people about the consequences of environmental problems (e.g., microplastics for human health), but also educating them about the solutions. Because without proper education, no waste management system can defeat pollution. We can clean our streets every day, but that is not a solution in the long run. For this reason, it is important for schools to collaborate with other professionals in the field, such as NGOs and museums. One of the interviewees, who is employed by an oceanographic museum, shows how it can provide educational, animation and pedagogical programs aimed especially at young audiences, starting at an early age.

Beyond these elements, interviewees also produce some data that could be used directly to refine design principles. Corresponding 2nd-order themes are colored in grey in the data structure and include the following items:

Environmental communication: Purpose, objectives, and domain - Environmental communication is specific, and so are its underlying goals: Unlike business-oriented communications, environmental campaigns are not focused on profitability. Rather, they aim

to raise awareness and motivate people to protect the natural environment. There is no one-size-fits-all approach to environmental communication, and its content, tools, and objectives depend on the target audience. Environmental campaigns can have different engagement patterns depending on their duration - there are “one-shot” campaigns (e.g. World Environment Day), where engagement is highest on one day, and long-term campaigns (e.g. UNEP’s CleanSeas), where engagement is longer but less intense³². The field of environmental communication is complex, multidimensional, and multidisciplinary. The synergy of actors from different sectors, as well as horizontal and vertical collaboration, is necessary to reach target audiences, as it can be difficult for global environmental organizations to address and track individuals directly. In short, global actors issue key calls to action, support regional and local actors, who then implement targeted campaigns and actions³³.

Psychological distance and direct experiences - The lack of direct experiences strongly influences people’s awareness and perceived psychological distance from a particular issue. For example, our data show how an oceanographic museum offers an open aquarium with species of marine life that visitors can touch and hold in their hands, and organizes educational activities such as zero-waste breakfasts. One of the successful examples of a museum’s efforts to raise awareness about marine pollution is an aquarium that contains plastic and other types of trash that end up in our oceans instead of fish. This aquarium has attracted a lot of attention, especially from pupils, because it provides a “window” into a normally unobservable circumstance under the sea. Because people’s attention spans are limited, experts suggest that experiential campaigns should last no longer than five minutes. Another popular experiential activity is a beach cleanup. Although she does not believe that cleaning will solve a problem, the founder of a non-governmental organization often organizes beach cleanups where she entertains and educates participants at the same time.

32 In addition, goals may vary slightly depending on the topic. For example, a museum’s communication efforts might be primarily focused on attracting visitors, while a non-governmental organization might be more focused on educating people about current issues and providing them with resources and tools to improve their sustainable behavior. Here is an illustrative example of a campaign’s call to action on two different topics: (1) a museum - “Buy your ticket now”; (2) an environmental NGO: “Share a pledge on your social networks.”

33 Here’s is an example: to communicate important research findings, large environmental organizations often work with long and complex scientific reports that are difficult for a mass audience to understand. To make this complex information understandable to the public and policy makers, they work with design and communications experts who transform these reports through effective data visualizations and human-centered design. Then, a global institution can work with a smaller local NGO partner that has more power to spread the message to individuals and effect action with local or national governments.

Personalization and identification – The data also show the importance of giving environmental issues a personal touch. For example, a campaign can involve local people and ask them to participate in the campaign. In this way, people not only consume the campaign, but also actively participate in it. Thanks to new digital media and technologies, communicators can now run personalized and individualized campaigns and let people “experience” the consequences of environmental threats in person. Appeals for donations can also be more effective if a “victim” is identified³⁴.

3.2.4. Social aspect of the artifact

As with the information aspect of the artifact, the first part of analysis includes the following elements:

Personal norms and perceived control – According to results, perceived control is an important internal mechanism in the process of behavior change. If perceived control over a situation is low, this could be a major barrier to behavior adoption. For this reason, interactive campaigns might be more effective: communicators should allow people to influence the outcome, even virtually or hypothetically. Moreover, people behave a certain way just for the sake of their public image. For example, people post environmentally friendly content on social networks to give their friends and acquaintances the impression that they are environmentally conscious.

Partnership with influential individuals and brands - In the case of environmental issues, as in other industries, our data shows that partnering with well-known individuals or brands can add value to a campaign. Recent trends to increase brand awareness include working with influencers on social media. Influencers and sustainability advocates could be hired to promote video games or drive immersive campaigns on social media platforms. “Think globally - act locally”: A current trend is to engage micro-influencers (profiles with 1,000 to 10,000 followers who are usually well-known in their market niche and have very high engagement with their audience (Bernazzani, 2019)), as they have easier access to the target audience and can engage

34 For example, a museum may use a specific animal in a fundraising campaign (e.g., a clownfish, which became the most popular fish in the museum after the release of the popular Disney movie “Nemo”) because people are more likely to have a personal connection to the issue than if the fundraising appeal is general and vague.

them directly. Even large organizations like UNEP rely on micro influencers to spread their global messages.

Credibility of environmental messages - People tend to question the credibility of fundraising appeals, which often has a negative impact on the financial resources of organizations. For example, the public assumes that a public museum is close to the government and has all the financial resources it needs. Therefore, they risk a negative image and bad comments if they launch a fundraising appeal. However, while large organizations attract larger sponsors, small organizations often struggle to find a budget for all the activities they need to do, as people prefer to support big names and well-known organizations. In addition, a questionable conflict of interest can be a barrier to campaign credibility. On the one hand, there are opportunistic brands whose marketing is based on greenwashing: Since “being green” is fashionable nowadays, some brands tend to spread misinformation about their sustainable business to increase their profitability. On the other hand, some experts and researchers are conditioned to spread misinformation about the current state of the environment and need to portray it better than it is in order to secure their jobs and positions.

The role of government - Governments could play a key role in motivating environmentally friendly behavior. Campaigns can raise awareness, but the final steps (implementation) often rest with governments. For example, a great organization of street cleaners can help reduce waste, but it is not a solution because it does not address the source of the problem. Indeed, a long-term solution lies in better education of those individuals who pollute.

Possible contextual barriers - No behavior-changing intervention can reach its full potential unless it is freed from contextual obstacles. Contextual barriers can vary, from mediators of an intervention to urban infrastructure. For example, when green interventions are implemented in schools using a particular technology, the outcome depends heavily on the teacher of the class. If the teacher is not comfortable with the new technology, there is a risk that students will not be animated and the intervention will not be successful. Furthermore, if the recycling system or infrastructure is not efficient, they can pose a major barrier to environmentally conscious behavior. Habits, culture and norms also shape behavior, so it can be difficult to change the shopping and pollution habits of our modern, consumerist society.

The second part of analysis (colored in grey in the 2nd order themes) includes the following items:

Social norms and peer pressure - People are social creatures and often feel the need to belong to a community, whether online or offline. People network digitally, follow trends and engage with influencers. Therefore, a campaign targeted at an individual may not make a big difference, but the synergy of a critical mass could bring about real behavior change in society. Social media provides fertile ground for building online communities and mass movements: The ability to easily share content between users sometimes leads to viral campaigns. Viral campaigns on social media may not change people's behavior immediately, but they are a good starting point for raising awareness about an important issue. However, it's sometimes hard to predict what will create a social media buzz and capture people's attention. And the more people speak out on social media and expose bad practices, the harder it is for the "bad guys" to hide. In addition, the social component of digital entertainment can be useful for behavior-changing interventions: The competitive nature of video games, e-tournaments, events, multiplayer, and challenges can be a powerful weapon to promote pro-environmental behavior.

Building social relationships with a computer - Real-world examples show that it is possible to build social relationships with a computer. For example, one respondent pointed out how video games can immerse the user in the world and create empathy with the game characters, while virtual people can have real influence on our decisions. Indeed, immersive computer simulations allow us to "embody" another person and experience what it is like to "live in someone else's shoes." One example that emerged in an interview is virtually experiencing the daily life of a person with a disability (e.g., a person who is losing their sight, is wheelchair dependent, has dementia, or suffers from autism) or a refugee in times of war. The goal of such virtual experiences is to help people feel more empathy for others. However, the interviewee who has experience with such interventions cautions that communicators should be careful, as it can cause negative feelings and mental fatigue.

3.2.5. Technology aspect of the artifact

The first part of analysis provides some interesting insights that could inform different aspects of the solution; they include:

Benefits of immersive over traditional media - Although traditional forms of communication are still very present in various industries, the development of the Internet and mobile devices

has triggered new trends in content consumption. People are often curious to explore new media. Therefore, communications and marketing managers need to follow trends and recognize that new technologies are important to attract “new”, younger audiences. One of the advantages of digital over traditional media is the greater ability to track behavior and measure the reach of campaigns. After all, behavior change is not a one-time event, but a process that requires many iterations and steps to achieve long-term behavior change. AR and VR could improve data visualization by converting complex data sets into an interactive 3D format. Respondents report that 3D content is much more engaging and interesting than 2D, as novices are truly impressed by the immersive technology and describe it as “mind-blowing.” Therefore, AR can be used for education and training. AR can make posts on social media more entertaining and engaging. AR Camera features reduce the time and complexity of editing video content (users do not need a laptop or video editing software). In addition, AR camera filters on Instagram can serve as a marketing tool by indicating who the creator of AR effect is and linking directly to the creator’s profile.

AR/VR: successful examples from practice - Novel AR artifacts may be inspired by successful already established examples from practice. During the interviews, participants named several inspirational examples from the AR/VR industry in the recent years: (1) An educational mobile AR game that educates users about alternatives to plastic products through a gameplay. Players must make sure that the main hero, a sea turtle named Victor, does not get harm by eating plastic trash floating in the ocean; (2) Pro-environmental AR Instagram campaign - AR camera effects educating people about actions they can take to address air pollution, switch to sustainable fashion, or appreciate cultural heritage. This UNEP’s campaign was launched with the help of sustainability advocates (social media influencers); (3) Impactful AR visualizations enhance news: One TV channel that provides national and local weather forecasts used mixed reality visualizations to warn citizens about the dangers of floods. Instead of 2D maps, the TV reporter was surrounded by "cliffs" of water showcasing its height compared to a human; (4) An immersive VR museum exhibition offers possibility to visit distant places. The exhibition was exposed in a large room - CAVE, where the projections of the Australia’s coral reefs are displayed onto the walls. Some species are interactive and responsive to visitors’ movements in a proximity; (5) VR narratives induce empathy by letting people live "in somebody else’s shoes": VR application with the goal to create empathy towards people from different cultures, disabled people but also animals. However, it is difficult to

animate and entertain people with serious games and get them to play any game that could possibly make them feel bad.

AR extension ideas for use cases – Some participants believe that it is unlikely that people will download an application just to see the negative consequences of environmental issues. Therefore, such AR experience needs to be integrated into a more developed system that adds value to the user and is enriched with other educational or entertaining content. For example, the AR simulations can be integrated into (1) a mobile video game (e.g., similar to Pokémon GO, where users have to find virtual animals in the real world and free them from plastic); (2) an educational multi-user mobile application that can be used in schools; (3) a social media camera filter as a suitable communication tool for sustainability advocates; (4) an immersive AR narrative that can be available during exhibitions, conferences, or museum visits. The experience should be interactive, and with a good user interface (UI), the application could have a call-to-action (for example, leading to a donation appeal).

Inviting people to try an AR experience - The difference between photo or video content and the AR experience is that AR must be experienced, unlike photos or videos that are viewed. This means that there should be a trigger or a call-to-action that invites people to engage in the experience. The call-to-action can be offline (e.g., a poster) or online (e.g., a link within a social media post). There are many ways that AR artifacts can be promoted. For example, an AR game could be promoted by an influencer; specialized press (scientific journals or portals); eSports events and tournaments; memes on social media. An AR narrative could be promoted through an installation in a museum or exhibition, a conference booth. AR Camera effect on social media can be promoted by social media influencers and sustainability advocates. A museum could place an informational sticker on the wall to invite an AR experience.

Adoption of AR - AR and VR are still perceived as emerging technologies, but with the rapid development of the Internet, social media, and mobile devices, they are increasingly being adopted. Schools, museums and others offering immersive experiences to newcomers should make sure the trial goes smoothly. The early uses of the technology are key to its future use. AR and VR may have different applications and purposes depending on the purpose of the experiences, but AR is still a novel technology and may be welcomed more by some audiences and less by others. Novices may be more impressed and AR may work better with younger audiences, Millennials, Generation Z, or 12-16 year old pupils. Although the range of audiences

for AR communications is broad, each audience may require a different AR form, content, and approach³⁵.

Challenges of immersive technologies - As with any emerging technology, there are still some challenges with immersive technologies that will likely be overcome in future phases of development. The biggest challenge is the dependence on the AR or VR supporting device. This may limit the use of AR in schools due to device availability or even permission to use smartphones. Other challenges are primarily related to the user experience of VR. First, users are essentially “entering” and surrounded by a whole new world with VR. This may cause some initial shock and resistance. Second, VR requires a headset that blocks the user’s view, and this total immersion sometimes leads to simulator sickness. In addition, the limitation of VR could be the age restriction - some vendors of VR do not allow children to use it. Finally, researchers and practitioners might encounter a methodological challenge during the evaluation phase of AR: Because AR is consumed through experience, it may be difficult to demonstrate and test an AR prototype in its conceptual phase.

The second part of analysis includes second-order themes that are more in line with the refinement of design principles. This is the case of the following items:

Gamification and interaction - Games can be entertaining and educational at the same time. Indeed, the exploratory nature of video games leads to more effective learning and memory retention. For example, while having fun, users can acquire new knowledge by solving quiz questions. Similarly, the recently popular mobile AR game Pokémon GO could serve as inspiration for developing a similar game that focuses on collecting trash instead of Pokémon characters. Similarly, a serious game can be an effective tool to illustrate the impact of our daily actions on the environment. For example, a game could be a hybrid that combines the real and virtual worlds, meaning our behavior in the real world can impact the game scenario. Games can also have a social component. In multiplayer mode, users can build social relationships with other users and enhance their creativity and cooperation skills. A game can be turned into a challenge for different teams, such as school classes or even schools, where teams compete against each other to achieve the “greenest” score. Based on the interaction, participants not

35 For example, the mobile game AR might be best suited for younger audiences, AR for older audiences, while AR camera filters can serve as an effective communication tool for sustainability advocates and social media influencers.

only observe the impact of their behavior, but the endorphins and dopamine released after positive feedback (e.g., receiving badges for the correct answer) can influence their attitude and perceived control, and thus their behavior. If the game is interactive enough, it is not necessary for digital elements to look realistic, as interaction can create immersion.

Technical details of an AR experience - AR the experience can take different forms and be experienced with different devices. The most convenient forms are mobile apps, web XR (an AR experience accessed through a website via an internet browser), or camera filters. Designers of AR should consider which option is most appropriate for an intervention. Unlike VR, which is fully immersive, AR only overlays the real world with artificial elements. Therefore, to make an experience immersive, the digital content on AR should be as realistic as possible. According to the experts we interviewed, such an intervention from AR does not need to be marker-based or limited to specific geographic locations, as it should symbolically show that trash can end up in the ocean no matter where the pollution starts. There are still some technical details that could be implemented to make the experience more realistic. For example, adding a shadow light effect that moves over the object, the object could realistically blend with the environment. It is even possible to replicate real ambient lights depending on the user's GPS location, which could increase integration with the landscape. These lighting effects can then be adjusted by light position, intensity and color (palette from blue to yellow). In addition, the animations of the animals are well integrated into the scenes and trigger emotions. However, interviews argue that adding an animal sound could make the scene even more dramatic. Finally, the user guidelines could include a short user tutorial explaining how AR works. After all, if someone is not familiar with AR, it may be difficult for them to understand the concept of a merged real and virtual world.

3.3. Discussion

Main results - The aim of this study was to find out how to design and implement a green artifact that uses mobile AR to visualize the consequences of plastic pollution and motivate people to adopt pro-environmental behavior. Based on extensive and informative theoretical and empirical evidence, we were able to answer this research question by proposing (1) a set of 7 design principles and (2) guidelines for the future practical implementation of such an artifact in the practice.

This DSR study (Hevner et al., 2004) introduces a novel Green IS (Elliot, 2011) – an artifact with the purpose of communicating environmental issues through AR simulations and promoting environmentally friendly behavior. We designed the artifact following three kernel theories (Trope & Liberman, 2010; Kelman, 1958; Fogg, 2003) and evaluated it through semi-structured interviews with 9 experts from the domain of environmental communication. This evaluation allows us to refine the original design principles based on kernel theories and ground them in practice. The results show that the use of AR technology in environmental communication is still in its infancy, but that it has great potential to improve traditional means of delivering pro-environment campaigns and behavioral interventions. We can summarize these findings in terms of three aspects of the artifact: information, social, and technology aspects (De Leoz & Petter, 2018).

First, the advantage of AR technology over traditional means of environmental communication (such as photos or videos) is its ability to make information more immersive (by embedding tridimensional elements in real environment), tailored (by making each experience unique), engaging (by vividly presenting content), and simple (by transforming abstract environmental data into visuals). To experience is to believe - if a person can consume information about an environmental issue by ‘living’ it, their awareness of risk is likely to be increased and psychological distance reduced (van der Linden et al., 2015; Trope & Liberman, 2010). Second, immersive technologies change the way we interact and therefore open up new possibilities for social influence. AR can serve as a social actor (Fogg, 2003), as people tend to build social relationships with virtual characters, and AR technology seems to be particularly powerful in this area (Miller et al., 2019). Moreover, AR experiences can be integrated into a multi-user platform to enable social interactions between users. Third, the artifact should use the potential of AR simulations to convince users of the benefits of pro-environmental behavior. The artifact could include interactive gamification elements (Oppong-Tawiah et al., 2018; Morganti et al., 2017) to make the path to environmental sustainability fun and engaging. However, since AR is still in its infancy, communicators should be aware of potential unfamiliarity with the technology.

The table below (Table 19) provides refined design principles for green AR artifacts, which could be generalized and applied to other similar areas of behavior-changing artifacts (e.g., related to health or prosocial behavior).

INFORMATION ASPECT	Design principle title	DP 1. Principle of tailored information
	<i>Aim, implementer and user</i>	In order for green AR artifacts to be effective in promoting individuals' pro-environmental behavior
	<i>Context</i>	in pro-environmental communication interventions
	<i>Mechanisms</i>	information presented through the artifact should be tailored and personalized, taking into account the heterogeneity of targeted audience
	<i>Rationale</i>	because there is no one-size-fits-all approach and the success of the intervention may depend on the individuals' personal characteristics
	Design principle title	DP 2. Principle of simplifying abstract information
	<i>Aim, implementer and user</i>	In order for pro-environmental messages to be understood by individuals
	<i>Context</i>	in pro-environmental communication interventions
	<i>Mechanisms</i>	abstract environmental data need to be translated into simple, vivid, visual narratives using user-centered design
SOCIAL ASPECT	<i>Rationale</i>	because complex data might cause cognitive load and might be hardly understandable
	Design principle title	DP 3. Principle of psychological distance
	<i>Aim, implementer and user</i>	In order to raise the perceived seriousness of environmental issues by individuals
	<i>Context</i>	in pro-environmental communication interventions
	<i>Mechanisms</i>	the environmental issues should be directly presented at familiar and relevant places
	<i>Rationale</i>	because direct, personally relevant experiences are likely to bring environmental issues psychologically closer
	Design principle title	DP 4. Principle of social influence
	<i>Aim, implementer and user</i>	In order to encourage individuals' PEB
	<i>Context</i>	in digital environment
TECHNOLOGY ASPECT	<i>Mechanisms</i>	the artifact should be integrated into a multi-user platform
	<i>Rationale</i>	because such platforms open avenues for social influence
	Design principle title	DP 5. Principle of social empathy
	<i>Aim, implementer and user</i>	In order to encourage individuals' PEB
	<i>Context</i>	in digital environment
	<i>Mechanisms</i>	the artifact should generate empathy towards virtual characters of endangered species
	<i>Rationale</i>	because social empathy with animals and nature may promote individuals' PEB
	Design principle title	DP 6. Principle of gamification
	<i>Aim, implementer and user</i>	In order for an immersive system to be effective
	<i>Context</i>	in attempts to promote PEB
	<i>Mechanisms</i>	the artifact should incorporate gamification elements
	<i>Rationale</i>	because gamified systems can be effective at influencing behaviors
	Design principle title	DP 7. Principle of interaction
	<i>Aim, implementer and user</i>	In order for an immersive system to be effective
	<i>Context</i>	in attempts to promote PEB
	<i>Mechanisms</i>	the artifact should be interactive
	<i>Rationale</i>	because letting a user impact the scenario of a virtual simulation strengthens their perceived self-efficacy and control

Table 19. Refined design principles for behavior-changing artifacts

Our grounded theory model summarizes the design and implementation process of using green AR artifacts in environmental communication campaigns and behavior-changing interventions. In summary, the design principles for the information and technology aspects of the artifact should be considered in the design and development phase, while the design principles dealing

with the social aspects are crucial in the later phase, i.e., the implementation phase. In the implementation phase, when the intervention can successfully address a person, the goal is not achieved until the path to pro-environmental behavior is free of contextual barriers (e.g., consumer culture or a lack of pro-environmental alternatives in the supermarket).

Potential practical implementation – In guidelines for potential practical implementation of green AR artifacts, we suggest following these 6 steps: (1) as with any other behavioral intervention, contextual barriers that might distract a person should be minimized as much as possible; (2) the AR experience should be integrated into a system that adds value to the user; (3) the artifact should include a brief user tutorial to explain the concept of AR to those unfamiliar with the technology; (4) the intervention should provide sufficient time and space for users to add to and freely interact with AR objects; (5) relevant others (e.g. social media influencers) should be recruited to promote the artifact; (6) the artifact should inform users about the next steps they should take.

3.4. Limitations

Limitations of AR technology – From a practical perspective, and despite its potential, communicators may face some challenges in promoting and using AR -based artifacts. First and foremost, AR requires a supporting device and (unless local device storage is used) stable internet access to access data stored in the cloud. Although most phones today have built-in technologies that enable the use of AR (Google, 2022) and millions of users have high-speed internet connections (Lv et al., 2022), communicators should be aware that AR campaigns will exclude users who do not meet these requirements. Second, the presence created in virtual environments plays an important role. If the experience of AR does not seem realistic enough, it may not succeed in persuading individuals to change their behavior. On the other hand, if it seems very realistic and the sense of presence is high, it may cause mental fatigue in users. Third, unfamiliarity with the technology can be another barrier to adoption of AR campaigns. Therefore, communicators should ensure that audiences understand how to consume AR content. Because AR is still an emerging technology and there is no one-size-fits-all recipe that will guarantee success, we recommend that communicators first evaluate AR campaigns with the intended audience before launching mass campaigns. For example, they can conduct focus groups with end users to get initial reactions (see example Buljat, 2022).

Limitations of the study – this study also has some limitations. First, given the emergent nature of the technology, it is difficult to generalize these findings to the entire population of environmental communication professionals. The nature of this study remains exploratory, but provides a foundation for exploring this novel concept of using AR for behavior-changing interventions. Future studies should complement these initial findings by focusing on a specific design concept or principle. The second limitation stems from limited access to relevant respondents, as it is difficult to find communicators specializing in environmental campaigns who are familiar with AR technologies. For example, we were unable to include social media influencers in our sample, even though they are recognized as playing an important role in the success of such artifacts. We contacted many Instagram, YouTube, and TikTok influencers from the environmental sustainability niche, but despite persistent efforts, none of them agreed to give an interview for this study. The last limitation is methodological and concerns the evaluation of the artifact AR. Demonstration of AR requires on-site experience, but some interviews had to be conducted online due to travel restrictions during the COVID -19 pandemic. We believe that conducting in-person interviews that allow for actual AR on-site demonstrations produce more accurate results. Finally, artifact evaluation is incomplete without feedback from actual end users (see Buljat, 2022). Further steps, therefore, include conducting a long-term experiment to test the actual impact of such an AR artifact on end-users' pro-environmental behavior.

3.6. Concluding Remarks

Faced with growing environmental crises, institutions, researchers, and communicators are looking for innovative ways to motivate individuals to adopt PEBs. Previous research has shown that direct experience with environmental threats is likely to influence people's concern, risk perception, and adaptive behavior. However, translating this theoretical assumption into practice has been difficult. In this DSR study, we develop a novel Green IS - an artifact that simulates direct experiences with environmental problems through AR - and evaluate it through interviews with professional users from the domain of environmental communication. Our results show that the artifact can be effective in motivating individual PEB and collective *green* movements. However, technology alone is not sufficient to change behavior, as it depends on many other contextual factors. In addition, our results suggest that there is no one-size-fits-all

communication strategy, so it is likely that AR will work well for certain audiences and perhaps not for other. The results allow us to identify possible extensions of the proposed system and ways to put it into practice. We believe this study has the potential to help future DSR researchers focused on behavior-changing artifacts make their studies more productive and insightful.

CHAPTER FOUR:

CONFIRMATORY STUDIES

In the previous chapter, I presented the results of exploratory studies using qualitative methods conducted with two different types of users (end users and mediators). These studies were informative and provided useful insights for the design and implementation of green AR artifacts. However, to fully understand the potential of the artifact in solving the real-world problem, this investigation must be complemented by an assessment of its utility (Hevner & Chatterjee, 2010).

Therefore, we ‘borrowed’ techniques from Behavioral Science, to test the utility of the artifact – its impact on people’s motivation to engage in pro-environmental behaviors. In this chapter, I present an evaluation study of the second design cycle, in which we addressed the specific research question, *“Can the green artifact AR reduce psychological distance and motivate individuals to engage in pro-environmental behavior?”*

To answer this question, we conducted a quantitative study: a controlled experiment in the laboratory and in the field with end users. During the experiment, participants interacted with a brief AR experience simulating the consequences of plastic pollution, after which we tested their environmental concern, psychological distance, intentions, and real monetary decisions (donations to an environmental organization). Overall, the results are mixed and suggest that the efficacy of the AR artifact may depend of personal characteristics of targeted individuals.

This study was communicated to the academic community at various stages, which greatly improved the quality of the final manuscript. Namely, first we presented the experimental design to the members of our laboratory. Then, we presented the preliminary results at national and international conferences and workshops in the field of experimental economics. Based on the constructive feedback, we decided to replicate our study in the lab-in-the-field settings and compare the results with the first study. Finally, the study was submitted to one of the leading journals in the field of environmental economics and management.

1. Augmented reality for environmental fundraising: Two experimental studies^{36,37}

Environmental nonprofit organizations play an important role in combating climate change: they communicate and educate on current issues, influence environmental policy, support environmental research and mobilize public support for environmental protection (Nisbet, 2018; Osuri, 2010). However, unlike companies, which generate their income through the sale of products and services, non-profits often rely on voluntary donations to carry out their activities. Therefore, understanding what motivates people to donate is crucial to the success of any non-profits' initiative (Freeling & Connell, 2020; Verssimo et al., 2018).

On the other hand, non-profits face a great challenge: communicating about environmental problems is difficult because people rarely experience them directly and may therefore perceive them as remote and irrelevant risks (Carmi & Kimhi, 2015; Spence et al., 2012). Psychological distance (Trope & Liberman, 2010) from environmental issues has been put forward by the literature as a possible explanation, albeit with mixed evidence, for the citizens' relative lack of concern or action towards climate change (McDonald et al., 2015). Although personal experience of environmental threats is likely to bring environmental issues psychologically closer and increase perceptions of their risks (Akerlof et al., 2013; van der Linden et al., 2015), exposing everyone to environmental threats would be complicated, lengthy, costly or even dangerous.

One idea to overcome this limitation would be to use emerging immersive technologies such as augmented reality (AR) or virtual reality (VR) in awareness-raising or fundraising campaigns. By providing sensory-rich experiences, these types of technologies can create a sense of presence (Mol, 2019) and make users feel like they are directly experiencing environmental issues. However, to our knowledge, there is no study that examines the impact of AR on psychological distance from environmental threats.

36 This study, co-written with Giuseppe Attanasi, Agnès Festré, and Andrea Guido has been presented at several conferences and workshops: International Conference of the French Association of Experimental Economic (ASFEE) 2022 (Lyon, France), Conference of the International Association for Research in Economic Psychology (IAREP) 2022 (Kristiansand, Norway), workshop BLUE-INNOV "Entrepreneurial Ecosystem, Blue Economy, And Sustainable Innovation" 2022 (Cannes, France). Finally, the manuscript has been submitted to the Journal of Environmental Economics and Management (JEEM) in March 2023.

37 The experimental studies have been financed from two projects: ANR and ABSolEU.

To address this gap, we conducted two incentivized experiments. First, we conducted a laboratory experiment to investigate whether AR visualizations can reduce psychological distance and promote pro-environmental behavior. Specifically, we designed two controlled conditions: in the treatment condition, participants used an AR-based application demonstrating the consequences of plastic pollution on the most affected animals, while in the control condition, participants only read a message describing the consequences of plastic pollution on marine life. In both conditions, we experimentally observed individual pro-social behavior³⁸, by measuring voluntary donations to an environmental organization using a well-established experimental paradigm.

We complemented donations choices with additional measures such as psychological distance, environmental concern, and intention to act. Then, we run a lab-in-the-field experiment by replicating the same lab experiment in a more natural setting to test whether the same AR intervention in the field is more effective than AR intervention in the context-free laboratory settings.

The results show that the effect of AR on psychological distance is zero overall in both the laboratory and the field, but heterogeneous at the individual level. After the intervention, individuals with low environmental commitment feel psychologically closer to the problem of plastic pollution, while the opposite seems to be the case for individuals with high environmental commitment. When evaluating the impact of AR on donation behavior, we find no evidence of a mediating effect between psychological distance and pro-environmental behavior on donation levels.

This study suggest important practical implications for policy-makers. The experimental results raise awareness about the actual effectiveness of new technologies, such as AR, in promoting behavioral change. Recent work has highlighted the importance of evaluating heterogeneous effects when designing interventions (Bryan et al., 2021). Policy-makers should move away from the idea of ‘one-size-fit-all’ solutions and be aware of the rise of possible unintended consequences affecting sub-group of the population before making decisions. We provide concrete guidelines for the use of AR in environmental interventions focused on fundraising,

38 Pro-social behavior refers to any costly individual actions that produce benefits to others. In the experimental literature, donations games are used to measure individuals’ levels of prosociality (see Bicchieri and Dimant (2019) for a similar experimental setting as ours). Our experimental design and used paradigm differ substantially from those deployed in choice experiments. Our goal is to study the causal effect of AR on donation behavior.

which can be useful for optimizing the communication strategy of policy makers, non-profit organizations and environmentalists. Second, the theoretical contribution of this study implies new insights into the use of novel technologies to promote pro-environmental behavior using a donation game. This is the first study to examine the impact of AR technology on individuals' motivation to engage in pro-environmental behavior by reducing their psychological distance from environmental issues. Third, the study provides a methodological example of using AR to bring context and field cues to laboratory experiments needed to evaluate policies and test individual decision-making.

1.1. Relevant literature and hypotheses

1.1.1. Psychological distance and risk perception of environmental issues

Despite urgent calls for action from global environmental institutions and researchers (UNEP, 2021c), the behavioral changes needed to achieve sustainability are still in their infancy. Even when people are aware of environmental issues, translating their intentions into actual behavior is no easy task (Kollmuss & Agyeman, 2002). Communicating environmental issues is challenging because of their abstract nature and the discrepancy between their causes and consequences. Indeed, we rarely experience environmental threats directly. For example, people living in the cities rarely observe the accumulation of plastic waste, as it is mostly found in remote locations – on exotic beaches or deep in the oceans. Research suggests that this lack of direct experience leads people to perceive environmental problems as temporally, socially or spatially distant events (Carmi & Kimhi, 2015; McDonald et al., 2015).

In psychological literature, this phenomenon is called psychological distance. As explained by Construal-Level Theory (CLT) – the theory that also partially informed the design of our artifact (see section 3 of Chapter 1) – psychological distance is a subjective perception of how far an object or event is from the here and now – from oneself, from this place and time. When we do not experience something directly, but think about it, remember it or imagine it, we create abstract mental construals. If, on the other hand, an object is psychologically close to us, its mental construal becomes more concrete and we can think about it in more detail. This perceived psychological distance can be measured by four interdependent dimensions (temporal, spatial, social and hypothetical) that influence the estimation of when, where, for whom and whether at all an event occurs (Trope & Liberman, 2010).

Therefore, we can assume that those who do not have the chance to experience environmental threats, but view them as something distant in space and time, perceive them as less real or tangible events that are not likely to happen to them in the near future, or not at all, leading to environmental behavior being seen as unnecessary adaptation. Indeed, some studies have shown that psychological distance can lead to environmental threats being perceived as abstract and not personally relevant risks (Carmi & Kimhi, 2015; Spence et al., 2012).

One study examined the relationship between participants' perceived psychological distance from climate change and their level of concern and willingness to act. The results suggest that reducing psychological distance may be a promising strategy to promote pro-environmental behavior, as it increases concern about the issue. In their study, concern about the environment was strongly related to intention to behave in an environmentally friendly way. Note, however, that actual behavior was not measured (Spence et al., 2012). In addition, one study showed that people feel more responsible for environmental degradation at the local level and less responsible the distance increases (Uzzell, 2000).

It seems that communicators should focus on finding a strategy to minimize psychological distance, as this could lead to greater concern and perception of environmental risks, greener behavior and greater support for environmental policies (Fox et al., 2020; Spence et al., 2012; van der Linden et al., 2015). Furthermore, effective pro-environmental communication should help people better understand the consequences of their actions and make an issue relevant to the target audience – their social group, place and time (Spence et al., 2012).

While concrete, direct experiences seem to be effective in raising people's awareness of risks and encouraging their environmental behavior (Akerlof et al., 2013; van der Linden et al., 2015), this approach can be complicated, costly or even dangerous in the real world – taking citizens to remote beaches and underwater to observe the effects of environmental crises such as ocean acidification and plastic pollution could even be counterproductive. Nevertheless, it is important to change behavior before more serious events occur.

One solution to overcome practical limitations and bring environmental problems psychologically closer could be the use of immersive media: content presented in an interactive and vivid format can translate abstract mental construals into concrete ones, bring distant places closer, bring future events sooner, and demonstrate the impact of environmental crises here and now, as suggested by Ahn et al. (2015).

1.1.2. Immersive technologies and the sense of presence

People have always been impressed by the idea of being in one reality and experiencing another at the same time. Technologies such as VR and AR have changed the way we consume content and experience the real and physical environment. While VR is fully immersive and ‘transports’ the user into a virtual environment by blocking the view with a head-mounted display (HMD), AR uses smart glasses or screens to blend the real and the virtual: by overlaying reality with three-dimensional digital objects in real time, it creates the illusion that they really exist there (Azuma, 1997). The rapid development of new technologies, the Internet and mobile devices has opened up new possibilities for the immersive technology market, making it affordable and popular for the general public (Flavián et al., 2019).

What distinguishes immersive media from other traditional media is its ability to produce highly vivid and interactive content that creates a sense of presence – the feeling of *being there* (Steuer, 1992). Presence is valued for its persuasive impact in a variety of disciplines, such as environmental and health communication (Bailey et al., 2015; Ahn et al., 2019). While VR gives users the feeling of being present in an artificial environment mediated by technology, AR tends to create the illusion that digital objects are present in the users’ real environment. If the virtual experience includes living beings, there is a chance of convincing users to see them as real and eliciting reactions such as fear or empathy. One of the first examples of emotional relationships with computers is Tamagotchi, a pocket device that acted as a virtual pet and got people to behave socially and form relationships (Fogg, 2003).

The compelling nature of immersive media makes it a suitable tool for environmental communication. If these sensory-rich immersive experiences could give users the feeling of directly experiencing the environmental threat and thus reduce the perceived psychological distance to environmental issues, immersive technologies could serve as Green IS – a technological solution that orients users towards green behavior (Melville, 2010). The impact of such a system could be assessed through an experiment, as explained below.

1.1.3. Virtual experiments related to environmental engagement

Laboratory experiments are used in the discipline of environmental economics as a valid and reliable method to test theories in a controlled, context-free environment (Sturm & Weimann, 2006). However, since people rarely make decisions in context-free environments (Harrison &

List, 2004), researchers came up with the idea of ‘*bringing the field into the lab*’ and using virtual environments to provide participants with the necessary context to test more realistic decision-making (Innocenti, 2017; Mol, 2019).

The concept of using virtual experiments to test environmental policy was introduced by Fiore et al. (2009), who showed that virtual experiences can reduce judgement errors. In their study, participants watched virtual simulations of forest fires on a computer screen, whereupon their responses reflected beliefs that were closer to actual risks (Fiore et al., 2009). Several studies followed, examining the effects of low-immersive (computer screen) virtual environments on internal determinants of environmental behavior and support for environmental policies (Bateman et al., 2009; Olschewski et al., 2012; Matthews et al., 2017). Lately, researchers moved on to high-immersive virtual environments that create higher levels of immersion, such as AR or VR (Innocenti, 2017; Ahn et al., 2014; Ahn et al., 2016). In one study, for example, participants experienced cutting down a tree in virtual reality, whereupon they used 20% less paper compared to participants who read a text (Ahn et al., 2014). Other studies suggest that immersive storytelling in VR can increase concern and risk perception about environmental issues (Chi et al., 2018), connect users more closely with nature (Ahn et al., 2016; Breves & Heber, 2020) and increase donations to environmental organizations for certain groups (Nelson et al., 2020).

A few studies have tested whether VR is able to manipulate psychological distance from environmental issues (Ahn et al., 2016; Breves & Heber, 2020; Markowitz et al., 2018). If computer simulations appear sufficiently *real* in a virtual environment, participants may treat them as if they really happened (Fiore et al., 2009). Consequently, the sense of spatial presence created in immersive virtual environments may minimize perceived psychological distance or increase risk perception for an environmental problem (Ahn et al., 2016; Breves and Schramm, 2021).

While VR technology tends to be represented in virtual experiments, three studies have experimentally investigated whether AR can guide people to adopt pro-environmental behaviors when grocery shopping. In these studies, participants used the AR application, which displayed additional information about products, such as their carbon footprint (Isley et al., 2017) Schaeffer et al., 2018; Joerss et al., 2021). The results suggest that AR can influence consumer behavior and encourage shoppers to make more sustainable product choices (Isley et al., 2017).

To our knowledge, however, there is no study that experimentally examined the effectiveness of AR on its ability to manipulate psychological distance from environmental issues. Therefore, in this study we investigated (1) whether AR is able to manipulate psychological distance to an environmental issue and (2) whether the reduced psychological distance could stimulate pro-environmental behavior at the individual level.

Immersive technologies can be used to virtually simulate experiences of environmental degradation. If the virtual experience seems sufficiently real, it can trigger a sense of presence or “being there” and thus serve as an alternative to a direct experience. If the feeling of presence is achieved, we assume that such an intervention can reduce the perceived psychological distance. Based on the existing literature on psychological distance (PD) and previous experiments with immersive media, we therefore hypothesize the following:

H1: AR intervention reduces psychological distance (PD).

Following previous literature on psychological distance to an environmental problem (climate change) and its association with intentions to act (Spence et al. (2012)), we hypothesize that reduced psychological distance can trigger pro-environmental behaviour, which we measure by voluntary donations to an environmental organization. Therefore, we hypothesize:

H2: Psychological distance mediates the effect of AR on pro-environmental behavior (voluntary donation to an environmental organization).

Considering that AR scenes of wildlife indoors may seem unrealistic (Buljat, 2022), we hypothesize that the same experience outdoors could seem more realistic and therefore be more effective in reducing psychological distance. We hypothesize the following:

H3: AR intervention in the field is more effective in reducing psychological distance (PD) than AR intervention in the laboratory.

For the same reason, we expect that an outdoor AR experience can trigger more pro-environmental behavior, which we measure by voluntary donations. We hypothesize:

H4: AR intervention in the field is more effective in promoting environmental behavior (voluntary donation to an environmental organization) than AR intervention in the laboratory.

1.2. Study 1 (Augmented reality interventions in the Lab)

We conducted a laboratory experiment to test the effects of AR on psychological distance and pro-environmental behavior. We tested whether participants' generosity towards environmental organizations responded to immersive AR experiences showing the consequences of plastic pollution for the five most endangered animals. The experiment was composed of several parts to collect pre-experimental measures, individual choices in a donation game and self-reported attitudes towards plastic pollution. In the following, we describe the design and procedure of the experiment.

1.2.1. Methods

Experimental procedures and treatments design

We employed between-subject experimental design with two experimental conditions: a *Control* and the *AR treatment*. The sessions were individual (one participant per session) and took place in the faculty premises, in two empty large classrooms with identical settings: closed windows, all lights on and a single table and chair in the corner. Upon arrival at the lab, participants signed an informed consent form, were given a code which they later used for the lottery, and were randomly assigned to either the control group or the AR group.

After entering the room, each participant took a seat at the table with the tablet device. The experimenter read out the introductory text (see Appendix 6.A), which contained information about the experiment, the rights of the participants, data collection and incentives. Participants were informed that they would be taking part in a decision-making study. Participants were informed that they had an equal chance to win €300 in a lottery and that they could choose to donate a desired amount to an environmental organization of their choice.

The first part of the experiment was the same for both treatments. Participants completed the pre-questionnaire, which collected demographic information, their environmental engagement, familiarity with technologies, previous donation experience and preferences for environmental organizations. Participants could choose to donate to one of the 12 well-known environmental organizations accepting donations through the website. The pre-questionnaire can be found in Appendix 6.B.

After the participants had filled in the pre-questionnaire, the experimenter gave them a sheet with a short text about the harmful effects of plastic pollution and the call for donations, as one might encounter in real life (see Appendix 6.C). The experimenter read the text aloud. After reading the text, participants in the control group moved on to the main questionnaire, while participants in the AR treatment group were asked to stand up and come to the center of the room. The experimenter set up the mobile AR application Eco Animals on the tablet and explained to participants how to use it. Participants were asked to interact with the application for 2 minutes and then continued with the main questionnaire.

The main questionnaire assessed psychological distance (Spence et al., 2012), environmental concern and donations in the Donation Game. Participants in the AR treatment answered three additional questions: whether they felt the presence of animals in the room, whether they had similar experiences in the past, and whether the application brought them closer to the problem of plastic pollution. The questionnaires were created via Lime Survey (an online questionnaire service used by our university that ensures data protection and complies with European data protection regulations) and participants completed them in the Internet browser using the same mobile device (Samsung Galaxy Tab S5e tablet). Details and questions of the main questionnaire can be found in Appendix 6.D.

The sessions lasted about 15 minutes. After each session, participants were given a show-up fee and left the session. To ensure the credibility of the decision task, the draw was conducted via online video streaming a few days after the sessions. After the draw, the winners were paid, the money was donated to the environmental organizations selected by these participants, and proof of the donation was sent by e-mail to all participants. The experimental procedure is summarized in Figure 25.

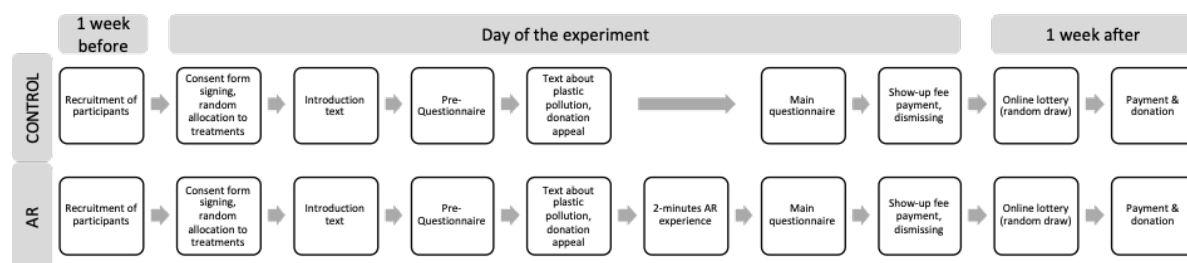


Figure 25. Experimental procedure

Stimuli

The mobile application *Eco Animals* was developed to our specifications by an external developer using the cross-platform game engine Unity. The application was installed on a Samsung Galaxy Tab S5e tablet running the Android operating system. The application illustrates the consequences of plastic pollution, presented in the AR format (see Figure 26). The visual content takes the form of the five animals most affected by plastic pollution: a sea turtle, a bird, a dolphin, a whale and a seal (Gall & Thompson, 2015). The scenes were inspired by real-life situations and anecdotal evidence.

After opening the application, users immediately see the image from the device camera. As soon as the system understands the environment and recognizes the flat surface, a white rectangle appears on the bottom. Upon clicking on it, an animated three-dimensional projection of a life-size animal being strangled with disposable plastic waste appears and merges with the real environment in real time. The projection is interactive – its appearance reacts to the movements of the tablet.

The simplified dashboard has a few buttons: arrows (to move to another animal), zoom (to zoom in or out of an animal) and a rotate function (to rotate an animal). Participants in the AR treatment were briefly instructed on how to use the application and then asked to freely interact with it for two minutes. The video demonstration is available on request.

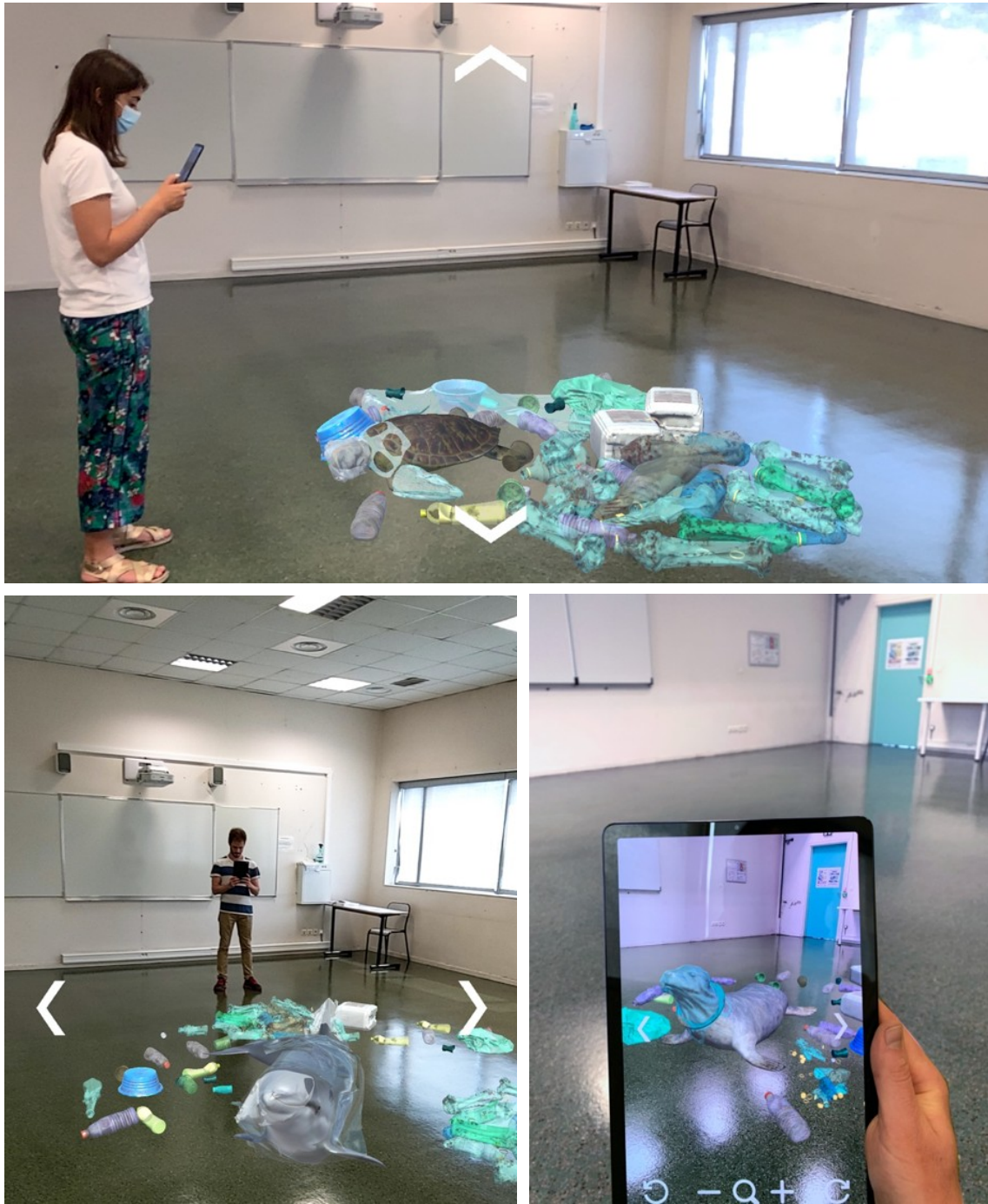


Figure 26. Examples of stimuli in the AR treatment

Experimental Measures

(A) Pre-questionnaire

- **Environmental Engagement Score (EES).** An environmental engagement score (Cronbach's $\alpha = 0.71$) was obtained from the pre-questionnaire. The scale was created by calculating the mean of four questions related to participants' self-reported current environmental engagement: Perception of being an environmentally conscious person; current level of environmental concern; current practices in purchasing eco-responsible products; recycling).
- **Past donation experiences and organizational preferences.** In the pre- questionnaire, we asked participants to indicate whether they had donated to an environmental organization in the past, on a 5-point scale from 'never' to 'more than 10 times'. We also asked participants which organization they would donate money to if they had the opportunity. Participants were able to choose from 12 well-known environmental organizations that mainly deal with plastic pollution and other related issues. Before adding an organization to the list, we checked whether it accepted online donations.
- **Frequency of using related technologies.** To assess familiarity and frequency of use of related technological devices and services, we ask participants in the pre-questionnaire to indicate how often they use these technologies on a 5-point scale from 'never' to 'every day': smartphone; video games; AR; social networks; AR filters on social networks.
- **Other demographic variables.** During the pre-questionnaire, participants were additionally asked to provide the following information: age; gender; education (last degree and field of study); pet ownership (whether they own a pet); vacation preferences (what would be the perfect vacation for them, between sea, forest/mountain, countryside, city or home); glasses (whether they wear glasses); dietary options (whether they are vegetarian).

(B) Main Questionnaire

- **Pro-environmental behavior (Donations).** We measured actual donations using an incentivized game. Each participant was endowed with €300 and made a decision on

how much to donate to a pro-environmental organization chosen from a comprehensive list. Participants were informed that decisions made were actually implemented according to the results of a lottery. Lotteries and raffles are often used in experimental economics research and public goods fundraising (Carpenter and Matthews, 2017). In particular, if a participant is randomly selected in the lottery, his decision made in the donation game is implemented. Hence, the amount indicated in the game is donated to the organization, while the remaining is given to the participant. Participants were given 10 donation options, starting with €0 and ending with €300 (see answer options in Appendix 6.E). Each participant had about a 1/30 chance of winning³⁹. The lottery results were announced publicly 1 week after the end of the experimental sessions.

- **Psychological distance (PD).** Following Spence et al. (2012), this measure combined four dimensions of psychological distance, namely: geographical distance, social distance, temporal distance and uncertainty. Geographical distance was assessed using two questions: One assessed the perception that plastic pollution affects one's local area; the other assessed the perception that plastic pollution affects distant areas. Social distance was also assessed with two questions: Participants were asked to rate whether plastic pollution was likely to affect mainly developing countries or people similar to them. Temporal distance was assessed with a single question asking participants when they think their country will feel the effects of plastic pollution. Uncertainty about plastic pollution was assessed with 5 questions about the perceived existence, severity, causes and effects of plastic pollution. The responses to the 7 items were combined into a single scale (Cronbach's $\alpha = 0.56$). The reliability of our composite measure increases when 2 items of the 7 considered are excluded ($\alpha = 0.6$)⁴⁰. In our analyzes, we use the latter measure, while the results of the former composite measure are used as robustness checks. The response options for all questions on psychological distance (with the exception of temporal distance) consisted of four- or five-point Likert scales. When necessary, responses were reversed so that higher scores represented a higher measure of psychological distance.
- **Concern about plastic pollution.** Following Spence et al. (2012), concern about plastic pollution was assessed using four similar questions: general concern about plastic

³⁹ Three lotteries were conducted: one for the control treatment and two more for the AR treatment.

⁴⁰ These items are uncertainty about the causes of and distance from pollution in developing countries

pollution; concern about the personal impact of plastic pollution; concern about the impact of plastic pollution on society; and concern about the impact of plastic pollution on wildlife and animals. These four questions were combined to form a reliable scale of concern (Cronbach's $\alpha = 0.76$).

- **Preparedness to act.** We assessed participants' behavioral intentions to engage with the problem of plastic pollution through three questions about their consumption habits, recycling practices and policy support.
- **AR treatment intensity.** Only at the end of the AR treatment, we assess three other control measures in the main questionnaire: (1) presence (we asked participants to rate on a 5-point scale (strongly agree - strongly disagree) how much they felt the presence of animals in the room); (2) perceived AR effect (we asked participants to rate on a 5-point scale (strongly agree - strongly disagree) the extent to which the experience at AR brought them closer to the problem of plastic pollution; (3) previous experience (we asked participants to indicate whether they had had similar AR experience in the past). The first two measures were later combined into one variable called treatment intensity.

Sample and procedures

We recruited a total of 86 students for the experiment from our university's web-based Online Recruitment System for Economic Experiments (ORSEE), who were randomly divided into the control group (29) and the AR treatment group (57). Appendix 6.F provides the demographic characteristics of the sample. The experiment was conducted in the Laboratory of Experimental Economics Nice (LEEN) in the period from June to November 2021. Several assistants were trained for the protocol and assisted during a total of 86 individual sessions over five days. Participants were incentivized with a €7 show-up fee. The recruitment and experimental design were approved by the Ethical Committee of our university under protocol #2021-030. All participants signed an informed consent form prior to participation.

1.2.2. Results

The main questionnaire assessed internal psychological determinants of environmental engagement related to plastic pollution, namely: four dimensions of psychological distance,

concern about plastic pollution, behavioral intention and actual behavior (donation to an environmental organization).

The effect of AR on PD

According to H1, we expect shorter psychological distance in our treatment condition relative to the control. Figure 27 depicts the distribution of PD between control and treatment condition. We report no statistical difference between conditions for this variable (Wilcoxon rank sum test, $p=0.66$). Results are also confirmed by regression models (Table 20, models 1-2). The indicator variable AR condition is not significant in any model specification. The inclusion of EES highlights a significant negative correlation between environmental engagement and psychological distance. Controlling for other measures, such as age, gender or past use of AR does not affect our results.

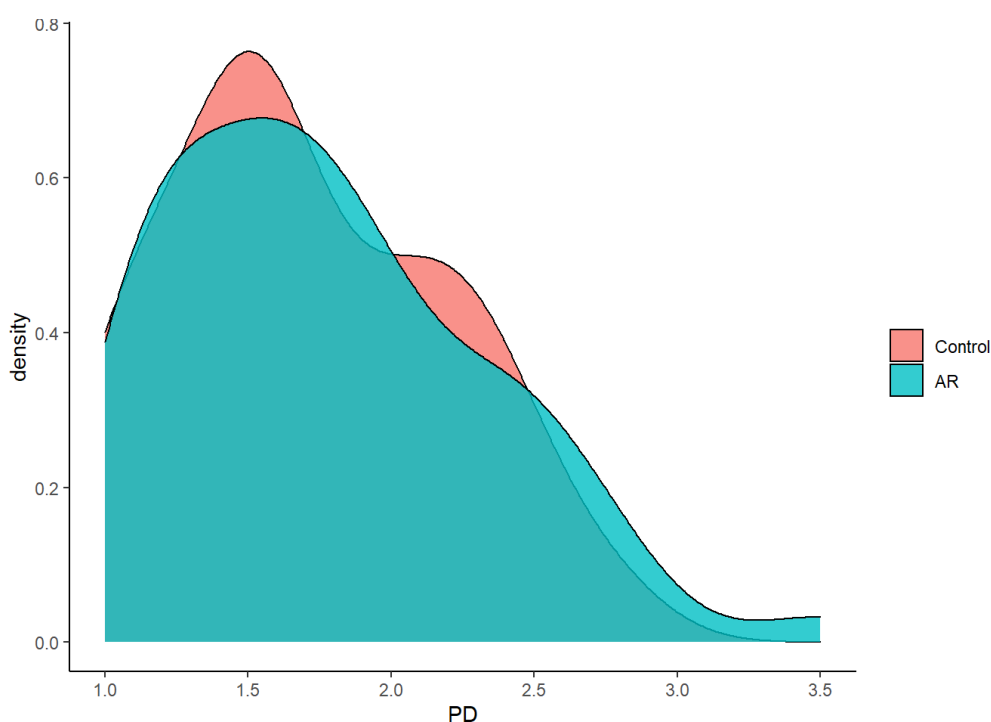


Figure 27. Distribution of Psychological Distance scores across conditions.

Despite the absence of significant differences in PD levels between conditions, we find evidence of heterogeneous effects within the AR treatment when considering individual perception of AR. Models (3-6) in Table 20 regress PD on Treatment intensity, a self-reported measure of how AR scenes were perceived as realistic and brought closer to plastic pollution.

Across models, we include EES and its interaction with Treatment intensity, as well as demographics and past use of AR.

	<i>Dependent variable: PD</i>					
	Full sample		AR sample			
	(1)	(2)	(3)	(4)	(5)	(6)
AR	0.069 (0.121)	0.080 (0.125)				
EES		-0.168** (0.080)		-0.225** (0.106)	-1.283*** (0.478)	-1.355** (0.531)
Treatment Intensity * EES					0.363** (0.159)	0.377** (0.174)
Treatment Intensity			-0.151 (0.105)	-0.175 (0.111)	-1.328** (0.533)	-1.381** (0.567)
Age		-0.005 (0.011)		-0.004 (0.012)		-0.006 (0.011)
Male		-0.118 (0.143)		-0.052 (0.191)		-0.110 (0.185)
Use AR		0.139** (0.064)		0.230** (0.103)		0.174* (0.103)
Study level		0.108 (0.089)		0.083 (0.119)		0.084 (0.114)
Use smartphone		-0.832 (0.542)		-0.683 (0.578)		-0.946 (0.569)
Use video games		0.062 (0.058)		0.004 (0.083)		0.051 (0.083)
Use AR filters		-0.022 (0.049)		-0.034 (0.060)		-0.041 (0.058)
Donated before		-0.065 (0.075)		0.016 (0.098)		-0.015 (0.095)
Constant	1.637*** (0.210)	5.813** (2.722)	2.199*** (0.302)	5.880** (2.911)	6.394*** (1.596)	10.900*** (3.634)
Observations	86	86	57	57	57	57
R ²	0.004	0.172	0.036	0.243	0.201	0.315
Adjusted R ²	-0.008	0.062	0.019	0.079	0.155	0.147
Residual Std. Error	0.532 (df = 84)	0.513 (df = 75)	0.547 (df = 55)	0.530 (df = 46)	0.507 (df = 53)	0.510 (df = 45)
F Statistic	0.328 (df = 1; 84)	1.558 (df = 10; 75)	2.079 (df = 1; 55)	1.480 (df = 10; 46)	4.434*** (df = 3; 53)	1.881* (df = 11; 45)

Note: *p<0.1; **p<0.05; ***p<0.01

Table 20. OLS regression models of PD

Results show no significant effect of Treatment intensity (model 3). Yet, the effect of this variable becomes significant when we account for individual controls (model 3) and its interaction with EES levels. Model 5 shows that for individuals that are not very environmentally engaged (low EES), a stronger intensity of AR scenes brought closer to the problem of plastic pollution (shorter PD). The opposite applies for highly engaged individuals

(high EES). Results remain unchanged also when adding individual controls (model 6). Figure 28 depicts these results broken down by three categories of individuals with low (1), medium (2.5) and high levels of EES (5). Based on initial engagement with the environment, the experience of AR scenes may shorten or increase psychological distance.

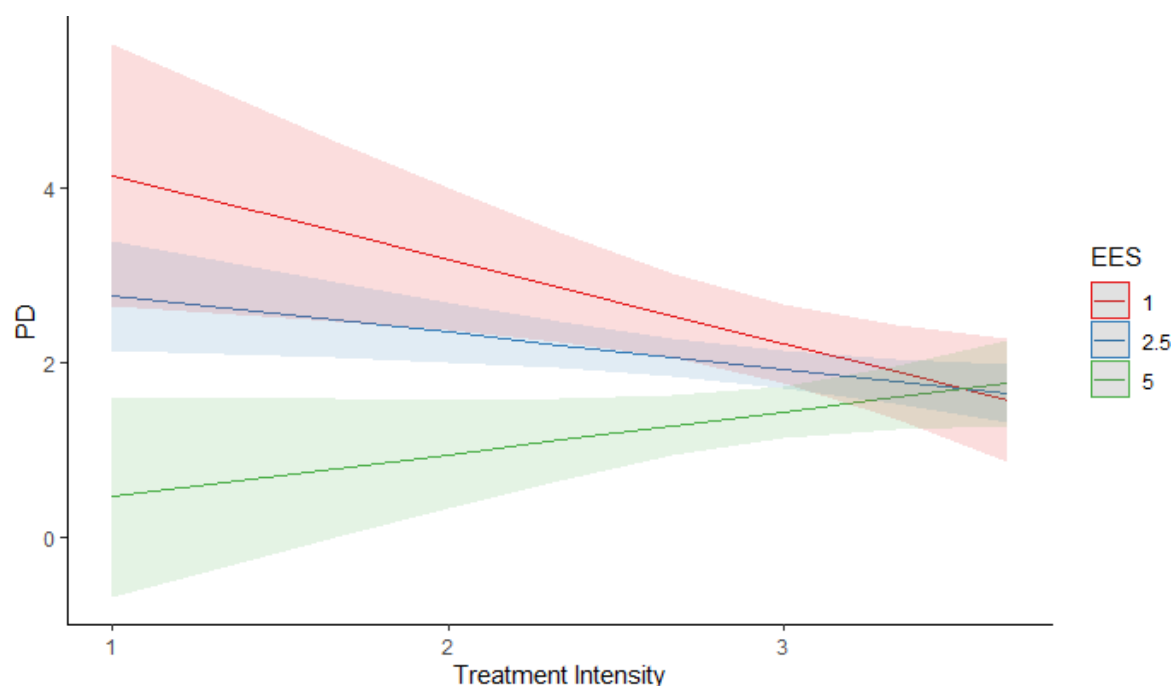


Figure 28. Predicted effect of Treatment intensity on Psychological Distance varying the level of EES

Donation levels and mediation effect of PD

Following H2, we test whether AR has had an overall effect on donations in the Donation Game and whether and to what extent the effect is mediated by PD. Figure 29 shows the distribution of donations in the two experimental conditions. The average donation amount in the control group is slightly higher ($\bar{x}_c = 100$) than in the AR Treatment ($\bar{x}_{AR} = 93$). However, this difference in donation level is not statistically significant (Wilcoxon rank sum test, $p=0.92$).

When assessing the impact of PD on donations, the regression model estimates show no statistical relationship between these variables (table 21, models 1-2). These results are not surprising considering that AR has no impact on PD, as explained in the previous section. As expected, individuals' self-reported environmental engagement (EES) has a positive effect on donations (models 2 and 4).

We additionally run a mediation analysis to jointly estimate the effect of AR on PD and, in turn, the mediated effect of PD on donations⁴¹. We run two analyzes, one for the full sample and another for the AR sample only to account for the heterogeneous effect of Treatment intensity on PD. In all mediation models, we account for a set of controls previously included in our analyzes, that is, demographics, past use of AR and EES. In both cases, we find no evidence of a mediating effect of PD on donations (Table 21).

In particular, when using the whole sample, mediation analysis results show no effect of AR on PD, and hence absence of mediation (Indirect effect, $b=-0.34$, $p = 0.88$). When considering the AR sample, we find mild evidence of the effect of Treatment Intensity on PD (Direct effect, $b=30.24$, $p = 0.08$, Figure 30). Yet, there is no evidence in support of the mediation role of PD (Indirect effect, $b=-3.03$, $p = 0.42$). Put together, our analyzes report not enough evidence in support of a mediation role of PD. Furthermore, neither the presence of AR nor the intensity of the treatment perceived by participants in the experiment affects donations.

41 We used the package mediator available from CRAN.

<i>Dependent variable: Donations</i>				
	Full sample		AR sample	
	(1)	(2)	(3)	(4)
PD	−10.384 (16.289)	4.382 (17.604)	2.999 (18.385)	26.542 (19.577)
EES		26.545** (12.500)		22.854 (15.098)
Age		0.079 (1.621)		0.254 (1.587)
Gender		−8.640 (21.128)		−21.969 (25.881)
Use AR		−12.601 (10.084)		−34.446** (14.242)
Study level		−19.464 (13.689)		−30.829* (16.136)
Use smartphone		−29.318 (84.155)		−25.432 (79.691)
Use video games		6.688 (8.898)		9.162 (10.899)
Use AR filters		−6.851 (7.329)		−1.249 (8.244)
Donated before		−0.534 (11.513)		0.567 (13.076)
Constant	113.551*** (29.814)	242.365 (427.610)	87.655** (34.170)	259.661 (413.827)
Observations	86	86	57	57
R ²	0.005	0.136	0.0005	0.245
Adjusted R ²	−0.007	0.021	−0.018	0.080
Residual Std. Error	79.539 (df = 84)	78.430 (df = 75)	75.923 (df = 55)	72.177 (df = 46)
F Statistic	0.406 (df = 1; 84)	1.181 (df = 10; 75)	0.027 (df = 1; 55)	1.489 (df = 10; 46)
<i>Note:</i>			*p<0.1; **p<0.05; ***p<0.01	

Table 21. OLS regression models of Donations

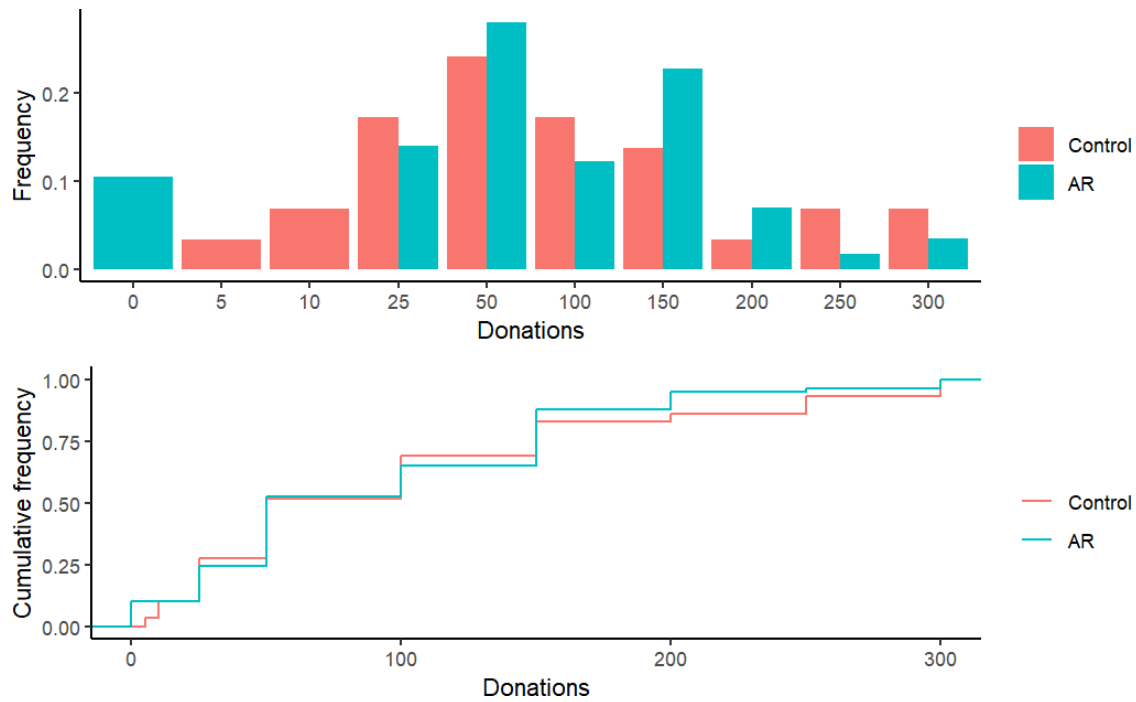
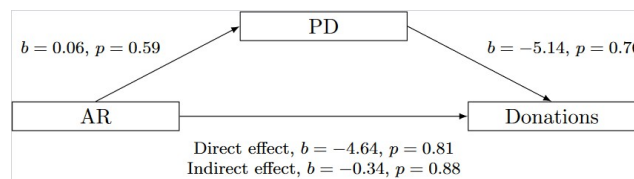
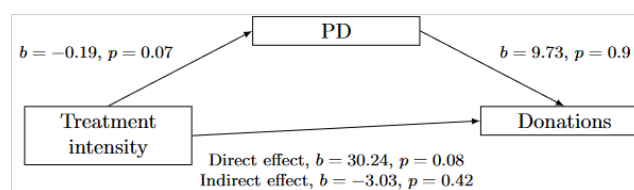


Figure 29. Donation levels by experimental condition



WHOLE SAMPLE



AR SAMPLE

Figure 30. Mediation analysis results: a) for the whole sample; b) for the AR sample only. In the whole sample, AR is a dummy variable indicating the experimental condition. Treatment intensity is a continuous variable.

Self-reported measures of concern and preparedness to act

We examine the impact of AR intervention on self-reported measures of concern about plastic pollution and preparedness to act. Preparedness to act consists of three questions about participants' plastic consumption habits, recycling practices and policy support. While AR scenes may increase concern, overall we find no difference in participants' preparedness to act (Figure 31-A; Wilcoxon rank sum test, $p = 0.63$). There are also no significant changes between conditions when looking at the individual items (see Appendix 6.G; Wilcoxon rank sum test, all results insignificant).

Similarly, we find no overall change in individuals' preparedness to act (Figure 31-B, Wilcoxon rank sum test, $p = 0.13$). Among the items composing our measure of preparedness, individuals' intention to support policy in favor of reducing plastic pollution slightly decreased upon AR interventions (see Appendix 6.H; Wilcoxon rank sum test, $p = 0.03$). All other items are statistically similar across conditions.

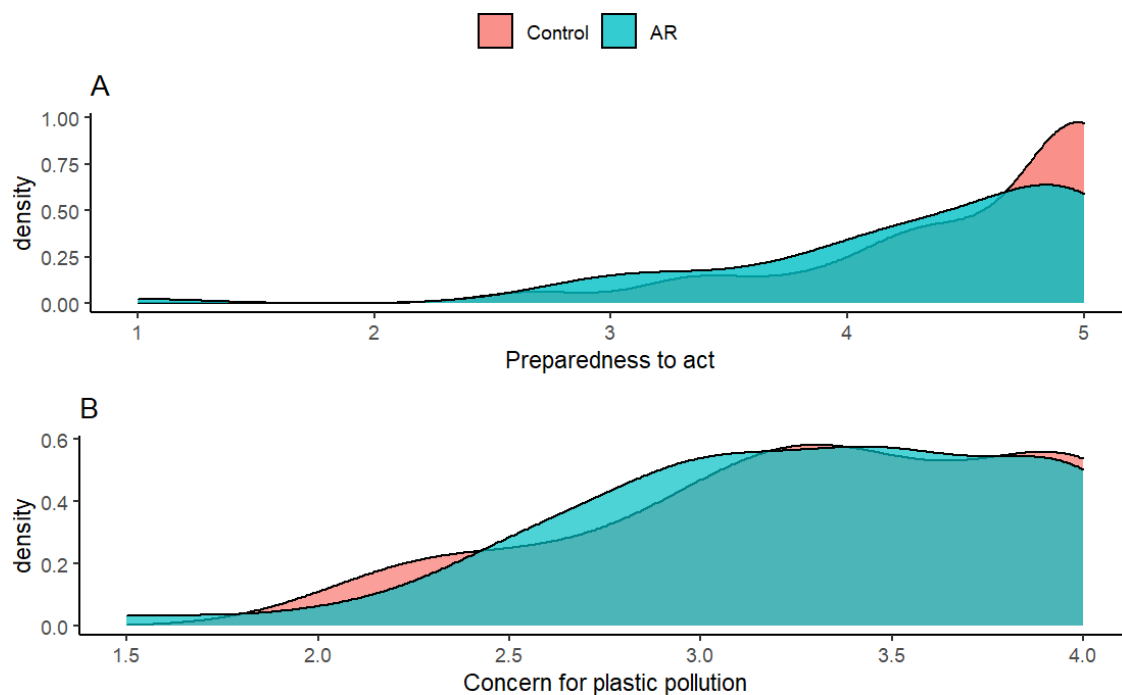


Figure 31. Distribution of A - preparedness to act, B - Concern for plastic pollution

1.3. Study 2 (Augmented reality interventions in the field): Results validation

The results of a qualitative study assessing the feedback on the design and performance of AR experiences indicated that the lack of visual fidelity could be a barrier to the effectiveness of AR interventions (Buljat, 2022). Participants stated that it was unusual for them to see sea animals on the floor of the classroom. Therefore, it is reasonable to assume that the overall impression of an AR experience depends on its visual fidelity and the context in which AR intervention is experienced. To address this issue, we decided to switch from the context-free laboratory setting to a more natural context and repeat the experiment from Study 1 on the beach, where the AR experience might appear more natural and realistic. Therefore, in Study 2 we investigate whether the results observed in the AR treatment of Study 1 can be transferred to a more realistic context⁴² (see Figure 32-A for the experimental setup).

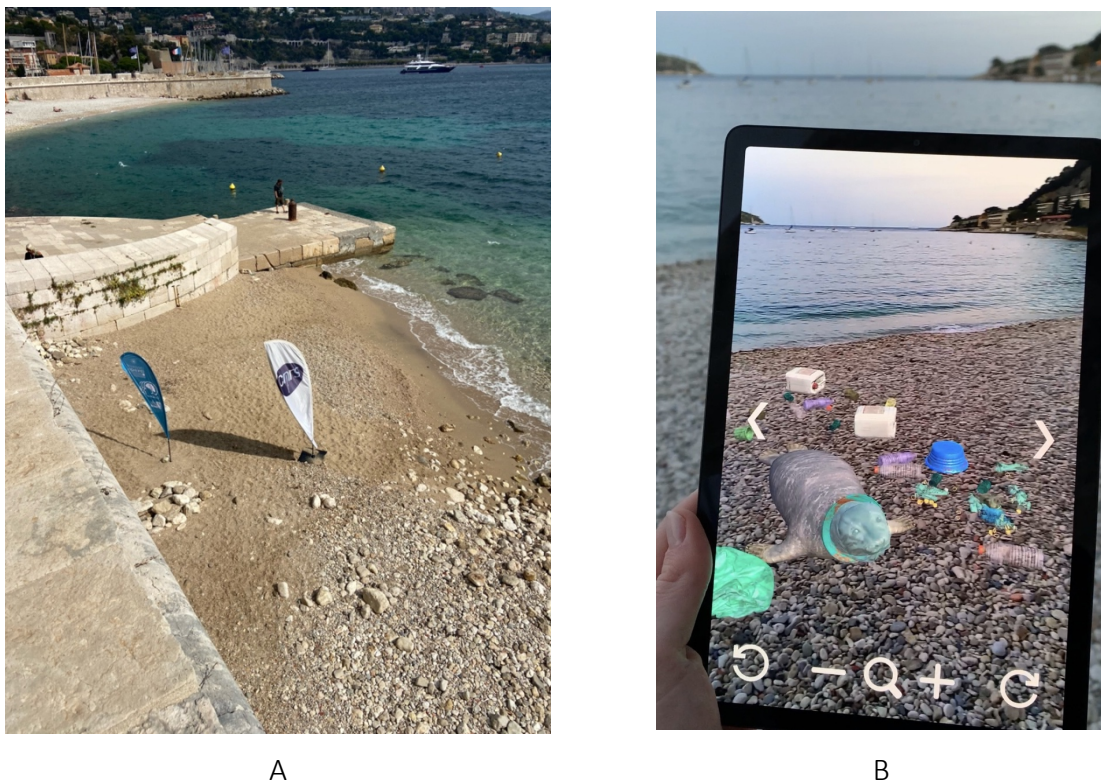


Figure 32. (A) Lab-in-the-field setup, (B) Example of AR visualization in Study 2

⁴² This study was pre-registered at https://aspredicted.org/X16_Z86

1.3.1. Methods and Sample

The experiment was conducted at the natural beach of the small town at the south of France called Villefranche-sur-Mer, in late September 2022. The protocol was the same as the Study 1 conducted in the laboratory. The experiment lasted two full days. An experimenter and two protocol-trained assistants guided participants in 73 individual sessions.

First, the participants came to the registration desk and signed a consent form. Then they sat down at the table and filled out a pre-questionnaire on a tablet. After completing the pre-questionnaire, they were asked to stand up and walk to a nearby sandy beach (15 m away) where the experimenter explained them how to use the AR application on a tablet (see Figure 32-B) and asked them to interact with it for 2 minutes. After the treatment, the participants sat down again at the same table where they filled in the main questionnaire. Before they left, we thanked them for participating and gave them the show-up fee.

We recruited a total of 73 subjects from the same population as in Study 1. Recruitment was done through our university's web-based online recruitment system (ORSEE) and we ensured that subjects had not previously participated in a similar experiment. See Appendix 6.F for the demographic characteristics of the sample.

We collected the same independent and control variables as in the Study 1. The validity of our compound measures is comparable to our previous study (PD - Cronbach's $\alpha = 0.45$, EES - Cronbach's $\alpha = 0.71$).

1.3.2. Results

We first investigate whether PD levels in the field differ from those measured in the laboratory. Results from model 1 in Table 22 report no statistical difference between field and laboratory measures ($b = 0.025$, $p = 0.77$). The association between EES and PD remains negative as in Study 1. When using Treatment Intensity, results from model 2 show a negative association between Treatment Intensity and PD as seen in Study 1 ($b = -0.883$, $p = 0.002$), and such an effect is heterogeneous depending on subjects' level of environmental engagement ($b = 0.228$, $p = 0.005$). These results hold even after the inclusion of our controls (model 3).

When passing on the analysis of Donation levels, we report no statistical difference between field and laboratory ($b = 4.602$, $p = 0.751$, model 4). Similarly, Treatment Intensity has no effect on Donations ($b = 10.471$, $p = 0.309$).

Overall, Study 2 replicates results seen in Study 1. PD levels do not differ between laboratory and field environment under the presence of AR. When using Treatment Intensity as main predictor, we still find heterogeneous effect based on subjects' environmental engagement (EES). Donation levels do not differ across conditions and seem not to be affected by one's perception of AR.

	<i>Dependent variable:</i>				
	<i>PD</i>			<i>Donations</i>	
	(1)	(2)	(3)	(4)	(5)
Field	0.025 (0.085)			-4.602 (14.464)	
Treatment Intensity		-0.883*** (0.287)	-0.899*** (0.286)		10.471 (10.245)
PD				-15.311 (15.614)	-13.039 (15.724)
EES	-0.302*** (0.058)	-0.904*** (0.233)	-0.930*** (0.234)	31.393*** (10.888)	29.580*** (10.900)
Age	-0.001 (0.006)		-0.001 (0.006)	3.180*** (0.994)	3.179*** (0.978)
Male	-0.061 (0.104)		-0.027 (0.101)	13.252 (17.806)	12.299 (17.717)
Use AR	0.119** (0.059)		0.126** (0.057)	-5.846 (10.145)	-7.371 (10.213)
Study levels	-0.022 (0.059)		-0.007 (0.055)	-13.489 (10.006)	-12.294 (9.707)
Use smartphone	-0.915*** (0.334)		-0.878*** (0.323)	-20.635 (58.577)	-25.140 (58.511)
Use video games	0.015 (0.044)		-0.006 (0.043)	1.460 (7.529)	2.675 (7.565)
Use AR filters	-0.045 (0.037)		-0.044 (0.036)	-11.571* (6.401)	-12.343* (6.424)
Donated before	0.034 (0.050)		0.026 (0.048)	-0.527 (8.535)	-1.487 (8.480)
Treatment Intensity * EES		0.228*** (0.081)	0.233*** (0.082)		
Constant	7.267*** (1.714)	5.143*** (0.808)	9.545*** (1.824)	132.924 (313.289)	115.989 (309.818)
Observations	130	130	130	130	130
R ²	0.275	0.255	0.337	0.296	0.302
Adjusted R ²	0.214	0.238	0.275	0.231	0.237
Residual Std. Error	0.456 (df = 119)	0.449 (df = 126)	0.438 (df = 118)	77.727 (df = 118)	77.418 (df = 118)
F Statistic	4.516*** (df = 10; 119)	14.401*** (df = 3; 126)	5.446*** (df = 11; 118)	4.521*** (df = 11; 118)	4.643*** (df = 11; 118)

Note: *p<0.1; **p<0.05; ***p<0.01

Table 22. OLS regression models of PD and Donations using data from Study 1 (AR treatment) and Study 2 (AR in the field)

1.4. Discussion and concluding remarks

In this study, we conducted two experimental studies, namely a laboratory and a ‘lab in the field’ experiment, to test how short AR experience illustrating the consequences of plastic pollution affect pro-environmental behavior (donating to an environmental organization). We also investigated whether the same AR experience is able to influence some internal psychological factors that are important for environmental engagement, such as psychological distance, environmental concern and behavioral intentions.

Although we expected that AR interventions, and especially those experienced in a realistic setting, would decrease psychological distance and increase pro-environmental behavior, we observed this effect only in a small group of participants. The results suggest that although participants stated that our intervention brought them closer to the problem of plastic pollution (M 3,9/5), there is no ‘*one size fits all*’ solution. Communicating about environmental issues via AR is likely to have a heterogeneous effect depending on the personal characteristics of the individuals: people who are already familiar with AR and already adopt sustainable practices (recycle waste, consume environmentally friendly products, etc.) may ‘backfire’ to this type of intervention and, in turn, increase their psychological distance. In contrast, communicating via AR might work better for people with low environmental engagement and no previous experience with AR, as they are likely to decrease their psychological distance to an environmental threat after such an intervention. A similar observation was made in a recent study: in an online experiment, participants who had previously shown lower environmental attitudes indicated a stronger intention to change their future environmental behavior after watching an environmentally friendly video, compared to those who had not been exposed to it (Moore and Yang, 2019).

There are several possible explanations for these results. First, we can conclude that a “scenario rejection” (Fiore et al., 2009, p. 72) can occur when a virtual intervention does not match an observer’s mental expectations. Indeed, our stimuli and context of use (seeing sea animals in the classroom) may not have been strong enough to influence all subjects, especially those already familiar with AR technology and regularly using it. The passive nature and questionable visual fidelity of the 3D models may have reduced the perception of the realism of the AR scenes. Secondly, there is a possibility that people with high environmental engagement may show a resistance to new technologies due to concerns about energy consumption (Dataquest, 2022). Finally, recent research highlights the need to consider the heterogeneity of target groups

when applying insights from behavioral science (Bryan et al., 2021). Indeed, behavior-changing interventions can sometimes be counterproductive for certain groups. In such situations, it may be time to consider more targeted or personalized approaches (Sunstein, 2022).

Moreover, we note that a decrease in PD does not necessarily lead to an increase in donations, at least in the case of plastic pollution. First, it could be that our PD scale (Spence et al., 2012) is not entirely reliable for measuring psychological distance in this context (Cronbach's $\alpha = 0.6$). Secondly, it could also be that people do not trust environmental organizations and therefore, although they are concerned about the problem, they decide not to donate money. However, as expected, those who report a high level of environmental engagement were also likely to donate more to environmental organizations.

Based on these findings, we suggest that AR interventions should be targeted at people with low environmental engagement and AR *newcomers* (people with no previous experience of AR). Influencing environmental engagement in other areas (recycling and consumption) may also have an impact on donation behavior.

This study has some limitations, first of all the small sample. In addition, we did not take into account participants' risk preferences and opinions on the AR technology, which could explain the heterogeneous effects of the AR treatment. Therefore, in the future, we should add more observations for both AR and the control group and measure additional variables. Furthermore, this experiment only tests the effects of the AR experience on immediate behavior. Future studies should examine the impact on long-term behavior.

Also, the AR experience may have been too short and not interactive enough to make an impact. We should work on improving the AR experience, making it more engaging and longer. Since, according to our results, creating immersion and a sense of presence seems to be a promising way forward, environmental communicators could consider AR glasses, which certainly offer more immersive experiences than mobile AR. However, as this has not been empirically tested, we suggest comparing different types of AR hardware: mobile AR and AR glasses.

Future steps should also include different behavioral measures (e.g. recycling plastic waste), different samples (e.g. older population or youth) or different treatments (e.g. photo or video). However, when comparing AR with photo or video, there is a methodological challenge to overcome: since each AR experience is unique and depends on the dynamics and movements of a user, it can be difficult to create a comparable screen capture.

One of the limitations of our experimental design is also the short time span between the treatment and the measurement of the behavior. This is because environmental behavior is complex and it may be unrealistic to expect it to change after a 2-minute intervention. Further studies should include longitudinal trials with more than one behavioral intervention.

However, the results of this study can serve as a basis for future studies measuring the effects of AR on pro-environmental behavior, which could be useful in a similar context (e.g. by simulating future or distant events to reduce psychological distance and induce behavioral change).

This study makes an important contribution to academic research and practice. This was the first attempt to measure the effects of AR simulations on pro- environmental attitudes and behaviors, so these results pave the way for further research. We assume that if we are able to achieve a high level of presence with AR experiences in a laboratory, this could be a way to bridge the methodological gap between laboratory and field experiments by providing natural cues in context-free laboratory settings.

In addition, this study can serve as a guide for environmental policy makers and communicators using AR in their pro-environment campaigns. For example, a non-profit organization can set up a spatial AR screen on the beach to warn about the harmful consequences of improper waste disposal, and policy makers can run a targeted AR campaign on social media to facilitate policy implementation. We believe that these findings are also applicable to other similar AR interventions aimed at changing behavior and warning about consequences that are usually ‘out of sight’.

GENERAL DISCUSSION

A 4-year DSR project provided rich and insightful knowledge useful for understanding and guiding future design initiatives of AR-based artifacts aimed at promoting individuals' pro-environmental behavior. Lessons learned from this project could be applied in design projects of other artifacts that serve similar purposes, which is an important added value of this thesis.

Although we were aware that the mixed-methods approach could be challenging and time-consuming, the combination of techniques from Design Science and Behavioral Science produced rich empirical data collected from multiple sources, that contributed to the validity and complementarity of the findings. These findings led us to develop a design theory for green AR artifacts, define several possible extension ideas, and propose strategies for implementing green AR artifacts in practice.

General Discussion contains six sections. In the first section, I draw conclusions about the direct and indirect impact of AR interventions on people's pro-environmental behavior. Then, in the second section, I present refined design principles for each of the three design aspects of the artifact (information, social, and technology aspect). In the third section, I suggest how to implement the artifact into practice by adapting it to the needs of different audiences and contexts. The fifth section highlights possible research and industry opportunities. The last section points out the limitations of the project and how they can be overcome in the future.

1. The impact of augmented reality simulations on pro-environmental behavior

Despite anecdotal evidence that immersive communication is effective in driving sustainable development and climate action (Duman, 2022), very few studies to date have examined the impact of AR or VR interventions on individuals' PEB (Soliman et al., 2017; Nelson et al., 2020; Moore & Yang, 2019). Furthermore, VR was a dominant type of immersive technology in these studies (see Section 2 of Chapter 1 for a full literature review). To address this gap, one of the goals of this research project was to investigate direct and indirect effects of the green AR artifact on PEB.

1.1. Direct impact

We conducted an experiment to investigate whether the consequences of plastic pollution on the most vulnerable marine animals, presented in 3D format in AR, can influence pro-environmental attitudes and behaviors. More specifically, we measured the effects of AR on psychological distance, concern, intention to act, and real PEB (voluntary donation to an environmental organization⁴³). The experiment consisted of three different treatments: (1) control (no treatment), (2) AR intervention in the laboratory (empty classroom in faculty premises); (3) AR intervention in the field (on the beach). Each treatment began with a brief text about the effects of plastic pollution and an appeal for donations (see Subsection 1.3 of Chapter 4 for experimental setup and design).

In short, the results did not meet our initial expectations: despite initial assumptions that the AR intervention would be more effective than text-only intervention in promoting PEB, our results were mixed, suggesting the existence of heterogeneous effects of AR depending on individuals' personal characteristics. Similar to a recent study by Moore and Yang (2019), the intervention was most effective for individuals who reported low environmental engagement and no previous experience with AR, while it was counterproductive for individuals who were already engaged with the environment and familiar with AR technology.

Following feedback from a qualitative study (Section 2 of Chapter 3) that the content of the AR experience (marine animals trapped in plastic waste) seems unrealistic when it takes place indoor (in a classroom), we repeated the experiment in a more realistic setting (on the beach). However, we found no significant difference compared to the laboratory experiment, suggesting that context did not play a major role in this case. Moreover, we found no evidence of a negative correlation between psychological distance and PEB (feeling psychologically closer to the problem did not lead to more PEB, in contrast to studies by Lorenzoni et al. 2007; Fox et al., 2019).

The main conclusions from this study are: first, the findings from the experiment suggest that there is no 'one size fits all' solution. If targeted to the 'wrong' audience, such AR interventions raise concern of having undesirable effects. Instead, attention should focus more on

⁴³ Besides paying a show-up fee to participants who took part in the experiment, we incentivized them with the opportunity to win €300 in a lottery (random draw). Then we tested PEB by giving them the option to donate the desired amount to one of suggested environmental organization (in case they were a lucky winner).

personalizing interventions and targeting heterogeneous subgroups of the population (Sunstein, 2022; Bryan et al., 2021). As our results suggest, the personal characteristic that should be considered could be familiarity with technology and personal engagement with the environment.

Second, the stimuli we used in the treatments may not have been strong enough to affect PEB, arguing for more effective AR interventions. As suggested by Fiore and colleagues, virtual simulations may not be persuasive if users encounter “scenario rejection”—a situation in which the simulation does not seem real enough to be taken seriously (Fiore et al., 2009, p. 72). Although three-dimensional and animated, passive viewing of the content of AR may not have been compelling enough, especially for experienced AR users. Perhaps a more engaging, interactive, and gamified (Morganti et al., 2017) approach could yield better results. In summary, we found no evidence that the green AR artifact created for this study generally impacts PEB.

1.2. Indirect impact

In addition to the weak results on direct effects on PEB, we found through our studies that the artifact has the potential to indirectly affect PEB. First, AR could improve traditional environmental communication by making it more interactive, engaging, and vibrant. But thanks to the constant evolution of mobile devices, the Internet, and social media, AR artifacts when placed in a social context, could also serve as a tool to increase general environmental awareness and promote environmental activism (Boulianne & Ohme, 2021).

Indeed, one of the greatest benefits of AR communication is its social component - AR experiences today can be easily created, retrieved, and shared with others (Chandhok, 2018). During the focus groups with end users (see Section 2 of Chapter 3), one of the conclusions that emerged from the data was that the appeal of AR content can provide fertile ground for creating ‘buzz’ on social networks (such as, for example, a recent green movement ‘Fridays For Future’⁴⁴). Given the critical role of social media in environmental activism (Boulianne & Ohme, 2022), enriching these community movements with AR content can help youth voices be heard by policymakers.

44 See <https://fridaysforfuture.org/take-action/social-media/>

Here is an example of how our artifact could be used in a social media campaign. It could simply serve as a tool for creating protest calls to brands, organizations, or policymakers to address the problem of plastic pollution. For example, imagine a scene where a giant whale is fighting with thousands of plastic bottles it has swallowed in front of a famous soft drink factory. Or the main square of a city full of sea turtles caught in plastic waste. Such images can send a powerful message of public protest against unsustainable practices and policies, and have the potential to go viral, to be seen and shared.

Two years after this PhD project began, UNEP launched an initiative to address the plastic pollution crisis in Asia. The campaign consisted of interactive AR experiences and games available on social media channels. The goal of the campaign was to increase public demand for a solution to the plastic pollution crisis, build support for more effective policies, and educate about circular economy practices (UNEP, 2021a). The fact that the world's leading environmental communications companies have begun to incorporate AR into their campaigns has reinforced that we are on the right track.

Note, however, that AR content is challenging to distribute because, unlike photo or video content that can be easily placed on a billboard, AR must be viewed by a person with a device pointing a camera at a specific location where they want to insert digital content. Thus, there is a need for 'a campaign for AR campaign'-a call to action that could be made by sustainability advocates, social media influencers, or similar individuals who would lead the movement (Vasey, 2021).

The rich empirical evidence from quantitative studies informed what we can expect when it comes to the direct and indirect effects of AR interventions on individuals' PEB. However, the exploratory part of the study examined how and why certain components of the AR artifacts were more or less effective. Therefore, we were able to specify the requirements for designing successful AR interventions that impact individuals' PEB. We summarize the key design principles and discuss them in more detail in the next section.

2. Design principles for green augmented reality artifacts

Most often, the contribution of a DSR project is a DSR artifact designed to solve a real-world problem (Hevner et al., 2004). The following figure (Figure 33) shows how the artifact evolved

through the different phases of the project, which resulted from several evaluation activities with different types of users. First, we developed a low-fidelity prototype with no interaction to demonstrate and explain to end users the concept of using AR in environmental communication. End-user evaluation raised concerns about the realism and low interactivity of the artifact, which led to refinement of the design. Interviews with environmental communication professionals provided new insights into how the artifact could be enhanced with more elaborated scenes and a higher level of interaction to provide value to end users. Finally, we were able to refine initial design principles for green AR artifacts and define how the artifact could be implemented in practice.

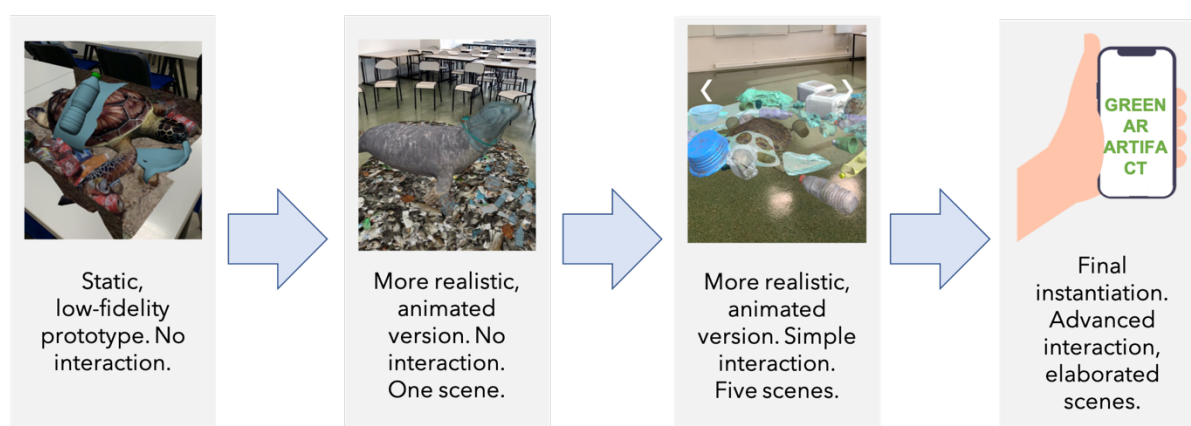


Figure 33. Evolution of the artifact during the DSR project

Following Gregor et al.'s (2020) scheme for specifying design principles for IT-based artifacts in sociotechnical systems, in this section we define and explain the design requirements for green AR artifacts that address individuals' PEB. These design principles (DP) fall into the category *About the artifact* (design principles that encapsulate the artifact's properties) and *About the user activity* (design principles that encapsulate the user's use of the artifact). The design principles are explicit and written in simple language so that they are understandable and useful in real-world design projects (they could be used by implementers who apply them in practice and theorizers who use them to generate knowledge (Gregor et al., 2020).

For each design principle, we specify (1) aim, implementer and the user; (2) the context (e.g., the conditions or setting in which the artifact is to be used); (3) the mechanisms (means of achieving aims, such as actions, activities, processes, or design components); and (4) the

rationale (justificatory knowledge, either derived from theory, or empirical evidence, or a synthesis of both, that provides a reason why the principle is valid) (Gregor et al, 2020).

Below, we list the design principles that have been identified as key factors in the success of creating green AR artifacts. We assign them to each of the three design aspects of the artifact, namely information, social, and technology aspects. Briefly, the information aspect of artifact design informs us about what information is conveyed and how, the social aspect addresses the social relationships and changes that can be influenced by an artifact, and the technology aspect defines the material and technical characteristics of the artifact, such as hardware and software (De Leoz & Petter, 2018). These design principles complement initial design principles presented in the Section 3 of Chapter 1, and are informed and refined after empirical findings of our studies.

2.1. Information aspect

Throughout this project, we have come to an important conclusion: Technology itself, even the most advanced, is unlikely to change behavior if the information it provides is inadequate. In other words, even if immersive technologies can enhance communication it is important to carefully define what content it will present and how. Here we specify design principles that address the information aspect of the artifact. These principles can also be applied to other non-AR-based interventions targeted at promoting behavioral change.

The first principle – the **Principle of tailored information** (Table 23) – informs us that green AR artifacts aimed at motivating individuals to adopt PEBs can be more effective if the information presented through them is tailored, personalized, and takes into account the heterogeneity of the target audience. That personalization is important is not only recommended by psychological science (van der Lineden et al., 2015), but also confirmed in our experiment – for example, the AR treatment was more effective in reducing psychological distance for the individuals who were not yet familiar with AR and do not have practices (such as recycling), while the opposite was true for the other group of participants.

Design principle title	DP 1. Principle of tailored information
Aim, implementer and user	<i>In order for green AR artifacts to be effective in promoting individuals' pro-environmental behavior</i>
Context	<i>in pro-environmental communication interventions</i>
Mechanisms	<i>information presented via the artifact should be tailored and personalized, taking into account the heterogeneity of targeted audience</i>
Rationale	<i>because there is no one-size-fits-all approach and the success of the intervention may depend on the personal characteristics of an individual</i>

Table 23. Principle of tailored information

Next, the **Principle of simplifying abstract information** (Table 24) suggests transforming abstract environmental data into simple and vivid images so that pro-environmental messages can be well understood by end users. Both end users and professionals agreed that environmental campaigns should be informative and educational. However, complex environmental data, often presented as long tables and graphs should take a form that is more understandable to the public. In this sense, '*visual is the way forward*', as one of our interviewees said.

Design principle title	DP 2. Principle of simplifying abstract information
Aim, implementer and user	<i>In order for pro-environmental messages to be well understood by individuals</i>
Context	<i>in pro-environmental communication interventions</i>
Mechanisms	<i>abstract environmental data must translated into simple, vivid, visual narratives through user-centered design</i>
Rationale	<i>because complex data might cause cognitive load and might be difficult to understand</i>

Table 24. Principle of simplifying abstract information

The **Principle of attractive information** (Table 25) addresses the problem of the limited attention span of end users caused by the constant intake of new information in modern media. To attract users' attention, environmentally friendly content should be explicit, familiar, shocking, and comprehensible. However, as one of the interviewees noted, '*too much fear can lead to climate apathy rather than climate empathy*', so it is necessary to balance shock and excitement (O'Neill & Nicholson-Cole, 2009).

Design principle title	DP 3. Principle of attractive information
Aim, implementer and user	<i>In order for individuals to notice a pro-environmental information</i>
Context	<i>in everyday media use</i>
Mechanisms	<i>the visuals should consist of explicit, familiar, shocking and comprehensible content</i>
Rationale	<i>to meet the limited attention span of users due to the constant information overload</i>

Table 25. Principle of attractive information

Finally, the last principle about the information aspect of the artifact, the **Principle of psychological distance** (Table 26), informs us about the need to bring environmental issues psychologically closer (Trope & Liberman, 2010), otherwise people perceive them as irrelevant (van der Linden et al., 2015). *Out of sight, out of mind*: end users recognize that the temporal and spatial distance of environmental problems can be a barrier to PEB. One way to help reduce psychological distance is through experiences that present environmental problems directly in familiar and relevant locations. Note, however, that in our experiment, reduced psychological distance did not necessarily lead to voluntary donations, but may be effective for other types of PEB (Fox et al., 2019).

Design principle title	DP 4. Principle of psychological distance
Aim, implementer and user	<i>In order to increase the perceived seriousness of environmental issues by individuals in pro-environmental communication interventions</i>
Context	<i>in pro-environmental communication interventions</i>
Mechanisms	<i>environmental issues should be presented directly in familiar and relevant locations</i>
Rationale	<i>because direct, personally relevant experiences are likely to bring environmental issues closer psychologically</i>

Table 26. Principle of psychological distance

2.2. Social aspect

The second group of design principles deals with the social aspect of the artifact. These principles aim to take advantage of social relationships that may be affected by the artifact, with possible implications for PEB. We have identified two important design principles related to the social aspect of the green AR artifact that should also be considered in the development of other similar pro-environmental interventions (not necessarily AR-based).

The first design principle in this set is the **Principle of social influence** (Table 27). Social influence is an important driver of a person's behavior - people influence each other in many ways (Kelman, 1958). Findings from behavioral and psychological research inform us about the usefulness of social norms interventions to promote PEB (van der Linden et al., 2015; Farrow et al., 2017). In this sense, integrating the artifact into a multi-user platform (e.g., a social network) can open pathways for community-driven movements that demand systemic change from policymakers. In addition, PEB can be promoted by engaging key referents (e.g., social media influencers) who position PEB as socially desirable behavior, or simply by people influencing each other by sharing environmental content.

Design principle title	DP 5. Principle of social influence
Aim, implementer and user	<i>In order to encourage individuals' PEB</i>
Context	<i>in digital environment</i>
Mechanisms	<i>the artifact should be integrated into a multi-user platform</i>
Rationale	<i>because allowing social interactions open up opportunities for social influence</i>

Table 27. Principle of social influence

The second design principle in this set is the **Principle of social empathy** (Table 28). This principle suggests enabling relationships between end users and the artifact itself, as such social relationships can influence behavior (Fogg, 2003). This can be achieved by developing emotional relationships with virtual characters – for example, by introducing interactions with virtual endangered species asking for help due to an environmental crisis. However, designers should approach such interventions with caution, because if they are too intense and emotional, they can lead to negative feelings and mental fatigue (Igras-Cybulska et al., 2022).

Design principle title	DP 6. Principle of social empathy
Aim, implementer and user	<i>In order to encourage individuals' PEB</i>
Context	<i>in digital environment</i>
Mechanisms	<i>the artifact should introduce virtual characters in emphatic situations</i>
Rationale	<i>because artificially created social relationships can influence behavior</i>

Table 28. Principle of social empathy

2.3. Technology aspect

Finally, the last set of three design principles relates to the technology aspect of the green AR artifact and provides guidance on the direction that the technological requirements (software, hardware, material, etc.) of the artifact should take. While the first two sets of design principles can be applied to any type of green intervention, the following three design principles are characteristic to immersive systems.

The first design principle in this set is the **Principle of fidelity** (Table 29), which asks whether the immersive experience faithfully and accurately reproduces reality. During our empirical studies evaluating the artifact, both end users and experts criticized the unrealistic visual representation of virtual objects. For immersive simulations to be more effective in attempts to change behavior, the fidelity of the immersive experience should be high, otherwise “scenario rejection” may occur (Fiore et al., 2009, p 72). Not only is the visual component of immersive experiences important, but also its interactions, scenario, or context of use as well (for example, participants found it unrealistic and sometimes even funny to see endangered marine animals in AR on the classroom floor. Therefore, communicators need to think of an appropriate environment and context for AR interventions, since AR’s core function is to blend real and virtual worlds at the same time).

Design principle title	DP 7. Principle of fidelity
Aim, implementer and user	<i>In order for immersive simulations to be convincing</i>
Context	<i>in attempts to promote PEB</i>
Mechanisms	<i>the fidelity of the immersive experience should be high</i>
Rationale	<i>because if the virtual simulation does not match users’ mental expectations, the intervention might be ineffective</i>

Table 29. Principle of fidelity

The second design principle in this set is the **Principle of gamification** (Table 30). As suggested by our interviewees, and in line with recent research, gamification – the use of game design elements in non-game contexts (Deterding, 2015) – can be an effective weapon to promote PEB (Oppong-Tawiah et al., 2018; Hoffmann & Pfeiffer, 2022). A gamified intervention does not have to consist of a full game experience, but can simply include game elements (Morganti et al., 2017). Therefore, an immersive system does not have to be a game

itself, but should include some of the gamified elements (e.g., getting points as a reward for a certain behavior).

Design principle title	DP 8. Principle of gamification
Aim, implementer and user	<i>In order for an immersive system to be effective</i>
Context	<i>in attempts to promote PEB</i>
Mechanisms	<i>the artifact should include gamification elements</i>
Rationale	<i>because gamification is effective at influencing behaviors</i>

Table 30. Principle of gamification

Lastly, the **Principle of interaction** (Table 31) should guide the design of immersive systems in a way that allows users to influence the scenario of a virtual experience. Indeed, interactive technologies are considered persuasive systems that have the power to influence or change behavior (Fogg, 2003). As the literature suggests and our qualitative studies confirm, enhancing perceived self-efficacy could be an important force to promote PEB (Ahn et al., 2014; Ahn et al., 2015).

Design principle title	DP 9. Principle of interaction
Aim, implementer and user	<i>In order for an immersive system to be effective</i>
Context	<i>in attempts to promote PEB</i>
Mechanisms	<i>the artifact should be interactive</i>
Rationale	<i>because the ability to influence the scenario of a virtual simulation may strengthen the user's sense of self-efficacy and control</i>

Table 31. Principle of interaction

It is important to note that an intervention can only be effective if users want to use it in a natural setting (Fox et al., 2019) – users need to have a reason to use such an artifact. However, one of the biggest challenges with green AR artifacts is implementation: why would anyone want to use a system that shows pleasant scenes of suffering animals? To address this challenge, we combined data from qualitative studies with end-users and experts to propose several possible extensions to the current artifact. Following sections can serve as a basis for creating future AR artifacts that end users might be likely to use.

3. Implementation and adoption of green augmented reality artifacts

3.1. Possible extensions, distribution and target groups

Once a product is on the market, implementation and acceptance by the target audience are the biggest challenges to overcome. Even if a product is useful in achieving its main objective (promoting pro-environmental behavior), it is a waste of money, time, and resources if there is little likelihood that people will use it voluntarily. Therefore, it is important to understand end users and identify the context in which they would be willing to use the product in natural settings (Fox et al., 2019).

The current project poses a particular challenge because its main component – the unpleasant visualization of the consequences of plastic pollution – is certainly something that no one would want to see voluntarily. Therefore, we realized that the original concept of communicating about environmental issues through AR is not a promising solution unless this concept is integrated into a more sophisticated product that offers added value to end users.

Depending on the project complexity and overall goal, an implementer may need to make some technical decisions, such as choosing the platform on which to build an AR system (e.g., integrating AR experiences into an existing mobile application, such as social media platform Facebook or building a stand-alone mobile application). There are some trade-offs in these types of decisions that impact the project's timeline, fidelity, budget, and target audience⁴⁵.

Inspired by the rich and insightful findings from qualitative studies with end users and mediators (Buljat Raymond, 2023; Buljat Raymond, 2022; Buljat Raymond & Arena, 2022), we propose and explain possible instantiations of the AR artifact below. For each instantiation, we provide a brief description and its purpose, suggest a target audience, and a method for promoting its adoption. We believe that these suggestions could be useful to inspire and guide future green AR initiatives. The overview and summary of the six proposed instantiations can be found in Table 32.

45 An AR experience developed for the Facebook platform may reach the target audience more easily, but it comes at a significant cost due to size constraints, hardware options (mobile devices only), and the need for an internet connection. A stand-alone mobile application built in Unity, on the other hand, is not subject to these development constraints, but requires users to download an application and may require more storage space on the device.

AR ARTIFACT TYPE	Hardware	Description	Aim	Advantages	Disadvantages	Mediator	End users	Suggested promotion strategy	Applicable design principles
Mobile video game	Smartphone or tablet	A multi-player mobile video game in which users search for animals superimposed on the real world, and free them from plastic	To entertain players while educating and raising awareness about environmental issues	Facilitates learning through a gamified approach; enables social influence through multiplayer mode	Complex development; users need to download an application	Video game producer	Gamers, younger audiences (generation Z), smartphone users	Social media influencers, specialized press, eSport events and tournaments	DP1, DP2, DP3, DP4, DP5, DP6, DP7, DP8, DP9
Educational mobile application	Smartphone or tablet	A mobile application designed to complement traditional classroom materials, using AR to visualize environmental data	To educate and raise environmental awareness, to make classes more interactive and engaging	Enhances traditional education methods and makes learning more engaging	Requires teacher familiarity with technology; requires smartphone in the classroom	Teachers and educators	Students and pupils	A teacher introduces the application during classes	DP1, DP2, DP3, DP4, DP6, DP7, DP8
Social media camera effect	Smartphone or tablet	A short AR experience that can be recorded and shared on social networks	To raise awareness of environmental issues, provide tool to initiate public dialog and put pressure on policymakers	Is easy to use; could achieve wide reach on a limited budget; encompasses social influence	The overall quality of the AR experience and visual fidelity may be low due to the size limitation	Social media influencers, sustainability advocates, nonprofit organizations	General public, social media users	Social media campaigns in a form of stories, posts and short videos	DP1, DP2, DP3, DP4, DP5, DP6, DP7, DP8, DP9
Marine encyclopedia in a mobile application	AR glasses or smartphone	A mobile application for on-site use (e.g., in a museum) that provides additional visual information about marine species and relevant topics by scanning a QR code	To provide added value for museum visitors, make museum visits more interactive, engaging, and informative, to raise awareness of environmental issues	Could tell a story in a more immersive and engaging way; could contribute to the visibility of the museum's brand	If marker based, it can only be used in a museum; visitors must download an application	A museum	Museum visitors	Museum guides, posters, info points, website, social media	DP2, DP4, DP6, DP7, DP8, DP9
AR storytelling experience	AR glasses	A compelling narrative about how plastic enters nature and affects animals. The story begins with a positive scenario of a beautiful ocean that turns into a shocking and contrasting ending: a sea polluted with plastic	To rise environmental awareness through the immersive experience of two parallel worlds: today's and tomorrow's	Is immersive; enhances traditional environmental communication methods	Could cause mental fatigue and anxiety; needs specialized hardware	Conferences, exhibitions, museum, public events	Visitors of such events	Social media, stands, posters	DP1, DP2, DP3, DP4, DP6, DP7, DP8, DP9
Interactive AR kiosk	AR kiosk	An immersive AR experience in which digital objects (e.g., animals suffering from plastic pollution) are superimposed onto public spaces through interactive AR screens	To visualize the consequences of environmental problems in places where they are usually invisible	Could reach wide audience	Limited to certain location where it is placed; requires specialized hardware	Local authorities and governments	Pedestrians or anyone who happens to be close to an interactive kiosk	Motivate recording and sharing the experience on social networks	DP1, DP2, DP3, DP4, DP6, DP7, DP8, DP9

Table 32. Green AR artifacts – instantiations ideas

Instantiation 1 – Mobile simulation game

First, AR simulations of environmental issues could be integrated into a mobile simulation game. This suggestion emerged from the data collected in both the interviews with mediators and the focus groups with end users, which is not surprising given that the dominant industry in which AR is used is entertainment (Farshid et al., 2018). Participants suggested an example of a popular game: Pokémon GO⁴⁶, in which players, instead of searching for Pokémon characters, search for endangered animals superimposed on the real world and free them from plastic. Such a game would not only serve to entertain, but could simultaneously educate users about the harmful effects of plastic and measures to reduce pollution. Using gamification systems to promote environmental sustainability (e.g., environmental education, consumer awareness, and pro-environmental behaviors) seems to be an effective approach because such systems offer incentives that motivate active participation (e.g., badges, medals, progress bars, metaphors, repetitions etc.) (Guillen et al., 2021; Morganti et al., 2017). For example, one study suggests that a serious game could positively influence learning outcomes related to knowledge and understanding of garbage sorting (Hoffmann & Pfeiffer, 2022). In another study, a mobile application was implemented at workplace, to encourage electricity conservation among workers. The application metaphorically represented current electricity consumption through images of healthy and unhealthy gardens (Oppong-Tawiah et al., 2018). There are numerous examples from practice, too. UNEP, a global leader in *green* initiatives, has recently launched a game to promote environmental awareness among youngsters (13-18 years old). The game – incorporating novel digital elements such as real-time 3D creation tool, metaverse and avatars – provides teachers with resources to educate students about the importance of environmental protection (UNEP, 2023).

In addition to gamification, the social component can contribute to PEBs: the multiplayer mode could enable social interactions, opening up opportunities for influence through social norms – an important lever for promoting PEB (van der Linden et al., 2015; Farrow et al., 2017). Besides complexity, the drawbacks of such a solution include the fact that users must download an application to access AR content. Suggested audiences and areas for promotion of the game could include specific niches of social media influencers or gamers, a sustainability-focused press, eSports events, and tournaments.

46 see <https://pokemongolive.com>

Instantiation 2 – Educational mobile application

A solution with a similar purpose, but slightly less entertaining, would be a mobile educational application that can be used by schools, colleges, and similar educational institutions. Using AR technology to visualize environmental data, the application would complement traditional classroom materials and make lessons or field trips more interactive and engaging. Recent research suggests that the use of gamification elements as well as immersive virtual experiences can enhance learning and facilitate knowledge acquisition in climate education (Markowitz et al., 2018; Putz et al., 2020). Such gamified systems have an advantage over traditional learning materials because they can be interactive and provide immediate feedback. For example, in one game, players had to sort waste correctly and then received feedback on their performance. The game improved players' sorting skills, which even affected real-world behavior observed in a student residency (Luo et al., 2019). However, while end users (pupils, students) certainly benefit, on the other hand, teachers could play an important role as facilitators: their familiarity with the technology could affect the overall experience and motivation of students, so it is necessary to provide them with adequate training beforehand, as one of our interviewees suggested (see Subsection 2.3 of Chapter 3). Another drawback is that such a tool requires the use of smartphones or other mobile devices in class, which may distract students.

Instantiation 3 – Social media camera effect

Probably the fastest to develop and easiest to use option would be AR experiences integrated with social media camera effects. For example, nonprofits could develop short, engaging AR games in which users must save an animal from the dangers of plastic pollution. Most popular social media platforms (such as Instagram, Facebook) now offer their users the ability to create their own AR camera effects, which has led to more than 700 million people using and interacting with AR in their applications and services (Cook, 2021). Global leaders in environmental communications, such as UNEP, have recently begun offering short AR game-like experiences on their Instagram profiles (UNEP, 2021a). The biggest advantage of such a solution is the ability to reach many users in a short period of time, as well as the social component of these platforms, which allows for easy sharing of content between users. However, the overall quality of AR experiences and visual fidelity might decrease due to the size limitation for camera effects for social media platforms (currently the file size limitation for Meta Spark effects is 4 MB for Instagram and 10 MB for Facebook (Meta Spark)).

Instantiation 4 – Marine encyclopedia in a mobile application

Another possible instantiation that would provide an added value to users would be a mobile marine encyclopedia enriched with AR content that can be used with either AR glasses or a mobile device. Such an application is preferably used on-site (e.g., in a museum) to enrich a traditional experience (see the example of Google's virtual replica of the National History Museum in Berlin⁴⁷). Take an oceanographic museum as an example: a section dedicated to endangered species could contain a QR code that, when scanned, triggers an AR experience that visualizes the issues threatening these species. Such an experience could make museum visits more interactive, engaging, and informative while raising awareness of environmental issues. The drawback of this instantiation is the need to download an application, as well as the spatial limitations of its use (if AR experiences are based on markers placed inside a museum, then it may not work outside a museum).

Instantiation 5 – AR storytelling experience

An immersive AR narrative is another option that could be offered to visitors of sustainability-focused exhibitions, events, and conferences (see, for example, a short, award-winning immersive virtual reality experience *The Oceans We Make*⁴⁸). To enhance immersion, this experience should be equipped with special AR hardware (AR glasses) provided to visitors. The AR experience could consist of a short story about how plastic gets into nature and affects animals. As recommended by one of the interviewees, the narrative should begin with a positive scenario of a beautiful ocean leading into a shocking and contrasting ending: an ocean polluted with plastic. The goal of the experience is to visualize the consequences of today's actions for the future. Such an immersive experience could increase the perception of risk and the sense of urgency to act. Indeed, the human brain gives preference to experience over analysis (van der Linden et al., 2015), i.e., our behavior is often driven by emotional responses as a result of intuitive, experiential, automatic, and affective processes (Loewenstein et al., 2001). However, care should be taken when designing negative experiences, as they can lead to mental fatigue

47 See <https://www.museumfuernaturkunde.berlin/en/uber-uns/neuigkeiten/explore-natural-history-vr-google-arts-culture>

48 See <https://www.warrior9vr.com/oceans-we-make-immersive-vr>

and anxiety (Igras-Cybulska et al., 2022). An alternative would be to make an experience interactive and allow users to change an outcome to increase perceptions of environmental self-efficacy (see Fox et al., 2019 for an example).

Instantiation 6 – Interactive AR kiosk

Another option suitable for public places and beaches would be an AR experience on interactive public kiosks⁴⁹ (see the example of Pepsi's interactive AR campaign at a bus station⁵⁰). Such a public campaign would aim to visualize the consequences of environmental problems in places where they are normally invisible because they are spatially distant from the campaign site (e.g., put a screen in the middle of the city to visualize the pollution on the coastline). The biggest advantage of such an artifact instantiation is a potentially large reach if placed on busy areas. In addition, this may be the only way to deliver AR content without asking end users to use their devices. However, such solution comes with certain limitations. First, campaign initiators must ensure that there is enough space around the kiosk where AR content will be digitally superimposed. Second, such AR campaigns are limited to the exact location where the screen is placed, and special hardware is certainly needed to ensure a realistic experience (large screen with integrated but hidden camera on the back of the screen).

3.2. Green AR artifact implementation guidelines

The choice of instantiations and methods of implementation is context dependent – it depends on the goal of the campaign, the time frame, the budget, and the target audience. When creating a pro-environment campaign, communicators should assess the potential outcomes and benefits of each solution and compare them to input costs and potential barriers.

In the guidelines for implementing a green AR artifact in the market, we suggest following these six steps (summarized in Figure 34):

1. First, environmental communicators, policy makers, and educators should be aware that PEB may depend on many other external factors that happen to come in the individual's way. Therefore, contextual barriers that may prevent an individual from exhibiting PEB

49 (see example <https://www.youtube.com/watch?v=V5bC4hnrPkg>)

50 See <https://grandvisual.com/work/pepsi-max-bus-shelter/>

(such as problematic infrastructure that does not allow for easy recycling of plastics) should be minimized as much as possible;

2. Second, the green AR artifact should be integrated into a system that adds value to the user, to ensure that end users are likely to use it voluntarily. For example, this could imply a game, social media platform, or an educational mobile application;
3. Third, brief user tutorial should be provided to those unfamiliar with AR technology. For example, this could imply short instructions about how to embed a digital hologram into one's surrounding;
4. Fourth, implementers should think about the environment and context of AR interventions, and ensure that users have enough time and space to freely interact with AR content. For example, billboards on a highway, or a busy street might not be the best solutions for AR campaigns. On the other hand, a public square with a space dedicated for interaction with AR content would be a more suitable option;
5. Fifth, to position the use of the artifact (and PEB in general) as a socially desirable behavior, referent others should be recruited to promote the artifact. For example, they could be social media influencers that are popular among the target audience;
6. Finally, once end users are motivated to adopt PEB, the artifact should educate them on the steps they can take to tackle the issue. This could imply specific actions they could take to reduce they plastic consumption, guidelines on how to improve their recycling habits, or alternatives for everyday single-use plastic products.

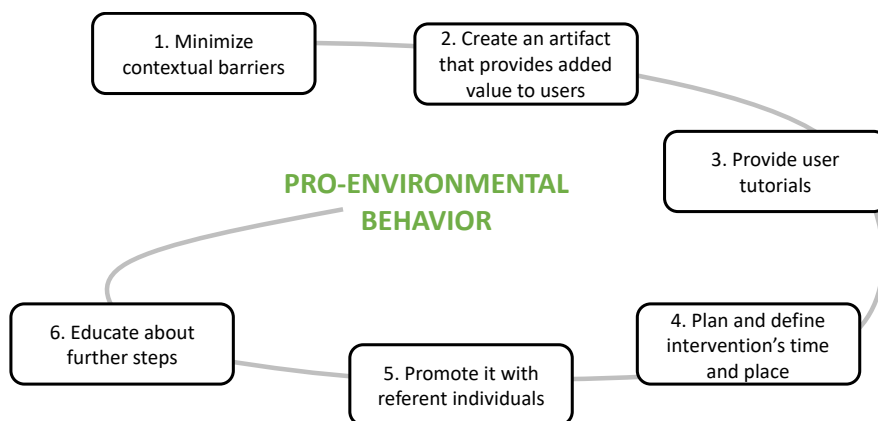


Figure 34. Green AR artifacts - implementation guidelines

Note that we live in a time when AR is becoming mainstream, and with continued advances in information technology, wearable devices, and the Internet, we may soon see AR used in innovative ways, with other hardware – such as smart contact lenses (Santiago et al., 2022) – and in new contexts – such as metaverses and immersive virtual worlds (Park & Kim, 2022). Thus, we may soon need to update these guidelines and refresh them with new hardware proposals and principles. Nonetheless, with these guidelines, we hope to have contributed to the implementation of immersive systems in practice for the purpose of behavior change.

4. Contributions of the thesis

The contribution of this thesis is threefold. First, it addresses the lack of papers on the use of AR/VR for environmental sustainability, and has produced new insights in the field of Green IS. Second, it has provides a methodological example of evaluating an AR artifact in its conceptual phase. Third, it has offered practical contributions for environmental communicators and policymakers in developing behavior-changing interventions and communication campaigns. In this section, we explain in detail each contribution of the thesis and their importance.

4.1. Theoretical contributions and grounded theory model

This research, combining science-based design (design principles based on research) and human-centered design (emphasizing the social aspect of the artifact, i.e., the activity of users and other stakeholders), resulted in a context-dependent scientific and practical knowledge useful for solving a real-world field problem (Pascal et al., 2013; Van Aken, 2005).

Based on the insights gained through our qualitative (Chapter 3) and quantitative (Chapter 4) empirical studies, we present a grounded theory model (Strauss & Corbin, 1990) to serve as a summary of our findings related to the design, development, and implementation of green AR artifacts (Figure 35). These findings could be applicable to green AR artifacts whose goal is to promote individuals' PEB, but also to other artifacts that serve a similar purpose (e.g., behavior change in the context of health or prosocial behavior).

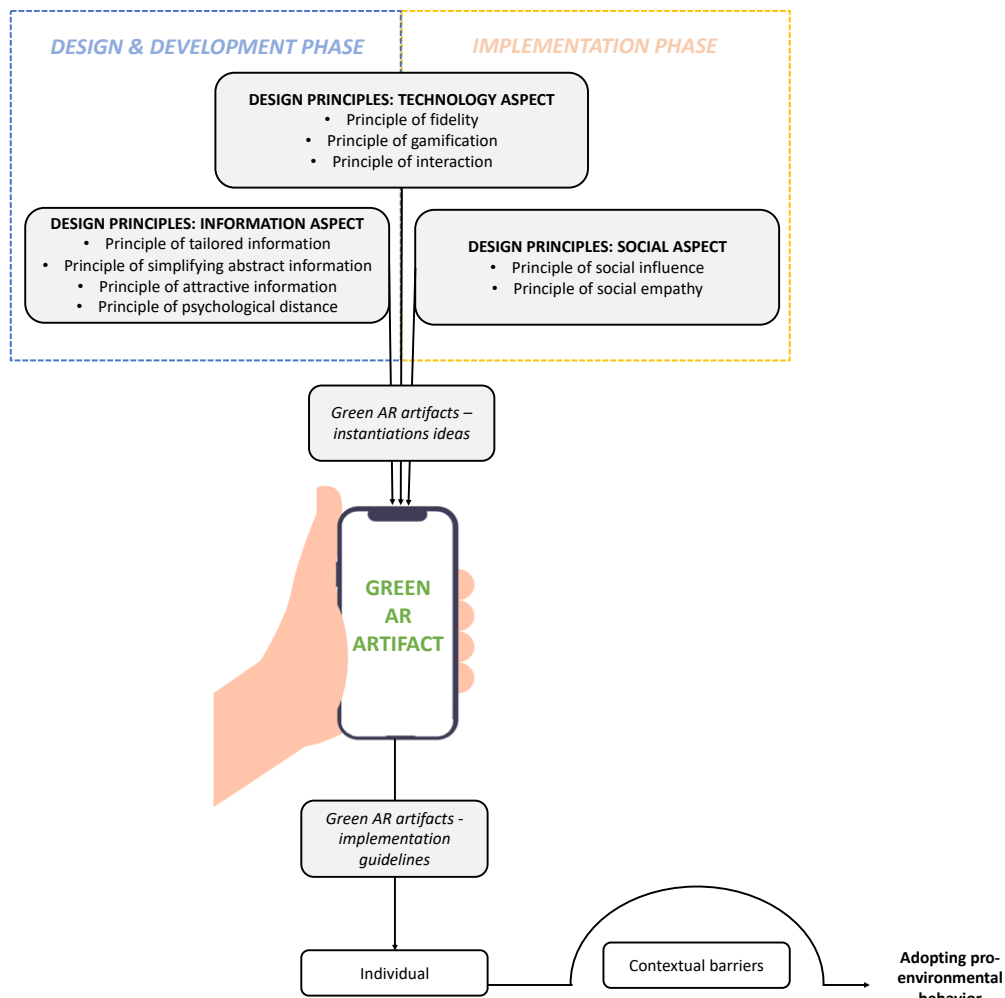


Figure 35. Grounded theory model: design, development, and implementation of green AR artifacts

As illustrated in the grounded theory model, the application of the design principles specified for each of the three aspects of the artifact (information, social, and technology aspects) should be done in a specific order, depending on the stage and maturity of the artifact. We recommend to start the design and development phase by specifying what information is to be presented (and in what way) by the artifact, and use the design principles for the information aspect for this purpose. The design principles that address the social aspect are more important in the implementation phase, namely when the artifact is ready to be implemented in the social environment. Design principles related to the technological aspect, on the other hand, should be considered in the design and development phase as well as in the implementation phase, because it is important to meet these design requirements not only when an artifact is created, but also when it is put into use.

A green AR artifact should then take the form of a system that adds value to users to increase the likelihood that it will be used voluntarily. At this stage, depending on the objective, budget, and target audience, implementers can be inspired and guided by the six *Green AR artifact instantiations ideas* of the artifact to construct a final product. The product could then be brought to market by following the *Green AR artifact implementation guidelines*. Finally, note that the success of any behavior-changing intervention may also depend on contextual barriers (e.g., system infrastructure, recycling policies, etc.) that must be avoided or at least minimized as much as possible to clear the way for individuals to adopt PEB (Steg & Vlek, 2009).

These informative and rich findings related to design, development, and implementation of green AR artifacts are the theoretical contributions of this work. According to the DSR Knowledge Contribution Framework, this research project falls into the category of *Improvement: New Solutions for Known Problems* (Gregor & Herver, 2013). This theory contributes to the Green IS (Elliot, 2011) domain, which is important because (1) there is a lack of IS studies that address the use of immersive systems in the context of environmental sustainability (Buljat, 2021) and (2) it is in line with AIS objectives to contribute to the field of Green IS (Watson et al., 2021; Elliot & Webster, 2017).

More precisely, the theoretical contribution of this thesis consists of two parts. First, the main theoretical contribution of this thesis is a *design theory* – a prescriptive body of knowledge summarized in design principles that provides explicit instructions for building an artifact (Gregor, 2006) that aims to use AR to motivate people to adopt PEB. Indeed, this *know how* is what distinguishes design science knowledge from other types of knowledge (Gregor et al., 2020). The second theoretical contribution is the *theory for explaining and predicting* (EP theory) – a descriptive theory that contributes to the understanding of causal relationships between cause and event (Gregor, 2006) – in this case, the use of green AR artifacts and individuals' PEB. Design theory and EP theory are closely related. Design theory provides prescriptive knowledge that informs the design and development of new information systems artifacts. The study of these artifacts then produce EP theory that informs us about the impact of these artifacts in the workplace and in society (Gregor, 2006).

When building our design theory, we addressed each of its eight components proposed by Jones & Gregor (2007), namely:

1. *purpose and scope* (motivating individuals to adopt PEBs);
2. *constructs* (artifact's information, social and technology aspects);

3. *principles of form and function* (design principles for a green AR artifact);
4. *artifact mutability* (changes in the artifact instantiations depending on the intervention's goal and target audience);
5. *testable propositions* (predictions about the artifact's efficacy in promoting PEB, tested in an experiment);
6. *justificatory knowledge* (kernel theories on which the artifact's design was based);
7. *principles of implementation* (artifact implementation guidelines);
8. *expository instantiation* (six proposed examples of instantiations) (Jones & Gregor, 2007).

Note that the theory generated from this research project could be applicable also to other artifacts serving similar purposes. Namely, in our studies, we found that in addition to the changes needed at the system level (Chater & Loewenstein, 2022), the challenges in promoting pro-environmental behaviors are primarily related to the inability of individuals to recognize the importance of today's actions that contribute to future' outcomes. Therefore, the temporal and spatial mismatch between the causes and consequences of environmental crises is at the root of individuals' difficulties in recognizing the seriousness of environmental problems (Van der Linden et al., 2015s).

Thus, these design principles could be applicable to other artifacts that serve similar purposes - namely, to warn of possible future consequences that are otherwise invisible (e.g., in the context of health-related behaviors: raising awareness and vividly demonstrating the consequences of current habits on a person's future health situation), which makes this theory relevant to a more general or archetypal problem (Rai, 2017) – designing information systems for behavior change under uncertainty.

4.2. Methodological contributions

The second contribution of this thesis is methodological. Combining design science and behavioral science (Hevner & Chatterjee, 2010), the research methodology used in this project provides an example of a novel and reliable approach to designing, demonstrating, and evaluating (1) an AR-based artifact; (2) an artifact designed to change behavior. We would like to inform future researchers working on similar projects of some important lessons we learned

during empirical data collection, which represents the methodological contribution of this research project.

First, in the early stages of adoption, when users are not yet familiar with the technology, it is difficult to demonstrate AR artifacts without a prototype. AR has penetrated in the market, but it is likely that the predominant AR content people are exposed to is very simplistic, such as AR face filters⁵¹. Although some participants in our qualitative studies stated that they were familiar with the AR technology, their surprised reactions when they saw the three-dimensional content in AR suggest that this may not be the case. Therefore, when presenting an AR artifact, even in its conceptual phase, we advise building a prototype.

Due to time and budget constraints, we learnt how to create AR experience. We used Meta's open-source software Meta Spark (previously Spark AR), which allows direct export of AR experiences in the form of camera filters to Meta's Instagram and Facebook platforms. We created a short manual⁵² that may be of help to other researcher and communicators who may need a fast and easy to use tool to create simple AR experiences. Since we had a prototype, whenever possible, we offered live demonstration and handled a device to participants so they can explore 'how it works'.

At a later stage, we encountered a difficulty to execute a live demonstration of the AR artifact, but we were able to successfully resolve it. During our evaluation cycles and interviews with environmental communication professionals, the world was hit by the COVID-19 pandemic and we had to move all our activities online - including the interviews and the AR demonstration. Therefore, we recorded the footage of AR experiences, created a short scenario, and used the free video editing tool Canva⁵³ to demonstrate the artifact⁵⁴. In this case, it is important to show the camera image right before embedding the AR content to demonstrate that AR embeds digital content into the real environment in real time, unlike video montage.

While most of the existing literature on AR/VR for dealing with PEB has not directly measured actual PEB, but rather emotions or attitudes that might drive PEB (see Section 2 of Chapter 1

51 See example: <https://about.instagram.com/blog/announcements/introducing-face-filters-and-more-on-instagram>

52 Manual on how to use AR creating tool „Meta Spark” is available here:
<https://sites.google.com/view/barbarabuljatrayment/research/manuals>

53 Manual on how to use graphic design and video editing tool “Canva” is available here:
<https://sites.google.com/view/barbarabuljatrayment/research/manuals>

54 Video demonstration of the artifact is available here:
https://www.youtube.com/watch?v=cZz0ox_mrSI&ab_channel=EFRIInformacijaskeznosti

for a literature review), our experiment provides an example of testing actual PEB, measured in generosity towards donating money to an environmental organization (see Subection 1.3. of Chapter 4). Given that environmental behavior is complex and there have been many research attempts to understand it, our example of testing PEB represents another important methodological contribution of this thesis.

Finally, we would like to point out the potential of immersive technologies to complement context-free laboratory experiments with field cues. Indeed, if we are able to achieve a high level of presence with AR experiences in a laboratory, such an approach could offer the possibility of bridging the methodological gap between laboratory and field experiments by ‘bringing the field into the lab’. Testing behavior and decision making in such a setting could offer more reliable conclusions and higher external validity of experiments (Innocenti, 2017).

Considering that research projects using immersive technologies to influence and test PEB (and similar behaviors) are still in their infancy, we believe that our examples of artifact design, demonstration, and evaluation could serve as inspiration to future researchers, which is the methodological contribution of our study.

4.3. Practical contributions

Finally, this thesis offers important practical contributions and policy implications. Although the artifact used for this research is still in the conceptual phase, it could serve as a basis for environmental communicators and storytellers to build upon and develop unique and effective behavioral interventions.

Based on the rich and informative insights gained through qualitative studies with end users and professionals, we realized that there is no ‘one-size-fits-all’ solution when it comes to promoting PEB, but many solutions for different audiences. Therefore, we focused on finding out what works best for each target group and proposed six possible instantiations of the AR artifact and ways to implement them in practice (see Section 3 of the General Discussion).

We believe we have provided answers to some unanswered questions about AR technology and its practical potential (and challenges). These guidelines, as well as the refined design principles, could serve policymakers, nonprofit organizations, teachers, educators, and other environmental communication stakeholders seeking new ways to improve traditional environmental communication through the use of digital technologies.

5. Further steps

Although this research project has evolved over the course of four years, it could also serve as a well-grounded foundation for a new research project. Although we have gained many new and rich insights, there are still many areas that are unexplored but worth investigating. In this section, we suggest some of the potential opportunities for research and practice, and point out to some possible challenges associated with AR technology.

5.1. Possible research and industry opportunities

The knowledge gained through empirical studies could be supplemented and enriched by expanding the sample base and evaluating the artifact qualitatively and quantitatively with different target groups. For example, it would be interesting to obtain feedback from younger users – preschoolers or high school students. Indeed, another popular AR-supported social networking platform, TikTok, is predominantly used by people aged 10-19 (Statista, 2021).

Also, it would be useful to repeat the experiment with a new, improved version of the artifact. By ‘improved’, we mean (1) an AR experience that could generate a greater sense of the presence and has higher visual fidelity of the AR content (indeed, in our experiment, we found that the treatment was not very effective or persuasive for participants who were already familiar with AR. For this reason, we hypothesize that a more advanced visual and perhaps auditory representation of digital objects may contribute to the effectiveness of such an intervention). In this case, it would be interesting to compare the same interventions with different hardware, i.e., to assess the extent to which the AR glasses contribute to immersiveness; and (2) a more sophisticated storyline of an AR intervention, e.g., developing a mobile game or making the experience more interactive.

Further studies could be devoted to examining the effectiveness of a particular component of the artifact’ design (e.g., a storyline, a visual display, interactions). Only by isolating a particular mechanism could we find out what really works and what does not. However, such approach can be very time consuming.

Another area worth investigating is the impact of the artifact on behavior in a social setting. Namely, during the design and development process, we paid attention to the social aspect of the artifact – we chose AR technology because AR experiences might embrace social

relationships between (1) users and (2) users and the artifact itself. Therefore, the future area of study could be the social relationships that are influenced by AR artifacts. To obtain reliable results, we propose a long-term (and if possible natural) field experiment with continuous use of the artifact.

In conducting a longitudinal experiment, it would also be interesting and important to investigate how effective the AR artifact might be in addressing habits – an important factor influencing PEB (Steg & Vlek, 2009). Indeed, as noted in environmental research, habitual behavior could be one of the barriers to maintaining PEB (Steg & Vlek, 2009). Therefore, we believe that conducting a longitudinal field experiment would provide many new and insightful results in the longer term, as we could investigate (1) the effects of the artifact on habitual and long-term PEB and (2) the effectiveness of the artifact on individuals' PEB in the social environment (when interacting with others).

Finally, at the industry level, this research project could serve as a theoretical foundation and guide for the creation of an IT startup. Thanks to the insightful study results, we now know about potential business opportunities, but also areas that need further improvement. This avenue is not out of the question for the future of this project, as we have made contact with many notable industry professionals (such as AR/VR designers and developers, researchers, and consultants from global environmental organizations) who have expressed interest in this project.

5.2. Potential challenges and barriers associated with augmented reality

Despite the exciting possibilities for further research or business that come with immersive storytelling, there is another side of the coin. Namely, there are some challenges associated with AR that should be considered when developing AR interventions to promote PEB and similar behaviors. Most of these challenges are technical in nature and should not cause major problems if carefully considered up front.

First, in order for AR content to be consumed, special equipment is required: in addition to software, AR supporting hardware and devices (e.g., a phone with all the necessary components such as a camera, sufficient processing power, location tracking systems - GPS, compass, accelerometer, etc. (Kipper & Rampolla, 2012)) are needed. This necessarily means that AR-

based campaigns exclude everyone else who does not have access to AR-supporting devices, or is not familiar with the technology.

Due to the often limited processing power and storage capacity of mobile devices, developers also often turn to cloud-based AR systems: storing and processing data in cloud databases can offload heavy tasks AR requires, such as image processing and rendering of the AR content (Shea et al., 2017). Therefore, besides equipment, the lack of a fast and stable internet connection can be the second technical challenge in AR interventions.

Moreover, the AR content does not just ‘happen’ by itself. Nor can it be placed on a billboard. People need to decide to engage with it, and they need sufficient time and an appropriate environment to interact with the AR content. Therefore, implementing AR campaigns can be challenging for communicators. First, AR interventions must be carefully curated to extend an invitation to an AR experience and ensure that the invitation is sent at the right time and place. For example, placing a *call to action* on a highway billboard is not the best option (it can be dangerous to use mobile phones and interact with AR content while driving). A better option would be to place a billboard in a pedestrian mall to ensure that passengers have enough time and space to interact with AR content. Also note that the environment in which AR is experienced can affect the fidelity of an overall experience, as indicated by end users (see Section 2 of Chapter 3).

Finally, communicators should offer AR content that is interesting to the target audience to avoid the question of *why anyone should interact with such a system*, which brings us to the next point. The fourth technical challenge is the AR design and development process itself. We encourage communicators to investigate in advance what content will resonate best with their target audience. Indeed, the literature in the area of fear appeals in environmental communication is inconclusive and inconsistent (O’Neill & Nicholson-Cole, 2009), and sometimes it is difficult to predict what will lead to better results. AR content is interactive, three-dimensional, and overlays the user’s immediate environment, so it can evoke natural responses and create the impression that virtual objects are real (Miller et al., 2019). However, it can also be complex, costly, and time-consuming to develop a realistic AR experience and ensure its constant updating to adapt to new operating systems and devices.

In addition, we need to point out some privacy challenges of AR that should be considered. For example, users’ privacy could be disturbed because the AR system needs access to users’ camera or location data (Kipper & Rampolla, 2012, Carmigniani et al., 2010). In addition,

communicators should be aware of the five possible areas of law that could be affected by AR: legal requirements to avoid potentially harmful effects on users' health and other devices - such as mental fatigue and anxiety (Igras-Cybulska et al., 2022); negligence due to user distraction, which can lead to disorientation and injury; copyright, which is difficult to regulate because it is impossible to see with the naked eye; privacy, which is considered one of the biggest impacts, especially because of facial recognition and its ability to identify the general public; and discovery, because it is nearly impossible to recreate or replicate the scene someone experienced in the AR space (Kipper & Rampolla, 2012).

Moving beyond AR technology; even if we meet all the technical and legal requirements, the success of such an AR intervention is not guaranteed because behavioral interventions are not universally effective and some behaviors are not easily changed (Bryan et al., 2021). Recent evidence from behavioral research shows that behavioral interventions focusing on the individual rather than attempting to change the system (rules, norms, and institutions) in which the individual lives and operates often have undesirable consequences, such as a lack of support for effective action or a situation in which an individual blames herself or himself for a problem that is actually caused by the system (Chater & Loewenstein, 2022).

Finally, environmental communicators need to be aware that environmental behaviors are dependent on many other internal and external factors that may be in an individual's path to PEB (Steg & Vlek, 2009). Even if we are successful in creating environmental awareness and internal motivation, there may be contextual barriers that could distract an individual on the path to sustainable behavior. For example, some focus group participants (see Section 1 of Chapter 3) stated that their failure to reduce their plastic consumption could be due in part to a lack of perceived self-efficacy and their frustration with the current consumer culture; in other words: they are not motivated to reduce their plastic consumption when everything is already packaged in single-use plastic. Therefore, collaboration with various stakeholders is crucial to encourage, motivate and maintain people's PEBs.

6. Limitations

As with any study, this research project has several limitations. Despite our best efforts, some of these limitations could not have been avoided, but they provide opportunities for future work. Below, we list these limitations and summarize them into three categories: (1) positioning in

the literature, (2) artifact validity, and (3) methodological challenges. We believe that these weaknesses can be addressed and transformed into new theoretical, practical, and methodological contributions in further research projects.

6.1. Positioning in the literature

As with any DSR project, during the pre-development investigation, a researcher should investigate relevant kernel theories to theoretically ground the design of the artifact and review similar existing artifacts (Gregor & Hevner, 2013). In this very first phase of the project, we encountered a positioning challenge. Because we had focused our work on the IS discipline and had decided to contribute to the IS community, we first examined the major literature in the field. However, we found that immersive technologies had not yet been explored or used in the context of environmental sustainability in the leading IS literature (see Section 1 of Chapter 1).

The main peer-reviewed studies on Green IS mostly examined green transformations within organizations, companies, and governments, but only several studies were conducted at the societal level. On the other hand, we found a total of only five papers in the leading IS journals that dealt with highly immersive virtual environments, suggesting that knowledge of VR and AR has been slow to build in the IS discipline (see Section 1 of Chapter 1).

Not finding relevant IS literature, we continued the search in other disciplines, where we found a total of 25 relevant studies (see Section 2 of Chapter 1). Thus, the first limitation of this thesis is its positioning in the literature: although the knowledge produced within this research project contributes to the IS literature, our literature review is based on theoretical findings primarily from computer science, human-computer interaction, communication, and psychology – disciplines from which we borrowed insights to design and develop our artifact.

6.2. Artifact validity

A second important limitation of the research project lies in the artifact itself. Namely, we relied on relevant kernel theories and prescriptive knowledge to theoretically ground the artifact. We then explored the development of AR artifacts to acquire technical knowledge and skills needed to understand the technical requirements of the artifact. While we created the first prototype (which took the form of a very simple AR experience overlaying a static 3D model of a turtle),

we needed the help of a professional to refine the design and create an improved version. So we reached out to industry experts (3D artists and AR/VR developers) and gave them detailed guidance on what we needed.

Here we encountered two constraints: time and budget. Getting an external designer to provide the instantiation took a great deal of time. We had originally set a 2-month timeframe for the project, but delivery extended to more than 6 months. In addition, while the new version of the artifact improved the features that end users complained about most (visual fidelity of digital objects), with the budget allocated to this project we could not ask for more than simple AR experiences with very little interaction. The mentioned challenge may have affected the outcome of our experimental study, as the stimuli may not have been strong enough to elicit a more pro-environmental response. We hope to be able to develop a more sophisticated version of the artifact and repeat the same experiment in the future.

6.3. Methodological challenges

The last important limitation is a methodological one. Although we followed established procedures and protocols for evaluating the artifact (Hevner et al., 2004), we lacked concrete guidelines for evaluating AR-based artifacts in its early conceptual phase. Therefore, we had to improvise at some stages and make some decisions that bound us for the rest of our work. In the following, we explain the sequence of these decisions in detail.

First, it is very difficult to demonstrate AR artifacts to new users. Unlike photos or videos that are consumed by passive observing, AR produces content that must be experienced and interacted with in order to be consumed. As a result, we knew we need a prototype of an actual artifact, which we had to develop ourselves due to budget constraints.

However, the prototype was not convincing enough for the entire sample. For example, while some participants were shocked to see the AR experience of a real-size animal trapped in plastic trash, for others the experience was unrealistic and even funny. Indeed, it was only then that we realized that seeing a marine animal on the floor of the classroom might seem confusing or strange, while participants might have been distracted by the sunlight and reflections on the tablet devices when they were outside. Therefore, we advise future researchers to think carefully about the environment in which they want to display the AR content, because the overall impression depends on how well real and digital merge together.

Next, in 2020, the world encountered a COVID-19 pandemic, which brought not only health-related crisis, but many work-related challenges as well. It affected this PhD project as well: most of the research activities were done remotely without impacting the quality of the research output, however, some activities would have brought more internal validity if conducted offline. While we successfully managed to conduct focus groups with end users on site, most of the interviews with experts were conducted via video conference. Therefore, we could not properly demonstrate the artifact in real time, but instead, we recorded a video explaining how the artifact could be used and how the AR projections look like.

Moreover, the samples we used in our empirical studies are small and focused, which makes it difficult to generalize results to a broader population. In focus groups and experiments participant were mostly educated students familiar with novel technology, which might have caused some biases to their feedback and responses. Moreover, while we aimed at capturing practical knowledge through the interviews with the experts from the domain of environmental communication, despite persistent efforts, we could not complete our sample with all the relevant subjects (for example, we could not neither reach a person from the government responsible for environmental policy, nor any green social media influencer).

Finally, the nature of our experiment required great amount of effort from the experimenters and many volunteers trained on the protocol who assisted during 5-days individual sessions. Unfortunately, we did not have time and resources to fix a couple of limitations we encountered after the study, such as: we focused on testing only one type of PEB (voluntarily donations to an environmental organization) and only a few PEB drivers (psychological distance, concern, and intention to act (Spence et al., 2012)), and we tested it immediately after the treatment. Also, despite our intention, we did not figure out a valid method to properly compare AR to other media content (e.g. photo or video) because each AR experience is unique and it would be challenging to decide what to include in other comparable (photo or video) treatments.

In future, we expect to address these limitations and provide more contribution to theory and practice. Despite mentioned limitations, we believe that our research project is very novel, informative and conclusive, and might serve policy-makers, teachers, researchers, nonprofit organizations and environmental communicators, who recognize the potential of immersive technologies but still had many unanswered questions about their design, impact and implementation.

GENERAL CONCLUSION

Pollution is a serious threat to our planet: to oceans, wildlife, society, and the economy. However, it is often out of sight of citizens, which poses challenges for environmental communicators in their task of promoting pro-environmental behaviors among people. The aim of this PhD thesis was to investigate whether and how AR technology can be used to make environmental communication more compelling and effective.

In this 4-year Design Science Research project, we designed a prototype of a green AR artifact that simulates plastic pollution and applied a mixed-methods approach to evaluate this concept from a multidimensional perspective (i.e. by using multiple methods and recruiting multiple types of users). Based on the rich and informative data collected from three qualitative and two quantitative studies, I would like to conclude this thesis with five ‘take-home’ messages.

First, *out of sight - out of mind*. As described in the literature and confirmed by empirical evidence, environmental problems are often not directly or immediately observable, so they are perceived as not urgent, not personally relevant, and psychologically distant. Environmental interventions should aim to bring environmental problems *to our backyards* while maintaining a reasonable level of fear so as not to generate resistance.

Although we have tried to use AR to bring environmental issues psychologically closer, we have found that such interventions do not always have the desired effect. In other words: *there is no one-size-fits-all communication approach*. For some individuals, immersive communication can have an impact, while for others it can even be counterproductive. Therefore, there is a need for customized and personalized interventions and instances that are tailored to specific target groups.

Third: *the way information is presented affects its reception*. In addition to technical features and visual fidelity, creators of green AR artifacts should also pay attention to the way the content is presented. The same information can be conveyed in many different ways, and a dynamic presentation seems to be more effective than a static one. Whenever possible, green interventions should therefore include dynamic elements such as interaction and gamification that can add value to users and motivate them to use the system.

Another element that might contribute to the dynamics of an intervention is the social interactions that could emerge from the use of the artifact. Therefore, in their attempts to

promote pro-environmental behaviors, environmental communicators should consider that *people are social beings and respond to social influence*, whether these social relationships are real (between humans) or virtual (between humans and machines). Therefore, the social aspect of IT artifacts should not be neglected whenever possible.

Finally, *environmental behavior depends on many internal and external factors*. Even if an intervention is effective in promoting pro-environmental behavior, technology alone will not be sufficient unless individuals' path to adopting pro-environmental behavior is free of contextual and other barriers.

This thesis contains theoretical, methodological and practical contributions. From a theoretical point of view, it contributes to the academic community and in particular to the Green IS community, by providing new design knowledge about the design of green AR artifacts aimed at promoting individual environmental behavior.

From a methodological perspective, this thesis contributes to researchers and practitioners by providing them with concrete examples of the use of mixed methods to evaluate (1) an AR artifact and (2) an artifact to motivate behavior change in the early conceptual phase, with different types of users, and at a stage when knowledge and guidelines are not available because the technology is still emerging.

From a practical point of view, this thesis may be of interest to stakeholders in the domain of environmental communication (such as nonprofit organizations, governments, policy makers, sustainability advocates, etc.) as it suggests guidelines for implementing the artifact in practice. More specifically, inspired by empirical data, we propose several possible extensions of the artifact (specific to the goal of the intervention and the target audience), suggest guidelines for their implementation, and provide information about potential challenges of immersive communication as well as advices on how to overcome them.

This thesis generates new and useful knowledge that could be applicable to the broader class of information systems used to change behavior in similar contexts - when there is a need to visualize future risks or negative but psychologically (spatially, temporally, socially, or hypothetically) distant outcomes of present behavior.

In this era of rapid technological development and the advent of immersive systems and metaverses, however, this knowledge is only the tip of an iceberg, and there are many more areas to explore. One of the limitations of this work is its questionable long-term impact,

considering that digital content creation is faster and easier than ever before, making it difficult to capture and maintain people's attention.

Finally, this thesis focuses on the pro-environmental behavior of individuals and will hopefully reach a wider audience than academics and professionals. It shows an example of how anyone can use the power of new technologies to raise their voice in public and send strong messages without saying a single word. I hope this work will serve as an thought-provoking literature that encourages people to believe in cumulative action of small steps for a better future of our planet.

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1.A) References from *Table 5. Summary and categorization of main empirical and theoretical contributions to Green IS research*

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1.C. Papers from the leading IS literature dealing with LIVE (references and categorization)

CATEGORIZATION:

Reference	Topic
Animesh et al. (2011)	Business aspect of virtual environments
Berente et al. (2011)	Business aspect of virtual environments
Goh & Ping (2014)	Business aspect of virtual environments
Goode et al. (2014)	Business aspect of virtual environments
Nah et al. (2011)	Business aspect of virtual environments
Yang et al., (2012)	Business aspect of virtual environments
Chaturvedi et al. (2011)	Design and creation of virtual worlds and 3D objects
Kohler et al. (2011)	Design and creation of virtual worlds and 3D objects
Seymour et al. (2018)	Design and creation of virtual worlds and 3D objects
Suh et al. (2011)	Design and creation of virtual worlds and 3D objects
Saunders et al. (2011)	Design and creation of virtual worlds and 3D objects / Usage/acceptance of virtual worlds
Jiang & Benbasat (2004)	E-commerce
Suh & Lee (2005)	E-commerce
Yang & Xiong (2019)	E-commerce
Zahedi et al. (2016)	E-health
Bhagwatwar et al. (2018)	Learning and collaborating in virtual worlds
Davis et al. (2009)	Learning and collaborating in virtual worlds
Mueller et al. (2010)	Learning and collaborating in virtual worlds
Nardon & Aten (2012)	Learning and collaborating in virtual worlds
Srivastava & Chandra (2018)	Learning and collaborating in virtual worlds
Roquilly (2011)	Legal aspects of virtual worlds
Schultze (2010)	Presence in virtual worlds
Goel et al. (2011)	Usage/acceptance of virtual worlds
Goel et al. (2012)	Usage/acceptance of virtual worlds
Junglas et al. (2013)	Usage/acceptance of virtual worlds
Lee & Chen (2011)	Usage/acceptance of virtual worlds
Nevo et al. (2011)	Usage/acceptance of virtual worlds
Schwarz et al. (2012)	Usage/acceptance of virtual worlds
Zhou et al. (2015)	Usage/acceptance of virtual worlds
Featherman et al. (2006)	Users' behavior in virtual worlds
Hinz & Spann (2008)	Users' behavior in virtual worlds
Hinz et al. (2015)	Users' behavior in virtual worlds
McKenna (2019)	Users' behavior in virtual worlds
Schultze (2012)	Users' behavior in virtual worlds
Schultze & Brooks (2018)	Users' behavior in virtual worlds
Schultze & Mason (2012)	Users' behavior in virtual worlds
Ketter et al. (2015)	Virtual environments for addressing environmental sustainability
Ketter et al. (2016)	Virtual environments for addressing environmental sustainability
Greenhill & Fletcher (2013)	Virtual games
Putzke et al. (2010)	Virtual games

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Appendix 2

Variables mapping – depended measures of surveyed studies and their alignment with identified PEB drivers (**LIVE** / **HIVE**)

Reference	Measures	Beliefs	Concern and awareness	Connectedness to nature	Intention	Psychological distance	Risk perception	Real behavior	Technical and control measures
Ahn et al., 2014	environmental locus of control	x							
Ahn et al., 2014	environmental behavior (number of napkins used to clean the water)							x	
Ahn et al., 2014	perspective taking propensity								x
Ahn et al., 2014	environmental behavioral intention				x				
Ahn et al., 2014	environmental behavior (self-reported)							x	
Ahn et al., 2014	awareness of consequences		x						
Ahn et al., 2015	environmental response efficacy	x							
Ahn et al., 2015	environmental behavioral intentions				x				
Ahn et al., 2015	environmental behavior (self-reported)							x	
Ahn et al., 2015	number of paper napkins used to clean up the water							x	
Ahn et al., 2016	body transfer								x
Ahn et al., 2016	spatial presence								x
Ahn et al., 2016	inclusion of nature in self			x					
Bailey et al., 2015	water temperature during handwashing							x	
Bailey et al., 2015	water amount during handwashing							x	
Bailey et al., 2015	vividness scale								x
Bailey et al., 2015	personalization scale								x
Bateman et al., 2009	willingness to pay for land use preferences				x				
Breves & Heber, 2019	spatial presence								x
Breves & Heber, 2019	environmental connectedness			x					
Breves & Heber, 2019	need for affect								x
Breves & Schramm, 2021	presence								x
Breves & Schramm, 2021	psychological distance					x			
Breves & Schramm, 2021	personal relevance of the environmental problem		x						
Breves & Schramm, 2021	perceived severity of the problem						x		
Breves & Schramm, 2021	pro-environmental behavioral intentions				x				
Breves & Schramm, 2021	prior knowledge								x
Breves & Schramm, 2021	physical condition after VR experience								x

Chirico et al, 2020	weekly plastic consumption								x
Chirico et al, 2020	emotions		x						
Chirico et al, 2020	sense of presence								x
Chirico et al, 2020	attitudes towards environment and plastics		x						
Chirico et al, 2020	behavioral intentions toward plastic				x				
Chirico et al, 2020	social desirability								x
Fiore et al., 2009.	policy choice				x				
Fiore et al., 2009.	risk preferences								x
Fiore et al., 2009.	presence								x
Fiore et al., 2009.	ease of use								x
Fox et al, 2019	psychological distance					x			
Fox et al, 2019	interactivity								x
Fox et al, 2019	risk perception						x		
Fox et al, 2019	environmental self-efficacy	x							
Fox et al, 2019	environmental policy support				x				
Fox et al, 2019	environmental behavior (self-reported)							x	
Greussing, 2019	knowledge acquisition		x						
Greussing, 2019	perceived message credibility								x
Greussing, 2019	prior knowledge								x
Greussing, 2019	involvement in the topic of climate change								x
Greussing, 2019	environmental concern								x
Hsu et al., 2018	cognition of daily water consumption		x						
Hsu et al., 2018	attitude toward water usage		x						
Hsu et al., 2018	self reported behavior intention to conserve water				x				
Hsu et al., 2018	extent of tightening of the virtual faucet				x				
Hsu et al., 2018	presence in the virtual environment								x
Isley et al., 2017	purchased items							x	
Isley et al., 2017	enjoyment								x
Isley et al., 2017	usefulness								x
Isley et al., 2017	intention to use								x
Joerß et al., 2021	frequency of using technology								x
Joerß et al., 2021	sustainable consumption habits								x
Joerß et al., 2021	technology as-solution belief								x
Joerß et al., 2021	AR-RA adoption intention								x
Joerß et al., 2021	product choices				x				
Joerß et al., 2021	app usage time								x
Markowitz et al., 2018	ocean acidification knowledge		x						
Markowitz et al., 2018	environmental attitudes		x						
Markowitz et al., 2018	presence								x
Markowitz et al., 2018	connectedness to nature								x
Markowitz et al., 2018	movement in VR								
Markowitz et al., 2018	inquisitiveness (asking for more information about ocean)				x				
Markowitz et al., 2018	species count and search activity								x
Markowitz et al., 2018	distance traveled underwater (in VR)								x
Matthews et al., 2017	willingness to pay for coastal erosion protection measures				x				

Moore & Yang, 2019	environmental attitude								x
Moore & Yang, 2019	trait empathy								x
Moore & Yang, 2019	recycling knowledge								x
Moore & Yang, 2019	eco-guilt		x						
Moore & Yang, 2019	environmental behavioral intention				x				
Moore & Yang, 2019	environmental behavior - water cup choice and recycling behavior							x	
Nelson et al., 2020	donation							x	
Nelson et al., 2020	emotions								x
Nelson et al., 2020	environmental engagement and personal perspectives		x						
Nelson et al., 2020	sense of presence								x
Oh et al., 2020	environmental self-efficacy	x							
Oh et al., 2020	issue involvement with global warming								x
Oh et al., 2020	perceived interactivity								x
Oh et al., 2020	message perceptions								x
Oh et al., 2020	perceived credibility								x
Oh et al., 2020	behavioral intentions to protect the environment				x				
Oh et al., 2020	prior experience with VR								x
Olschewski et al., 2012	willingness to pay for avalanche protection options				x				
Prada et al., 2015	quality of the game and the players' experience								x
Prada et al., 2015	knowledge acquisition related to the ecological impact of the agriculture		x						
Schaeffer et al., 2018	choice of products (their ecological scores and prices)				x				
Soliman et al., 2017	relatedness of nature to their self-concept			x					
Soliman et al., 2017	connectedness to nature			x					
Soliman et al., 2017	mood								x
Soliman et al., 2017	presence								x
Soliman et al., 2017	fun								x
Soliman et al., 2017	choosing a hard copy of debriefing							x	
Soliman et al., 2017	signing for a sustainability newsletter							x	
Soliman et al., 2017	downloading campus sustainability plan							x	
Treuer et al., 2018	degree of worry about sea level rise		x						
Treuer et al., 2018	willingness to move out from the region				x				
Treuer et al., 2018	willingness to take self-protecting flood measures				x				
Treuer et al., 2018	source of worry		x						
Treuer et al., 2018	information use (when, how often a type of information is clicked)								x
Zaalberg & Midden, 2013	emotions		x						
Zaalberg & Midden, 2013	information search related to the evacuation from the threatened area				x				
Zaalberg & Midden, 2013	coping intentions				x				
Zaalberg & Midden, 2013	presence								x
Zaalberg & Midden, 2013	instructions check								x

Appendix 3

Focus group guide from the study “*Gathering early opinions on the use of AR in environmental communication: Pilot focus group with end users*”

FOCUS GROUP GUIDE

Acceptance, opinions and attitudes about augmented reality as a means of pro-environmental communication from the point of view of end users in Croatia

Introduction

Hello. Thank you for your participation in this focus group. The aim of this research is to examine the acceptance, opinions and attitudes about augmented reality as a means of pro-environmental communication from the point of view of end users in Croatia. All collected data will remain strictly confidential and will be analyzed on an aggregate level. If at any time you want a break, or if you want to leave the discussion, you have the right to do so. The discussion in the focus group will be recorded for easier data processing. If you agree with the above, please sign the consent form and fill in the table with demographic data.

- Giving a consent form and short demographic survey to the participants.

Questions

1. Have you heard about plastic pollution? How did you hear about it? Can you give me an example of campaign about plastic pollution you saw? Did it have any effect on you – did it change your perception or behavior? Is a person who is promoting it important – who would you trust?

At this moment 2 posters regarding plastic pollution will be presented to the participants: one showing consequences of plastic pollution (animals in danger), and another one not.

2. Could you comment these campaigns? Which of these two messages would have more impact on you?
3. What do you think about experiential learning (learning through experiencing)? Does it have more effect than learning through text or images?
4. Have you ever experienced augmented reality? Please tell me something about your experience.

At this moment, participants will have a chance to experience augmented reality projection of turtle wrapped in plastics.

5. Imagine seeing this projection at your favorite beach. What do you think: could such experience have effect on people and raise their awareness of plastic pollution?
6. What do you think: how can you make people voluntarily look at something not pleasant and “ugly”?
7. What do you like and dislike about this image? Do you think that seeing more realistic image has bigger effect? Or it can induce fear and disgust?
8. In your opinion, which animal would cause bigger empathy: dolphin, turtle or bird (or any others)?
9. To conclude: what do you think about raising awareness of a problem by simulating its consequences? what do you think about augmented reality as a tool to raise awareness about plastic pollution?
10. Would anyone like to add any final comment or conclusion? Or do you want to suggest a way we can fight plastic pollution?

Thank you for your participation. Please feel free to contact me if you have any additional question.

Appendix 4

4.A) Focus group guide for the study “*Augmented reality for promoting pro-environmental behavior: Evaluation through a qualitative study with end users*”

FOCUS GROUP GUIDE

ARTIFACT EVALUATION WITH END USERS

Introduction

(NAME TAGS – write with marker)

Dear participants, hello, welcome, and thank you for your participation. This focus group is a part of the doctoral thesis project “augmented reality – a tool for raising awareness of plastic pollution”. My name is Barbara Buljat and I will be your moderator today.

Plastic pollution is a big environmental threat. Its high consumption and improper waste disposal create accumulation of plastic trash in the environment. The aim of this research is to find a way to more effectively communicate with public on this issue. We proposed AR – a technology in which people can virtually experience environmental damage. Today’s discussion and your opinions will contribute to writing a scientific paper. Namely, you represent potential users of proposed technology, and we would like to assess your attitudes towards it.

Focus group is a group interview with moderator who will lead you through the topics we have to cover. The moderator will ask you a question, and then you are free to discuss about it between yourselves. Please keep in mind that there is no right or wrong answer, and you are asked to share your honest opinion. It is important to let us know if you see things differently from the others. However, please don’t criticize each other and respect everybody’s opinion, even if it’s different than your own. In order to ease the data generating process, we will audio record the session, and then transcribe it. Therefore, try to speak clearly and one at the time. All of the data will stay confidential, and your name will not be mentioned. Please take a moment to turn off the sound on your phone. The session will take approximately 1 hour, and if you want to have a break, or leave, you are free to do it at any time.

We will cover several themes: plastic pollution in general, your opinions about environmental campaigns, environmental behavior, social networks, and we will ask you to try ad comment pro-environmental AR experiences. Do you have any question?

Please, now fill this short questionnaire ([GOOGLE FORM LINK, QR CODE](#))

- CHAIR CODES
- START RECORDING

THEME 1: WARM UP

1. Have you ever heard of plastic pollution? In what way?
2. If you had to remember an environmental communication campaign, what would it be? Why did it particularly impress you / what did you remember?
3. When you see an environmental campaign, do you look at who is behind it? Give an example? Does it change anything for you? Would the message have more impact if a close person told you about it?
4. Now, I'm going to show you two campaigns and tell me which one impacts you the most and why? Impact of animals (positive or negative)? P: N:
5. How many of you are concerned about plastic pollution? N:
How many of you are active in the fight against plastic pollution (recycling, etc.)? N:
Among those who do not feel concerned, what is the biggest barrier in your behavior?
6. In your opinion, can social networks (Facebook, Snapchat, TikTok, Insta) contribute to more "eco-friendly" behaviors?
7. In your case, have you already shared pro-environmental content on the networks? N: What purpose ?
8. How many of you have already tried AR filters on social media (Instagram, Snapchat)? N:

THEME 1: EXPERIENCE

Now, let's talk about the project. We propose AR as a way to bring the problem of plastic pollution psychologically closer to people. Probably you've already heard about virtual and augmented reality, but let's do a short debriefing. VR totally blocks your sight – you have to put a headset on your eyes, and all you see is a virtual world. Unlike that, AR adds digital elements in your real world, and creates the illusion that these elements exist there. It merges real and virtual world in real time. A common examples of AR are Instagram face filters, which adds element on your face when you look at your camera feed. (If it's necessary, we can additionally explain/show AR to you.)

The idea of this project is to use the power of AR to let people experience the consequences of plastic pollution. Unlike observing a photo or video, or reading a text, you can literally experience AR - wherever you are, with your phone. You don't even need to download the extra app because this could be available through Facebook or Instagram, as camera effects. It can be proposed by environmental agencies, or governments, which would invite people to use their phones to experience it. Also, everybody can record it, download it as a video or

photo, and share it with their friends or post in on social networks. That way it could become viral - we can all easily spread the word about plastic pollution and raise awareness of each other.

We choose the 5 most impacted animals (seal, turtle, bird, dolphin, whale) and, inspired by real scenes, created the 3D projections. These animals are trapped in single use plastic items, such as bottles, bags, and food containers. We have a prototype of one animal – a seal, and now you will have a chance to experience it.

- **AR LIVE DEMO; VIDEO, ASKING IF EVERYBODY UNDERSTOOD.**

9. What do you think of this App?
10. How many of you would use it in real life? N:
11. What do you like using it? What you did not like? (fun, exciting // threatening, fearful, disgusting, graphics...)
12. Do you see any risks in using this App (manipulation, privacy, kids related issues, etc.)
13. Do you find it easy to use (you understand the logic)?
14. On what medium would you use it most easily (free app, Facebook, Insta, internet browser...)? Why ?
15. Would you share this content on your social media accounts / with your friends?

THEME 3: IMPACT

16. Compared to the first two campaigns, does the third make you feel more concerned about plastic pollution? Why ?
17. In what way, for you, can this tool be a good marketing lever for a pro-environmental campaign?
18. Could you share this content, just to give yourself a good image on the networks?
19. Other coments / final conclusions?

- **POST-QUESTIONNAIRE : GOOGLE FORM, QR CODE**
- **CONSENT FORM**

CLOSING

Dear participants, we are now at the end of our focus group. Thank you very much for your participation. We appreciate your time and input into this research. If you have any questions, or you are interested in a final copy of the report from this research, please feel free to contact me.

4.B) Codebook of transcription from the artifact evaluation with end users

<i>THEME</i>	<i>CODE</i>	<i>QUESTION THAT THE CODE ANSWERS</i>
ENVIRONMENTAL COMMUNICATION <i>(This theme implies various elements of an environmental campaign. Such elements are under control of a campaign creator, because they can be integrated into a communication strategy.)</i>	Experiences and actions	<i>How impactful are action-based campaigns (such as clean-up actions, educational field trips, etc.)?</i>
	Content, form & presentation	<i>What kind of campaign content is remarkable, rememberable, and shareable? What form of the content presentation (video, photo, billboard...) is the most impactful?</i>
	Credibility	<i>Is credibility of a message important in an environmental campaign? What makes a campaign credible? Is the source of the message important?</i>
	Media platforms	<i>What media platform is the most promising for environmental campaigns? Which social network is the most effective for environmental messages?</i>
	Influencers and celebrities	<i>What is the role of influencers and celebrities in environmental campaigns?</i>
	Incentive-based campaigns	<i>How effective are incentive-based campaigns (a type of campaign that offer some kind of reward in return for a green behavior, such as jewelry from recycled material, or planting a tree for a donation)?</i>
	Education	<i>How important is environmental education? Is environmental data too complex to understand?</i>
	Audience	<i>Is there one-size-fits-all communication solution, or there are different strategies for different target groups?</i>
	Brand initiatives	<i>How does public react to green initiatives from commercial brands?</i>
OTHER FACTORS THAT INFLUENCE PRO-ENVIRONMENTAL BEHAVIOR <i>(This theme implies elements that are not necessarily a part of an environmental campaign, but positively or negatively influence execution or intention to execute pro-environmental behavior. These elements are usually out of control of a campaign creator)</i>	Social influence	<i>Does societal pressure and norms play a role in forming environmental attitudes? How important is personal image and following trends?</i>
	Internal motivation	<i>What internal motivation influences individual's environmental behavior?</i>
	Governmental initiatives and regulations	<i>How effective are government's initiatives? What is the public opinion about monetary regulations?</i>
	Institutional trust	<i>Does public have difficulties in trusting institutions?</i>
	Culture & society	<i>How does culture and society impact individual's environmental behavior?</i>
	Psychological distance	<i>Does psychological (spatial and temporal) distance of environmental problems plays a role in forming environmental behaviors?</i>
	Context barriers	<i>What are the contextual barriers (such as supermarket prices and options availability, waste management system, infrastructure) to individual pro-environmental behavior?</i>
THE ARTIFACT: PRO-ENVIRONMENTAL AR EXPERIENCES <i>(This theme implies opinions about the proposed novel artifact, possible extensions, launch, downsides etc.)</i>	Positive feedback	<i>What is well rated about the artifact?</i>
	Negative feedback	<i>How should the artifact be improved?</i>
	Possible extensions	<i>What are the possible extensions of the artifact?</i>
	Form	<i>What is the appropriate form of the artifact?</i>
	Launch	<i>How to launch the product on the market?</i>
	Risks	<i>What are the risks associated with the artifact?</i>
	AR in general	<i>What is the opinion about augmented reality in general?</i>
	Project explanation	<i>Transcription including project explanations and demonstration</i>

Appendix 5

5.A) Interview guide for the study “AR for environmental communication: Evaluating the artifact with professionals from the domain of environmental communication”

INTERVIEW GUIDE

ARTIFACT EVALUATION WITH PROFESSIONALS

Introduction

Hello, my name is Barbara Buljat, I am a PhD student in Economics at the Université Côte d’Azur. First of all, I would like to thank you for your time today. It is my big pleasure to have this opportunity to learn from an expert like you. This interview is a part of the big empirical study in which I am investigating the role of new mediums for environmental communication. Since you are an expert in this field, I am curious to find out about your valuable opinion, and eventually make conclusions about how to use new technologies to improve environmental communication.

There is no right or wrong answer, it’s your opinion that interests me. If you don’t mind, I will record the interview and later transcribe it, so it is easier for me to analyse the data. Please be sure that your name, and the name of your organization won’t be mention, unless you want to. Ok? Please make yourself comfortable and feel free to stop me and have a break whenever you need. If, at any moment, you want to give up on the interview, you have the right to do so. The interview will take approx. 45 minutes. Do you have any questions before we start?

- Start recording

1 – PRESENTATION OF THE INTERVIEWEE AND OF HIS/HER GENERAL PERCEPTION OF COMMUNICATION CONCERNED WITH ENVIRONMENTAL PROBLEMS

Sub-theme	Questions	Follow-ups	What we are looking for
Interviewee’s presentation	Please, tell me something about yourself and your organization.	What does your job consist of (what’s a representative day at work)? Since when are you part of this organization?	General information on the interviewee

Environmental sustainability awareness	How do you see the role of your organization in promoting environmental sustainability?	Could you provide examples of specific missions / projects? How do you evaluate your impact on environmental sustainability?	How much engaged with promoting environmental sustainability the organization is? (Ref, in terms of degree of maturity of environmental engagement?)
Communication of environmental issues	What do you think it is the biggest challenge of communicating about environmental problems?	How do you overcome it? Provide examples of specific campaigns.	Empirical barriers (media ?) to communicating about environmental issues (Ref)
Communication to enhance green behavior	What do you think it is the biggest challenge of communicating to motivate people to adopt green behavior ?	(psychological distance, contextual barriers, mistrust, social norms...)	Role of communication to enhance green behavior (Ref)
Familiarity with AR	How familiar is augmented reality technology to you?	Have you used any kind of immersive experiences in your communication?	Familiarity with technology (Ref, precursory users vs experts?)

2 – CAMPAIGN ELEMENTS

Sub-theme	Questions	Follow-ups	What we are looking for
Campaigns to promote green behavior (possibly answered in part 1)	Which means do you usually use to promote sustainable behavior?	campaigns, educational activities, school, exhibition...? Which forms? (video, photo, posters) On which platforms (social media? newspapers? billboards?)	To what extent, do organizations use traditional campaigns to promote green behavior?
Information / content provided by the campaign	When you create a campaign - what are for you important elements? Is credibility important? how do you make sure that you message is credible?	What is a good content of environmental campaign? Could you provide examples of a « good” campaign in terms of content	Relevant information provided by sustainable campaign

Behind textual information, the role of visuals in campaigns perception	How do you choose visuals for your campaigns?	Can you comment the role of fearful visuals (for example, animals in danger because of climate change)? Did you get any feedback? How do you measure the impact of visuals?	Role of visuals in environmental campaigns
Type of media support to communicate efficiently	In your experience, can you comment the role of social media in promoting environmental behavior?	Do you hire other influential persons to advertise you such as influencers, celebrities?	Recently, we've seen how social media can play a big role in societal movements, such as Black Life Matters, Fridays for Future or Earth Hour (Ref)
Type of audience	What audience are you usually trying to reach?	Do you make segmentations if different audiences?	Targeted audience of environmental campaigns (ref)
Quantified goals of campaigns	What are usually your campaign goals?	What is, in your opinion, successful environmental campaign and how do you measure success?	Evaluation/ Role of environmental campaigns (Ref)
Impact of communication on policy makers (part of one of the targeted audiences?)	Do you think social media campaign can put pressure on policymakers and make an impact?	How? Can you illustrate with a personal experience or an anecdote you know?	How much sensible policy-makers are to this kind of campaigns? (ref/ empirical research?)

3 – ARTIFACT EVALUATION

Thank you very much for this useful insight. Now, I would like to present you a prototype of an IT artifact that is still in the early phase of development, and in order to improve its design, I need your feedback. Research says that the lack of direct experiences of environmental problems (for example, wild fire or marine pollution) leads to lower perception of risk and lower motivation to engage around such issues. So, this artifact is based on the idea to provide direct experiences of environmental threat, in the form of augmented reality.

Augmented reality is a technology that superimposes digital objects over the real world, and creates an illusion that they actually belong there.

By using your smartphone, you can virtually insert any 3D digital object in your immediate surrounding, in real time. This technology is supported by every newer mobile device nowadays, and is mostly used in the form of Facebook or Instagram camera filters. So, instead of using posters or videos to communicate about environmental issues, governments, museums or nonprofits can now provide audience with interactive tridimensional experiences. We took an example of a growing and urgent global problem: plastic pollution. The artifact you are about to see is inspired by real scenes, and demonstrates 5 most impacted animals struggling with single use plastic trash. First, I am going to give you a short video explanation, and then I will demonstrate it to you on my smartphone/tablet.

- **Video demonstration**
- **Live demonstration**

Sub-theme	Questions	Follow-ups	What we are looking for
First impressions	Could you share your first impression?	How did you feel experiencing AR? Did you feel like animals were there?	User's first impressions and opinions
Positive aspects	What is good about using this technology for environmental communication?	Do you think AR is a good supplement to traditional environmental campaigns? Why? Can this be a good marketing tool to lead users to a specific page/ raise visibility of an organization?	Positive aspects of the artifact
Negative aspects	What are the risks, downsides?	Privacy? Not realistic?	Negative aspects of the artifact
Possible extensions	What should be improved/extended?	Video game, filters, app, message, call to action...	How can the prototype be upgraded
Form	There are 3 possible forms such experiences could take: as a (free) mobile app, social media camera	Why? Elaborate...	Optimal artifact form

	effect, and as interactive experience within a website in a browser. What do you think is the most appropriate?		
Launch	How would you advertise (launch) such virtual experience, to make people want to click and experience it?	Photo, video “call”? Influencers? What timing? Marker based/markerless?	How to advertise/launch the experience
Buzz	AR campaigns can generate infinite amount of unique content created by users. What do you think about this?	Can such AR experiences lead to a buzz and eventually to a social media movement? Can it become viral?	Can such campaign lead to a buzz, movement, become viral
Audience	Who do you think is appropriate audience for such campaigns?	Age, gender... Eco-oriented or no...	Appropriate audience
Perceived ease of use	Do you think AR technology is easy to use?	What makes it hard/easy...	Perceived ease of use
Intention to use	(In case they haven’t used already) Would you use this kind of medium in your future campaigns?	Example...	Intention to use
Other remarks	Final comments...		Other remarks

CLOSING

We came to the end of this interview. Thank you so much for your time and valuable feedback. Do you have any final comment or anything that you want to tell me? I will now stop recording. In case there is something that later comes to your mind, or have any other question, feel free to write me by email.

- *Stop recording*
- *Signing consent form*

5.B) Codebook of transcription from the artifact evaluation with professionals

Major themes	Codes	Question that this code answers	Transcription excerpt
INFORMATION ASPECT	Environmental communication: The purpose/goal/impact	What are the goals of environmental communication efforts, and how are these goals achieved?	<i>Interviewee_9: “Like for instance, the Clean Seas campaign has different topic areas that they focus on. The activations that are coming out in the next month or so is all about avoidable and harmful plastics. That would include those fishing gear, as you mentioned, the nets, forever chemicals, and how these types of chemicals, even if you break them down to microplastics, they still exist and can end up in the furthest away places where there’s no human interaction whatsoever, but they’re still there... If we’re, for instance, doing a tourism activation, that’s very much based on the individual and what they can do when they’re traveling, at home, when they’re on the road, in terms of car tires and taking off the microplastics of the car tires.”</i>
	Environmental communication: challenges	What are the biggest challenges of communicating about environmental problems?	<i>Interviewer: “From your experience, what was the challenges of environmental communication? Why is it difficult to transfer scientific knowledge to people?”</i> <i>Interviewee_6: “I would say that the main barrier is actually the language. I feel like, and this is where I think design is helpful here, so much of the documentation and information that is produced by UN Environment Program in Europe and in Latin America and all over the world, are very technical, and the recipients of this information are actually not end users.”</i>
	Experiential	Are direct experiences impactful and why?	<i>Interviewee_1: “Sometimes you have to see it...”</i> <i>Interviewer: “It’s different when you see it than when you have to imagine it.”</i> <i>Interviewee_1: “Yeah. Sometimes it’s-- it seems, uh, maybe stupid, but, uh, it is the-the best demonstration, even if it’s, uh, really small”</i>

	Psychological distance	What is the role of psychological distance in taking an environmental issue seriously?	<i>Interviewee_9: "I think until somebody sees it right in their face and gets directly affected by it, they're not going to really be paying attention to the issue. Unless they're really being affected and going to a highly polluted place, I think they're going to be this problem doesn't affect me directly so I don't need to be so active about making a change because my life is not directly being affected by it. I think with that kind of mindset, it's actually very difficult to again create behavioral change unless we can make it I guess in their facing, like this is the reality."</i>
	Content, visual, fearful	What is appropriate content of environmental campaigns? What is the role of fearful (negative) visuals?	<i>Interviewee_5: "I read a little bit, especially about climate change communication, and when you have this story that's doom and gloom, like they call it, that it's very sad, then, generally that doesn't help. What I read is that it generally makes people feel sad and that they don't have agency, that they can't do anything about it."</i>
	Education	How to incorporate educational content into environmental communication?	<i>Interviewee_5: "For example, with this tournament, we also had lectures about plastic pollution, about recycling, and so on. There was this specific educational component. Also, there were short lectures not to bore the students because they were waiting for the tournament but because they were waiting for the tournament."</i>
	Personalization / identified victim/embodying	What is the effect of personalized communication?	<i>Interviewee_6: "I do feel like VR has the opportunity to make you really close, different to what you see when you watch the news or you see a documentary, like this idea of having plastic on your face, like make it really personal."</i>
	Form/placement/media platform of communication	What media platform or types are recommended for environmental communication?	<i>Interviewee_6: "I do believe that the, perhaps in my generation, we were the first with social media and in our 20s and 30s we did not understand very well, or this is the thing I see with other clients I have, is that you cannot have the same content in every network. Twitter, Instagram, TikTok, you cannot have the same kind."</i>

SOCIAL ASPECT	Partnership with influential people/brands	Can collaboration with an influential individual or brand give more visibility to a campaign?	<i>Interviewee_7: “I do think it would be great to be able to see that in the hands of actual sustainability advocates who are doing beach cleanups as well. (...) For example, we chose 30 sustainability advocates across the Asia region to then help us then use all of the four AR experiences in the “100 days to beat plastic pollution” toolkit. Then they would share that with their friends, et cetera.”</i>
	Social norms, social influence, viral campaigns, movement	How important is social component of environmental communication and why?	<i>Interviewee_5:” The idea was to have one person on stage and the other cheering like in eSports events. But, even though now it’s possible to have untethered stand-alone headsets, I would still go with making big events where you can see someone playing because, in that way, you make it more of a social experience.”</i>
	Government, policies	What is the role of government and policies in environmental initiatives?	<i>Interviewee_2: “And I can tell you one comment. I one got from my mother. Uh, she said to the little boy who was going to put his trash in the trash bin, she said to him, “Oh, you don’t need to, because you see, those people, they are cleaning up after us anyway.”“</i> <i>Interviewer: [chuckles]</i> <i>Interviewee_2: “Can you believe it? So, I mean, this is the thing. (...) But as more people you have to go and clean, and as more trash bins you are putting up, as less you will educate people to just keep their trash with them, like they do in Japan. I think they’re fantastic. They keep their trash.”</i>
	Personal norms and perceived control	Do individuals believe they can make a difference?	<i>Interviewee_2: “Yeah. That’s good. Because a lot of people are too, um, too optimistic and too blind about the impact they can do. And they think, “Oh, yeah, we suggested this in fantastic,” but I’m like, “I tried to, from the time to, you know, three years ago and it’s not working,” you know, huh. But this comes also with experience and this comes with when you are living it.”</i>

	Trust & credibility, greenwashing, conflict of interests	Is trust and confidence important in conveying environmental messages?	<i>Interviewee_2: "They know what's wrong, but then if they say something, they can't get a job. I was, uh, I was asking, needs to be in, um, uh, whatever advisory report, also a plastic pollution. I was once there. And I was saying my opinion and (...) you know, and they were all, grrrr and, you know, they did know more and so on. And-and I have not been invited since."</i>
	Context that impacts the success of the intervention	What are the possible contextual factors that may impact the outcome of an environmental intervention?	<i>Interviewee_5: "Regarding other institutions that develop different applications, VR applications for themselves, I would say that 90%, maybe 80% of the success for a project like that lies on the teacher because there are teachers that take the goggles and they say, "Oh this is great. Let's do it." "</i>
	Building social relationships & empathy with computer	Is it possible to build social relationship with a computer and how?	<i>Interviewee_8:" Yes. I also cooperate with a psychologist from Warsaw and together we are reviewing VR applications in which you can see the world from the perspective of someone with disability. For example, when a person who is losing sight or is on the wheelchair or has dementia or autism or Asperger's syndrome and so on. There are several such applications or movies, 360 degree movies. The reason for this is to make people feel more empathy who take, for example, colleagues at university or coworkers who suffer from this kind of disabilities."</i>
TECHNOLOGY ASPECT	Benefits of digital/social/immersive over traditional media	What are the benefits of modern over traditional media in environmental communication?	<i>Interviewee_1: "And that's why I told you that, um, the digitalization is really important. Uh, we can, as you know, measure the impact of, promotion, the concern of, uh, the person, if, for example, they subscribed on the newsletter,-"</i>
	AR/VR/Immersive communication – examples of use	What are some successful examples of AR/VR instantiations?	<i>Interviewee_3:" well for me there we have on the one hand virtual reality which could also very well exploit the subject but on a more fictitious side, that is to say create stagings, create fictions perhaps same, or reproduce events that have already taken place"</i>

	AR vs VR	What are the advantages of AR over VR?	<i>Interviewee_6: "I think it should be wide (the audience). Well, with augmented reality, the good thing is you can work with children too. Because with VR, you can't because you have to be over 12 think. Just because of fitting and dizziness and that."</i>
	Challenges of AR/VR	What are the challenges of AR/VR communication?	<i>Interviewee_5: "I wouldn't say that it's a big age difference but for older people, you have to show them first of all that this is 3D. Often, I have to take the person's hand-" Interviewer: [chuckles] "And move them around?" Interviewee_5: "in space so that they get this concept of 3D because they're used to sitting in front of a computer where you just move the mouse with your hands and there is no physical movement. That's the first barrier. The second is that the older generation is less keen to explore."</i>
	Extension, Embedding it in marketable product	How should the artifact be extended into a useful and marketable product?	<i>Interviewee_1: "Yeah. Okay. It's a nice idea, but you have to, as I told you for the museum, maybe doing like a game. And, uh, you know, like a game for the recycling, uh, like your yellow, green, and gray. You put here what you are using, like your product and saying what kind of project you're using, and seeing the impact on the animals."</i>
	Technical details (Design, placement, UX, form, hardware)	How could the artifact be technically improved?	<i>Interviewee_4: "Yes, but for smartphones today we have standards. It's a good starting point to develop for standard phones, and maybe we'd create settings with better graphics to let the user decide. Let the application decide, dependentless on the device quality of the hardware." Interviewer: "Yes, yes. I see I see." Interviewee_3: "Yes. You can choose quality depending on the device. That is a possibility, and for me, honestly, the graphics are okay. The 3-D model are good. The animation are okay. I just think with the shadow it will be good for the infiltration with the decor."</i>

	Promotion, buzz, viral, social networks, nudge to try	How to promote and distribute the artifact among the target audience?	<p><i>Interviewer: "When you create a game, how do you advertise it? How would you advertise this kind of serious game?"</i></p> <p><i>Interviewee 4: "We are using, for sure-- I don't know how to say that, an influencer. I think, for this kind of project, there is also an organization, communication. I'm thinking about ..."</i></p> <p><i>Interviewee 3: "Maybe also magazine, like Science & Vie, Science et Avenir, Nature, Geo, all these kinds of magazine."</i></p> <p><i>Interviewee 4: "The specialized press."</i></p>
	Audiences	Who may be the target audience for such an artifact?	<p><i>Interviewer: "Who do you think is the appropriate audience for this kind of game?"</i></p> <p><i>Interviewee 3: "Every person. I think, by example, my daughter of 9 years could be interested by this kind of experience."</i></p> <p><i>Interviewer: "But younger audience, minus 20 years?"</i></p> <p><i>Interviewee 3: "No, the advantage AR is that it is compatible with all mobile device. There is a large target."</i></p>
	Intentions to use AR, familiarity, future of AR/VR, ease of use	Are AR/VR technologies likely to be used more in the near future?	<p><i>Interviewee_5: "Four years ago or three years ago before the Oculus Quest that was quite game-changing. It was the first stand-alone VR headset that was really a good product. Before that, you had the cable, you had the computer, you had base stations. It was VR. It wasn't so easy to have at home. You could not have so many headsets. Now you can have 30, 40, 50 Quest headsets."</i></p>
	Gamification, interactivity	Could gamification approach improve environmental behavioral interventions?	<p><i>Interviewee_6: "I don't see how you can make people come back to the app if you don't have any interaction. I think it's a really great point for a start, but I'm thinking, if the graphic are not going to be really realist, I know this is a prototype, it might have the opposite impact of you not believing what you're seeing, but this is not bad. You can go the other way. You can go the gamification way and make things that if you can't get the reality, you maybe can get something actually less real and spend resources on doing it interactive."</i></p>

Appendix 6

6.A) Screenshot of pre-questionnaire page: introduction of the experiment

LB11 PRE-QUESTIONNAIRE

Bonjour et bienvenue au LEEN (Laboratoire d'Economie Expérimentale de Nice) !

Vous allez participer à une expérience de prise de décision. La tâche à laquelle vous allez participer consiste à compléter 2 questionnaires et à lire un texte. L'expérience prend une trentaine de minutes.

Dans cette expérience, chaque participant a une chance égale de gagner 300 € lors d'une tombola. Vous avez reçu un code que vous devrez indiquer dans le questionnaire. Veuillez conserver ce code. Nous l'utilisons pour annoncer le gagnant de la tombola. Dans le cas où vous seriez le/la gagnant(e) de la tombola, vous avez la possibilité de faire un don à une organisation pro-environnementale de votre choix.

La tombola sera faite en ligne (conférence Zoom) à une date et un créneau qui vous seront annoncés par email. Elle sera enregistrée pour ceux/celles qui ne pourraient pas y participer. Le don à l'organisation pro-environnementale se fera après la tombola, et une preuve de paiement sera adressée à tous les participants.

Votre participation à cette enquête implique votre compréhension des informations suivantes.

Tâches et temps : L'expérience durera environ 30 minutes.

Confidentialité : la participation à cette étude est anonyme. Les données que nous recueillons seront utilisées dans nos articles de recherche académique (communications à conférences, publications scientifiques) dans le cadre d'un projet multidisciplinaire. Les données que nous recueillons ne seront pas vendues.

Rémunération et participation volontaire : vous serez rémunéré(e) pour votre participation à l'étude. Vous êtes libre de refuser de participer à cette étude ou d'y mettre fin à tout moment au cours de l'étude. Toutefois, seule la pleine participation (questionnaires complétés et participation à l'expérience en laboratoire) pourra être rémunérée.

Vous pourrez compléter ce questionnaire seulement une fois, et vous n'aurez pas la possibilité de stopper le questionnaire et le recommencer dans un deuxième temps.

[Suivant ▶](#)[Sortir et effacer vos réponses](#)

6.B) Pre-questionnaire from the study “augmented reality for environmental fundraising: two experimental studies”

Variable	Questions	Answer options
Environmental Engagement Score (EES)	I consider myself to be an eco-responsible person.	5-points scale (Strongly agree – Strongly disagree)
	I generally feel concerned about environmental issues.	5-points scale (Strongly agree – Strongly disagree)
	Whenever I can, I choose eco-responsible products.	5-points scale (Strongly agree – Strongly disagree)
	Whenever I can, I recycle the waste.	5-points scale (Strongly agree – Strongly disagree)
Past donation (donated before)	Have you ever donated money to an environmental organization?	5-points scale (Never – More than 10 times)
Organization (organization)	Which of these agencies would you be willing to donate money?	4Ocean, Colibris 06 Nice, Fondation Prince Albert II de Monaco, Greenpeace, National Geographics, Parley, Plastic Pollution Coalition, Surfrider, The Ocean Cleanup, The Sea Cleaners, World Wildlife Fund (WWF), Zero Waste France
Frequency of using smartphone (use_smartphone)	Please indicate how often do you use smartphone.	5-points scale (I never used it – I use it every day)
Frequency of playing video games (use_videogames)	Please indicate how often do you use videogames.	5-points scale (I never used it – I use it every day)
Frequency of using AR (use_AR)	Please indicate how often do you use augmented reality.	5-points scale (I never used it – I use it every day)
Frequency of using social networks (use_social_media)	Please indicate how often do you social networks.	5-points scale (I never used it – I use it every day)
Frequency of using AR filters (use_AR_filters)	Please indicate how often do you use augmented reality filters on social networks.	5-points scale (I never used it – I use it every day)
Age (age)	Age	Short answer
Gender (gender)	Gender	Male / Female
Study level (study_level)	Last diploma	Without study, Primary school / college, Secondary school with the bac, Bachelor, Master, Doctorate, Other
Study field (study_field)	Field of study	Short answer
Pet (has_pet)	Do you have a pet?	Yes / No
Vacation preferences (perfect_vacation)	For you, perfect vacation is...	In forest / mountain, At the sea, In the city, In the countryside, At home, Other
Glasses (wears_glasses)	Do you wear glasses ?	Yes, regularly, Yes, sometimes, No, never
Vegetarian (vegetarian)	Are you vegetarian	Yes (I don't eat meat or fish), Yes (but I eat fish), No

6.C) Text about plastic pollution and donation appeal

Chaque année, des millions de tonnes de plastique sont déversées dans les océans. Si aucune action n'est entreprise, l'impact des plastiques sur nos écosystèmes, notre santé et nos économies va être de plus en plus préoccupant. Nous devons prendre toute la dimension du problème en stoppant en amont la production de plastiques et en nettoyant nos océans des déchets plastiques non dégradables. Votre don nous aidera à agir pour une planète débarrassée de la pollution par les plastiques.

English translation: Every year, millions of tons of plastic are dumped into the oceans. If no action is taken, the impact of plastics on our ecosystems, our health and our economies will become increasingly serious. We need to address the full scope of the problem by stopping the production of plastics in the first place and cleaning our oceans of non-degradable plastic waste. Your donation will help us take action for a planet free of plastic pollution.

6.D) Main questionnaire from the study “augmented reality for environmental fundraising: two experimental studies”

Variable	Questions	Answer options
Geographic distance (PD geographical local and PD geographical distant)	My local area is likely to be affected by pollution	5-points scale (Strongly agree – Strongly disagree)
	Plastic pollution will mainly affect areas far from here.	5-points scale (Strongly agree – Strongly disagree)
Social distance (PD social devcountries and PD social lookalike people)	Plastic pollution will mainly affect developing countries	5-points scale (Strongly agree – Strongly disagree)
	Plastic pollution is likely to have a big impact on people like me.	5-points scale (Strongly agree – Strongly disagree)
Temporal distance (PD temporal)	When, if at all, do you think France will start to feel the effects of plastic pollution?	7-points scale (Never – We are already feeling the effects)
Uncertainty/scepticism (PD uncertainty cause)	Plastic pollution is a completely natural process and is not caused by human activities.	5-points scale (Strongly agree – Strongly disagree – I think there is no such thing)
	I'm uncertain that plastic pollution is really happening.	5-points scale (Strongly agree – Strongly disagree)

	The seriousness of plastic pollution is exaggerated.	5-points scale (Strongly agree – Strongly disagree)
	Most scientists agree that humans are causing plastic pollution	5-points scale (Strongly agree – Strongly disagree)
Concern about plastic pollution (concern_pp)	How concern are you by plastic pollution?	4-points scale (Very concerned – Not at all concerned)
	Considering any potential effects of plastic pollution which there might be on you personally, how concerned are you with plastic pollution?	4-points scale (Very concerned – Not at all concerned)
	Considering any potential effects of plastic pollution which there might be on society in general, how concerned are you with plastic pollution?	4-points scale (Very concerned – Not at all concerned)
	Considering any potential effects of plastic pollution which there might be on marine wildlife and animals, how concerned are you with plastic pollution?	4-points scale (Very concerned – Not at all concerned)
Preparedness to act (intention)	I am prepared to greatly reduce my plastic consumption to help solve the problem of plastic pollution	5-points scale (Strongly agree – Strongly disagree)
	I am prepared to greatly improve my recycling habits to help solve the problem of plastic pollution.	5-points scale (Strongly agree – Strongly disagree)
	I am prepared to support stricter environmental policies to help solve the problem of plastic pollution.	5-points scale (Strongly agree – Strongly disagree)
Donation	You have a chance to win 300 € in a lottery. If you are the winner, how much would you be willing to give to the pro-environmental organization of your choice (chosen during the pre-questionnaire)?	10 options from 0 € to 300 €
Presence (presence)	Only for AR Treatment I felt the presence of animals in the room.	5-points scale (Strongly agree – Strongly disagree)
Perceived AR effect (perceived AR effect)	Only for AR Treatment The augmented reality experience brought me closer to the problem of plastic pollution.	5-points scale (Strongly agree – Strongly disagree)
Had similar experience (had similar experience)	Only for AR Treatment Have you ever had a similar experience with augmented reality?	5-points scale (Strongly agree – Strongly disagree)

6.E) Screenshot of Donation Game page

Vous avez une chance de gagner 300 € lors d'une tombola. Dans le cas où vous êtes le/la gagnant(e), quelle somme seriez-vous disposé(e) à donner à l'organisation pro-environnementale de votre choix (choisie lors du pré-questionnaire)?

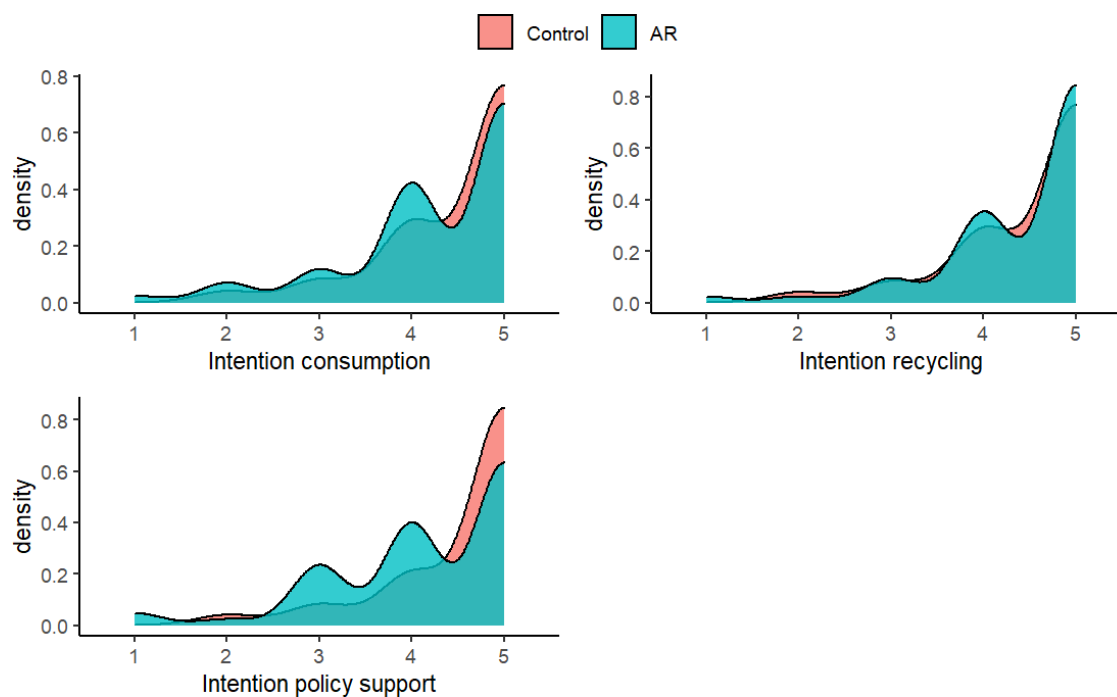
Veillez sélectionner une réponse ci-dessous

☐ 0 €
☐ 5 €
☐ 10 €
☐ 25 €
☐ 50 €
☐ 100 €
☐ 150 €
☐ 200 €
☐ 250 €
☐ 300 €

6.F) Socio-demographic characteristics of experimental sample

		Control (%)	AR (%)	AR - Field (%)	Total (%)
Gender	Male	7 (24%)	27 (47%)	36 (49%)	70 (44%)
	Female	22 (76%)	30 (53%)	37 (51%)	89 (56%)
	Total	29	57	73	159
Education	Bachelor degree	9 (31%)	29 (51%)	16 (22%)	54 (34%)
	Master degree	9 (31%)	15 (26%)	14 (19%)	38 (24%)
	Other	11 (38%)	13 (23%)	43 (59%)	67 (42%)
	Total	29	57	73	159
Average age		23.31	23.81	26.01	23.64
Average EES		3.43	3.44	3.67	3.44
Average Use of AR		1.76	1.77	1.69	1.77

6.G) Distribution of items composing Preparedness to act



6.H) Distribution of items composing Concern for plastic pollution

