Virtual Reality Behavior Change Interventions for Environmental Sustainability

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Climate change is a pressing issue where dominant research modes have not provided sufficient solutions for endeavors such as affecting sustainable behavior. Contemporary technological advances may provide new solutions when studied through multidisciplinary analysis. The use of virtual reality for this purpose has great potential, explored in this thesis as a medium for changing the behavior related to environmental sustainability of individuals and groups.

In this thesis, an exploratory framework is created. This is done through an exploration and combination of three areas of research: sustainability communication, behavior change interventions, and virtual reality experiences. Guidelines are gathered from each area, which are analyzed for two and three-way synergies to find actionable items to form a framework usable for any experience combining the three areas of research.

A step is taken in verifying the exploratory framework by reflecting on it through a pilot study. An intervention doubling as an infotainment virtual reality experience on fuel use in cruise ships is created using the framework. The practical functionality of the framework is reflected by its applicability in creating such an intervention, and by the degree of success attained by the intervention. Indicative results tell of the success of the intervention and the validity of the theory used to form it. The framework is found to be practically functional, and possible directions to iterate it further through more practical and literary studies are identified.

The framework and its contributing research contribute to the scientific rigor with which the three areas of research can be studied, and in providing much needed actionable ways to further environmental sustainability.

Keywords: VR, Virtual Reality, XR, Extended Reality, Behavior Change, Behavior Change Intervention, Sustainability, Sustainability Communication, Environmental Sustainability, Maritime Industry, Cruise Ship

Contents

List of Figures

List of Tables

1 Introduction

As climate change advances, the need for climate action becomes increasingly important. Both the communication of a complicated subject like environmental sustainability and affecting the behavior of others reliably and verifiably are notoriously difficult tasks.

Simultaneously, regulations and goals put in place by the United Nations, specific countries, and organizations such as the International Maritime Organization put pressure on corporations to gather sustainability data and to encourage their customers to choose their more sustainable options. This is exemplified by the Sustainability Through Information Flows project [1] that the experimental part of this thesis was created for.

A potential solution for aiding in the understanding of complicated subject matter, concretizing data, and delivering verifiable interventions for affecting behavior can be found in virtual reality (VR). VR experiences have unique features and advantages over other forms of media, such as the feeling of existing in a different place, intuitive control schemes tracking real world movements, and a high degree of control over what the user perceives. As the technology enabling such experiences has seen rapid advancements, the advantages and best practices of using VR may not be clear for those designing projects utilizing VR. A multitude of such explorations exist already [2] [3], but specific application areas remain less explored, such as utilizing VR to advance environmental sustainability. A change in the dominant research modes is needed, if we are to reach the agenda set by the United Nations [4, p. 587], making it a valuable application area of VR to research.

This application area of environmental sustainability can be explored through many scientific areas of research, but perhaps among the most direct approaches are the areas of sustainability communication and behavior change interventions. As a form of media,

VR related to sustainability would certainly be a form of sustainability communication, and the most desired goal of most sustainability communication is a change in behavior [4, pp. 581, 590, 71–84, 301–316, 397–415, 463–483]. These three areas of research seemingly have potential overlap, which would make utilizing all three in the design of an experience worthwhile.

The research questions of this thesis are as follows:

- RQ1: In the context of virtual reality behavior change interventions for environmental sustainability, what are the best practices of sustainability communication, behavior change interventions, and virtual reality experiences?
- RQ2: Can overlaps and synergies be found from these best practices to create a framework for creating aforementioned interventions?
- RQ3: What features of the framework can be validated by creating and reflecting on a practical, aforementioned kind of intervention?

In this thesis, an exploratory framework for creating virtual reality behavior change interventions for environmental sustainability is created. Chapter 2 provides justification for the goal of changing the sustainability behavior of individuals and groups, as well as introducing sustainability terminology and exploring its concepts. Chapter 3 further expands on the topic by exploring sustainability communication. It is the first of three chapters exploring the best practices and advantages of the three chosen areas of research, and concludes with a list of *guidelines* derived from the literature. Chapter 4 explores the concepts and literature of the second area of research, *behavior change interventions* and psychological concepts relevant to sustainability. This chapter provides a list of guidelines as well. Chapter 5 explores the third and final area of research, *virtual reality experiences*. Along with providing a list of guidelines from the best practices and advantages of VR, the wider topic of *extended reality* is explored. These chapters, along with the further exploration of the applicability of these guidelines in Chapter 9, are used to answer RQ1.

Having formed the three sets of guidelines, it is possible to explore RQ2. The search for synergies between the three areas of research is used to form *design questions*, tools

for exploring the design space in the form of questions the creators of sustainability VR interventions can ask themselves. The design questions are sought from two areas at a time: first from VR experiences and environmental sustainability, and then VR experiences and behavior change interventions. This forms two sets of design questions, albeit without exploration of three-way overlaps between all areas of research. The guidelines and design questions formed this way form the framework, which can be found in Appendix A and summarized in Chapter 6. To support this framework, three-way synergies are also explored by comparing each design question with the guidelines from the third, missing area of research. This work can be found in Appendix B, listing the ways in which following a design question fulfills the guidelines or vice versa. These additional synergies further clarify each design question and provide ways to put guidelines into practice. They are summarized in Chapter 6 as well. This multi-stage creation process of the framework may be difficult to comprehend from this short explanation. The process will be made more clear in Chapter 6 and the appendices.

To answer RQ3, the created exploratory framework is analyzed through an intervention study. This intervention, an infotainment VR experience of fuel use in cruise ships, is introduced in Chapter 7. The chapter includes a brief exploration of green purchase behavior, the target of the intervention. Chapter 8 summarizes the results of the study, showcasing success in the metrics utilized. Indicative results point to changes in green purchase behavior on the n = 70 recipients. Limitations of the study are showcased as well, namely the non-involvement of the exact target group and limited possibilities of confirming actual behavior change. Chapter 9 reflects on how well the framework can be applied to the design and creation of an intervention. This is done by reflecting on how each guideline and its relevant research questions could be applied to the intervention study. This reflection shows how parts of the framework were applied successfully, and confirms assumptions such as the unfeasibility of following every design possibility of the framework in a single intervention. It also revealed how some desirable features for an intervention related to practical arrangements could be less feasible in practice than assumed. Finally, Chapter 10 summarizes findings and answers the research questions.

The creation and partial validation of this exploratory framework in this thesis assist the creators of virtual reality experiences, behavior change interventions, and environmental sustainability communication projects to apply a more robust application of scientific theory, especially at the intersection of all three areas of research. In practice, such a theory based approach allows for the creation and validation of hypotheses to contribute to each area of research, the iterative refinement of the framework, and both verifying and iterating on the creation itself. Additionally, the framework offers a way to explore the design space of the relevant research areas to find innovative design opportunities where innovation may be sorely lacking.

2 Environmental Sustainability

This chapter will cover the basics of climate change, key concepts about sustainability and environmental sustainability, and forces enabling and hindering humanity achieving sustainability.

The concept of sustainability is derived from the concept of sustainable development, first introduced in 1987 in the book *Our Common Future: Report of the World Commission on Environment and Development*. This book created by the United Nations, also known as the *Brundtland Report*, explores different aspects and requirements for sustainable development, which it defines as achieving economic development while meeting the needs of the current generation without compromising the ability of future ones to meet theirs [5, p. 58]. The book emphasizes the interlocked nature of meeting these needs in the ecological, economic, and social areas. While meeting the needs of both current and future generations is a very succinct definition, in practice, the term is used with various meanings and points of focus. While the areas of sustainability from the book are indeed interlocked to a considerable degree, this thesis will focus on the ecological area, also known as *environmental sustainability*.

2.1 Climate Change and Human Action

The existence of climate change and the role of humanity in it are well established, but, for a solid foundation for the rest of this thesis, their basics will be covered. The amount of greenhouse gases in the atmosphere fluctuates over long periods of time, but it has seen an unprecedented increase for the modern era since the start of the pre-industrial era [6, p. 4]. The same applies for the rate of global warming, and the two

are intrinsically linked. Climatic impact-drivers mean physical climate system conditions that affect a society or ecosystem. These are adverse effects which will grow increasingly more common as climate change advances. They include conditions such as raised mean ocean temperature, coastal floods, and cold spells. [6, p. 26] Some changes caused by global warming are irreversible already, at least in the span of centuries or millennia [6, p. 21]. Two of the most certain changes to come are the further rising of global mean sea levels and increased ocean acidification [7, p. 13]. In practice, adverse effects from these changes include a huge increase in the overall amount of extreme sea level events and unsuitable living conditions for some forms of ocean life.

To limit global warming caused by humans to a specific level, at least net zero CO_2 emissions must be achieved, as well as strong reductions in other greenhouse gases [7, p. 19] [6, p. 27]. On the journey of humanity toward sustainability, emissions exceeding net zero will inevitably cause some amount of global warming. The United Nations' current targets for limiting global warming are 1.5°C (with over 50% certainty) or 2°C (with over 67% certainty). These certainties come from calculated levels of certainty within specific climate change models. Reaching one of these goals requires drastic and fast action globally [7, p. 19].

Human actions affect how climate change advances. There is no consensus on how to calculate this rate of advancement. There are different ways to mathematically model climate change and there are many uncertainties regarding the values used within these models as well, resulting in greatly varying results. One commonly used model is Equilibrium Climate Sensitivity (ECS). ECS measures how much doubling the amount of CO_2 in the atmosphere compared to pre-industrial levels would increase the surface temperature of the earth after the climate of the globe reaches an equilibrium. Equilibrium is used here to account for how changes in climate are gradual and the actual increases in temperature might only be realized a hundred years after reaching a certain CO_2 level.

All in all, the calculations are complicated and always involve a degree of uncertainty, and many of the effects are far removed from the people of today.

2.2 Sustainability Terminology

Sustainability and sustainable development, being widely used and seldom clearly defined terms, will be discussed in detail in this section. The Brundtland Report, discussed earlier, has a global and national level scope. It is based on sustainable development rather than sustainability, development referring to economic growth. The book considers this growth to be instrumental for solving key sustainability issues, the two most emphasized by the book being the eradication of poverty and solving long-term environmental issues.

The United Nations has kept the term of sustainable development with its nuances as a goal to strive towards, rather than using the term sustainability [8]. This goal is divided into the widely influential 17 *sustainable development goals* (SDGs) of the United Nations. The goals continue to hold economic growth integral, and consist of a noticeably wide range of goals including the eradication of poverty, taking climate action, ending world hunger, gender equality, and affordable and clean energy. However, the SDGs can be used, and indeed have been used, to argue in favor of clearly unsustainable practices, such as shale gas development, better known as fracking [4, pp. 361–373]. While a comprehensive analysis of the effects of such arguments would be required to make conclusions about the unsuitability of the SDGs for communicating about sustainability and analyzing the sustainability of specific actions, this is indicative of the danger of valuing the ecological and economic areas of sustainable development similarly. The SDGs have been criticized by some environmental *non-governmental organizations* (NGOs) as being naively optimistic in their wide scope, instead suggesting to prioritize environmental sustainability. It should be noted these NGOs considered the SDGs to be an important step forward in the sustainability debate regardless. [4, p. 469]

Sustainability is not a term explicitly linked with economic growth, being otherwise very similar to sustainable development. The yearly report by The Intergovernmental Panel on Climate Change, the AR6 Synthesis Report: Climate Change 2023 defines sustainability as

> A dynamic process that guarantees the persistence of natural and human systems in an equitable manner.

The term "dynamic process" is key here, as sustainability is not seen as a goal that can be wholly defined in advance, reached, and then persisted in without effort. Constant re-evaluations of goals and methods to reach those goals are expected. This also holds true for sustainable development. The three areas of sustainable development (ecological, economic, and social) are commonly kept as interlocked concepts for sustainability as well. The three areas of sustainable development are also commonly referred to as the three pillars of sustainability, exemplified in the *three pillars of sustainability-model*. Referring to them as pillars implies the necessity of focusing on all three at once or sustainability would, proverbially, collapse. [4, p. 325]

Fighting climate change is only a subset of the ecological area of sustainability. This is by design, as the equitable persistence of human and natural systems can be threatened by any number of things. These include the depletion of essential resources, such as topsoil, groundwater, tropical forests, fisheries, and biodiversity, along with the degradation of land and atmospheric quality [9].

As a term, sustainability has been criticized for ambiguity, complexity, and being used for too wide a range of meanings, even identified as one of the most abused terms in corporate speech, referring to everything that can be considered positive [4, p. 530] [10]. At least within the scope of United States news coverage, the term sustainability seems to be increasingly used as a shorthand for ongoing business success [4, p. 200]. It is not uncommon to see sustainability used to only refer to the ecological area of sustainability [4, p. 326, 576]. This thesis makes this choice explicitly with the choice of focusing on environmental sustainability (ES).

Environmental sustainability is roughly equal to the ecological area of sustainability, though more explicit definitions exist. It could be argued that the areas of sustainability are not equal. Environmental sustainability is already present in nature, absent of human society or economy, and can thus exist without the other pillars. Conversely, neither a social system nor an economic one could continue to persist outside a system where resources enable it. [10] Environmental Sustainability can be defined through three rules or principles, simplified here [9]:

- Output Rule, or keeping the waste output from a project or action within the capacity of the local environment.
- Input Rule, or keeping the use of renewable resources within their regenerative capability and not using up nonrenewables faster than their substitutes are developed.
- Operational Principles, where the human economic subsystem is kept within the global carrying capacity, technological progress should be efficiency- rather than throughput-increasing, and renewable resources should be exploited on a sustained-yield, sustainable, yet profit-optimizing basis.

With ES as a focus, previously mentioned issues with the terms of sustainability and sustainable development should be somewhat mitigated. For a more in-depth definition of ES and a longer list of guiding principles, see article *Environmental Sustainability: A Definition for Environmental Professionals* [10].

It should be noted that fundamental disagreements on how sustainability can be reached indicate uncertainty about the helpfulness of even behaviors that seem obviously more sustainable at a surface level. Denying the concept of sustainable development on the grounds of thinking infinite economic growth is unsustainable itself would make any behavior assisting in it unhelpful or even hindering of true sustainability. This thinking manifests itself through a distinction one can make between two different routes to sustainability: a transformation of the current system or a transition into a new one [4, pp. 82–84]. Some sources claim the transformation approach to be ineffective or harmful [9] [4, p. 580]. Despite these claims, the concept of the economic area of sustainability should not be disregarded even within environmental sustainability. In practice, going against the current economic systems might hinder sustainability efforts to the point of unfeasibility.

As each piece of research used throughout this thesis uses either a specific, often not clearly specified, definition for sustainability, environmental sustainability, sustainable development, or other related term, the scientific validity of making conclusions combining their findings can be called into question. The overlap between the meanings of the

different related terms should allow for an acceptable degree of scientific validity. The term environmental sustainability will be used sparingly in this thesis, as much of the literature is focused on sustainability and sustainable development instead.

2.3 Enabling and Hindering Forces of Sustainability

As the goal of sustainability behavior change interventions is working towards sustainability, it is important to understand what drives governments, organizations, and people to further it. It makes sense for businesses to generally only take actions for sustainable development that economically benefit them. This can create conflicts of interest, with many questioning how valid the claims of sustainability from businesses truly are [11]. There is evidence, however, that a focus on sustainability can contribute to superior business performance [12] [13]. A survey among United States companies revealed the most important reasons the companies engaged in business practices related to sustainability. The most prevalent reason being *enhanced reputation* reported by 90% of the surveyed companies and the next reasons, in descending order, being *competitive advantage*, *cost saving*, *following industry trends*, *CEO/board commitment*, *customer demands*, and *demands from socially responsible investors* [14]. These reasons should not be assumed to be reliably applicable across cultures and economies, but they offer a potential overall order of importance of drivers for businesses to focus on sustainability. An alternative, more abstract list of reasons for this focus consists of global competition, governmental regulations, and resource constraints [12]. While demands from socially responsible investors had only the sixth highest prevalence in the study introduced earlier on reasons why companies perform sustainability related business practices, both the economical performance and non-financial sustainability performance of a firm are negatively associated with how risky of an investment the firm seems to investors. Higher levels of non-financial sustainability performance can even cause the link between lower seeming risk and economical performance to be stronger. Short-sellers also avoid firms with higher *corporate social responsibility* (CSR) scores, *environmental, social and governance* (ESG)

scores, or levels of overall sustainability. [13] These pieces of evidence suggest that the multi-trillion industry of sustainable investment is based on the reduced assumed amount of risk associated with sustainable companies.

Legislation on the level of governments, and intergovernmental organizations such as the United Nations and the European Union are a potential impetus for sustainability behavior change. Governmental sustainability regulations stem from complicated political processes, which are certainly at least somewhat influenced by the SDGs. Bottom-up social change, or the acts of individuals affecting the larger system as a whole, is something behavior change interventions might commonly aim to accomplish. It is not recommended, however, for these to replace top-down legislative changes. The two processes for change are more effective as complementary. [15] The Brundtland Report states a need for an involved, well-informed public as greatly helpful for large scale projects that require multiple points of view. Citizen participation is recommended for political systems as well. [5, pp. 57–58]

In practice, when efficiency measures have been put in place, a rebound effect has been observed. Achieving greater efficiency, ecologically or otherwise, enables a smaller amount of resources to be used for the same results. Conversely, it also allows for the same amount of resources as before to be used for greater results, resulting in no change to consumption. This is called the *rebound effect* and it has been estimated to undo from 10% to 60% of the reduction of consumption of efficiency measures. [4, p. 266] This effect must be taken into account when designing and measuring the success of sustainability efforts through increased efficiency.

One approach toward sustainability is to focus on enhancing the ability of society to appropriately respond to sustainability issues instead of pushing for specific behaviors. This more hands-off approach might be preferred if one subscribes to the thought that every communicative act is considered somewhat political, and wants to avoid overt direct political influencing. [16, pp. 64–65]. The line between manipulation and communication for behavior change might be one of nuance or affected by personal agenda. It could be argued that the more effective communications become, the more it starts to resemble

unethical manipulation. For example, the use of stories where some fact is taken as a part of the story setting is effective in making people accept that fact, due to the way it suppresses the tendency of the reader to argue against it, by not presenting it as a claim at all [4, p. 124]. Such ethical deliberations must not be shied away from when creating a behavior change intervention and will be analyzed throughout this this thesis where appropriate, but it will not be a central theme.

This chapter revealed a lack of consensus on the specifics of sustainability: as a term, how certain aspects of it can be represented numerically, and whether specific approaches are fundamentally compatible. These are some of the reasons sustainability communication requires good planning, and further study, which are topics covered by the next chapter. This chapter also gave a sense of the large and growing body of study on the topic of sustainability. This can enable a more scientifically rigorous pursuit of this vitally important topic.

3 Sustainability Communication

This is the first of three chapters introducing an area of research used to form a framework in Chapter 6. The lens of *sustainability communication* (SC) will be introduced by first looking into literature about SC itself, then introducing corporate SC, the context in which the practical portion of this thesis takes place. What follows is an introduction to science communication, which the communication of sustainability is heavily linked with. The chapter concludes with a list of guidelines for SC, which draws on all the communication concepts analyzed in this chapter.

SC is a relatively new principle that can be seen from multiple perspectives: as a communication principle originating from environmental communication but with the broader scope of sustainability, as one of the instruments facilitating sustainable development, and a theoretical frame drawing from interdisciplinary sources such as communication theory and psychology. It has been argued too little consensus exists on it for it to be used as a genuine framework. [17, p. 140] However, the slowly building body of research on it should allow for it to be used as a more and more rigorous scientific concept.

3.1 Overview of Sustainability Communication

The main source for contemporary recommendations on SC used in this thesis is the book *The Sustainability Communication Reader: A Reflective Compendium* [4]. The book concludes with the disclaimer that it is currently unclear whether SC should be considered a unique area of research with its own methodological approaches, or even if it will continue its existence as a relevant part of communication studies. Yet, they make the claim it is valuable to continue studying it, as a change in the dominant research

modes is needed, if we are to reach the 2030 agenda of the UN. [4, p. 587]

Sustainability communication research seems to be mostly focused on communicating environmental sustainability through applied communication research. SC literature often divides the communication into three different types depending on its goals: communication *about*, *of*, and *for* sustainability [4, p. 269] [17, p. 142]. In other words, these are the exploration of the concept of sustainability, learning about sustainability, and transformation toward sustainability, respectively [17, p. 140]. These divisions can greatly influence the form SC takes, warranting an analysis of each of them outside the more general list of guidelines in Section 3.4.

Communication about sustainability explores the concept of sustainability, as well as the exchange of interpretations, options, and opinions about specific issues. Achieving these goals might be assessed through changes in the amount relevant topics are discussed on mass media, improvements on who can access to the communications, or the amount and ease of knowledge transfer across different spheres, such as a pipeline from scientific spheres to political ones. [17, p. 143] Communication of sustainability is primarily one-way communications, with the goal of raising knowledge about sustainability, and its specific topics and issues [17, pp. 143–144]. It typically involves information flowing in a hierarchical, top-down manner instead of peer-to-peer. It includes formal reporting, such as mandated corporate sustainability reports. Achieving such goals could be measured by assessing whether the knowledge transfer has been successful, by an increased personal level of knowledge on an individual level and through assessing information flows within companies or entire industries. Communication for sustainability is roughly equal to communication with sustainability behavior change as a goal, though it does include upholding sustainable behavior as well. The literature on sustainability communication seems to converge around the fact that these interventions are the most desired goal for all sustainability communication [4, pp. 581, 590, 71–84, 301–316, 397–415, 463–483] The same holds true for campaigns for achieving the sustainable development goals [4, p. 25]. This lends credence to the assumption of this thesis that sustainability communication and behavior change interventions have valuable overlap.

The *information deficit paradigm* has been prevalent in SC for a while, but is slowly being phased out. It includes the assumption that the main issue in sustainability was the lack of information on the public and focused mostly on the communication *of* sustainability: a top-down, one-way process. Reasons for contemporary preference of communication about and for sustainability instead include the knowledge-behavior gap in sustainability, the sometimes adverse effects of inciting fear, and the naive assumption of the model that people always reach a decision through conscious analysis.[16, p. 82] This erroneous paradigm is prevalent for policies related to pro-environmental behavior as well [18].

3.2 Corporate Sustainability Communication and Marketing

While this thesis acts as a general guide on sustainability behavior change interventions through VR, different contexts will require different approaches. The virtual reality behavior change intervention pilot, explored more closely in chapters seven through nine, involves *corporate sustainability communication* (CSC) in a *business-to-customer* (B2C) context. Best practices from corporate sustainability communication are covered here rather than included in the list of overall sustainability communication guidelines at the end of this chapter, as this corporate context is more narrow. The CSC context can be specified further by focusing on the target of the communication. For example, it is recommended to focus on internal publics prior to external ones to build up infrastructure on sustainable business behavior [14] [19]. Practically this means raising company employee awareness about sustainability, which helps shape internal policy to support external communication, be it through eventual official external communication or through the external everyday communications of the employees themselves. Company public relations can also be used as a way to legitimize the place of the company in society [14]. Customers have the power to affect the sustainability actions of a business by their purchasing behavior. Business customer purchasing behavior is even more effective in

pressuring businesses to be sustainable than end users. [12] It can be argued that information asymmetry between shareholders and management results in moral hazards. This means incentives for management often focusing on short-term earnings causing long-term performance of the company for shareholders to be a secondary concern. [13] Sustainability, as a risk reducing mechanism, is considered a factor in the long-term performance of the company for shareholders. Therefore, reducing information asymmetry between shareholders and management through increased monitoring using sustainability reporting is a viable sustainability goal for a company.

Another way to structure CSC is to divide it into four categories [20]:

- Raising consumer awareness or causing behavior change
- Sustainability reporting
- Sustainability and green advertising
- Greenwashing

Raising consumer awareness is considered a method of behavior change and will be discussed outside this section on CSC, but the other categories will be analyzed here as concrete ways CSC can manifest.

Sustainability reporting refers to formal channels through which companies can perform internal and external communication, often through numerical data. This is categorized as communication *of* sustainability. Sustainability reporting is a requirement for truly sustainable business practices [4, p. 571] Formal reporting could well act as a supporting structure for scientifically accurate sustainability communication, but might be an unoptimal channel for sustainability interventions if it is constrained by its information types and presentation methods. It is recommended that sustainability reporting focuses on materiality, or in being relevant to stakeholders [21, p. 48].

Sustainability/green advertising has existed longer as a concept than sustainability communication itself [20] and, through the very nature of advertising, it can be considered as an attempt at behavior change in itself. This makes it a very suitable context for a behavior change intervention. Applying marketing communication has had a wide range

of success in solving social issues through public behavior change and public awareness [4, p. 283]. Service dominant logic of marketing is one framework that could be utilized in behavior change interventions as well. It rejects the notion seen in older marketing theory where communication has meaning without a recipient, and instead places emphasis that this meaning is created in a dynamic process between marketers and customers. [4, p. 288] For example, a company making a claim of having sustainable practices could spend all its efforts on the creation of a perfectly convincing message in a vacuum, only to be completely denied by a climate-conscious consumer who has identified the very industry of the company as unsustainable. When it comes to branding, a common piece of advice from SC consultants is to use integrated communication strategies to associate brands with sustainability. [4, p. 3] Promotion efforts for green products should not solely focus on the greenness of the product, but should rather focus on how the ecological aspects complement functionality to add value for the product [12]. The public can perceive sustainability marketing as an inauthentic ploy to sell products, or greenwashing for profit [22].

Greenwashing is a term with a negative connotation, referring to attempts at unethically making something seem more sustainable than it is. This should not be considered a context in which an ethically sound behavior change intervention can be performed, but rather as a potential catastrophic categorization of the intervention by its recipients. As will become clear in this chapter, much of the sustainability communication centers around trust between the provider and recipient of the information, holding greenwashing in direct contrast.

3.3 Communication of Scientific Data

Science communication is something sustainability communication draws from [17, p. 141], making them appropriate to be discussed together. This section will briefly introduce science communication and its challenges, but the specific guidelines can be found combined with the sustainability communication guidelines in the last section of this chapter.

The validity of scientific results are called into question for a variety of reasons. This includes political reasons and suspecting misinformation, which may spread in an unprecedented manner through social media [4, p. 589]. However, as it is inadvisable to blame the receiver of SC for their lack of following its advice, it is more fruitful to understand the causes of this distrust in science more comprehensively and focus on building up that trust through increased capability of understanding. A pillars of trust model by the All European Academies organization (ALLEA) holds four things as necessary for this trust: integrity, transparency, autonomy, and accountability. The scientific way of knowing could be characterized by four values: Capability of being critiqued and self-correcting, acknowledging the limitations in data and methods, faithfully accounting for evidence, and precise, clarifying specification of key terms [23]. There is an overall demand for better scientific transparency [4, p. 528].

Empowering and informing an audience for long term attitude and behavior change is the core challenge in science communication for sustainability [4, p. 282].

3.4 List of Guidelines for Sustainability Communication

The existing body of research about sustainability communication covers a range of situations and goals far beyond the scope of this thesis. Therefore, features found to be important by the selected literature on sustainability communication are evaluated not only based on how important a source considers them, but also the relevancy of the source for this thesis. Some features were discarded for not being suitable to apply to a virtual reality behavior change intervention. For example, features related to methods of delivery that exclude virtual reality, and features only related to overall project management were not considered suitable. The chosen communication features were prioritized for having high prevalence among the selected literature, and for having clear overlap with other feature categories inside this thesis. A known limitation for this thesis is the lack of a systematic literature review for any of the feature categories, leading to the range of

found communication features and their relative ranking being more approximate than scientifically comprehensive. This thesis is made with the assumption that the amount and quality of sources lead to approximations where the most important features found are most likely the same as what a more comprehensive scientific literature review would reveal.

What follows is a collection of methods, paradigms, and advice from SC research. They are referred to as *guidelines* to capture how they should be used: not as ironclad rules, but as helpful, research-backed best practices and alternatives that can be selectively used based on the circumstances of applicable interventions. Each guideline has a tag (e.g., "SC1") to make referring to them easier. The numbering does not reflect on their importance.

Table 3.1: List of sustainability communication guidelines

Tag	**Guideline**
SC1	Use Innovative Alternatives to Mainstream Communication Methods
SC2	Understand the Recipients and Tailor the Content to Them
SC3	Uphold Accuracy and Truthfulness
SC4	Utilize Scientific Theory
SC5	Prioritize Hope Over Fear
SC6	Use Two-way Communication
SC7	Help Recipients Reason by Themselves
SC8	Utilize Storytelling

3.4.1 Use Innovative Alternatives to Mainstream Communication Methods (SC1)

Using a novel way to communicate a message helps in getting a message heard in an information-overloaded world [24, p. 12] [25]. What has been done so far in pursuit of sustainability has clearly not worked well enough, so a change in goals or methodology seems appropriate [25]. Using pictures over words is cited as a common piece of advice from SC consultants, meaning the use of more engaging communication methods than text delivered in some form [4, p. 3]. Communication through text can not, and most likely should not, be avoided in all cases. The same holds true for utilizing mainstream communication methods. Using such methods should also follow best practices, such as avoiding overuse of the term "sustainability" itself [25].

A course suggested by some research is *turning to experience*, or using material resonating with the experiential registers of the recipient. This register consists of perceptive, embodied, and emotional aspects. [16, p. 4] Knowing and witnessing are said to have an emotional gap, the filling of which has been found to raise both the level of concern of the user and their motivations to act. A possible paradigm for sustainability-improving interactive media is focusing on immersion, the sense of presence in situations that may help form emotional bonds with an issue. [4, p. 78]

3.4.2 Understand the Recipients and Tailor the Content to Them (SC2)

Sustainability communication should be three things: precise, direct, and simple [4, p. 528]. Understanding the target groups and goals of the SC can be of immense help for directness and simplicity. "Targeting works", is one of the three major facts of the public sustainability campaign guide by the UN. A piece of practical advice given regarding this fact is that it is often more effective to focus on a single issue relevant to the target group than to communicate the whole concept of sustainable development [24, p. 14]. It is considered vital to identify the target audience at the start of planning a strategic

communication process [4, p. 287]. It is recommended to use language relatable to the audience, such as using the correct units of measurement [25]. It is important for SC to pertain to messages personal to the recipients and for the behavior targets to be practical for them as well. Behavior targets where infrastructure does not allow recipients to efficiently perform them can be pointless. [20, p. 11, 15, 25]

Precision, directness and simplicity can all three help prevent green fatigue. This is the concept of the overexposure to environmental sustainability communications causing a loss of interest and focus on the message, instead becoming so called green noise. This raises uncertainty and other negative emotions, which can easily lead to inactivity and helplessness [22].

At least in journalism, there is an issue of journalists raising themselves morally above the people with unsustainable behaviors using juxtaposition. People want to know what they can do instead. However, people typically only want to do actions that do not compromise their standards of living and preferably do not cause considerable changes [16, p. 66]. [4, p. 528]

Persistent problems exist in SC: what is being communicated is something invisible, abstract, complex, non-immediate, with uncomfortable and controversial social implications. These factors cause SC to differently affect people with different values, knowledge, and goals. [4, p. 586] For recipients to take action, there are things more effective than simply transferring knowledge: taking into account the everyday concerns of people and decision-makers, increasing perceptions of response efficacy, and encouraging social norms and identities that promote taking these actions. [4, p. 588]

3.4.3 Uphold Accuracy and Truthfulness (SC3)

As mentioned in Subsection 3.4.2 (SC2), preciseness is something all SC should aim for. The main function of this guideline is to reduce doubtfulness in recipients: about the legitimacy of climate change, actions of a company or similar entity for sustainability, or even science as a whole. Entities communicating about their sustainability without supporting policy is a common mistake [24, p. 11]. Incongruence between words and

actions can lead to the erosion of the trust that is vital to all effective communication. This effect is not limited to corporate communications and greenwashing, as the *Intergovernmental Panel on Climate Change* upholding of a dubiously scientifically backed claim about melting glaciers contributed to public confidence declining in climate scientists [17, p. 144]. Simple ways to combat this lack of trust are transparency and basing SC on facts and data [25].

A lesson from science communication is the surprisingly beneficial act of admitting uncertainty. While intuition might guide one to believe people prefer communication that at the very least pretends to have an unshakeable certainty, research seems to indicate a more complex relationship, where a correctly communicated scientific uncertainty has neutral to positive effects on the trust of the public [26] [27] [28] [29] [30] [31] [4, p. 25]. Negative effects on the trust of the public seem to be fostered by indicating uncertainty by providing conflicting evidence, or by otherwise communicating a lack of consensus among scientists. Other contributing factors can be distrust in science and scientists, the lack of understanding of the inherent uncertainty of science, and confirmation bias and motivated reasoning. [26] How strongly people react seems to be inverse to the indicated level of uncertainty: an indicated high uncertainty, or a lack of indicated certainty, evokes a weaker response than an indicated low certainty [27]. One of the guiding principles for sustainability campaigns is focusing less on the transmission of sustainability knowledge, and more on disclosing positions and contradictory interpretations [4, p. 25].

The reduction of the complexity of sustainability is a "wicked problem" in SC, at the interface between SC and scientific communication. The reduction of the complexity of scientific facts can be considered the responsibility of those responsible for SC in general: organizations, corporations, and political institutions. [4, p. 180]

3.4.4 Utilize Scientific Theory (SC4)

Measuring the effectiveness of SC is impossible without valid and reliable metrics. These metrics might be very desirable for entities responsible for the intervention to prove the measure of success. Without measuring the effectiveness of interventions, building up

scientific knowledge on scientific communication and interventions becomes challenging. It is for these reasons alone that the utilization of scientific theory already has merit, but theories should also act as a way to help in the creation of more effective interventions in the first place. Measurements can be expensive, especially regarding behavior change, since attitudes and self-reports do not reliably correspond with behaviors. Despite this, measuring relevant metrics remains recommended by sustainability communication guides [24, pp. 18–19]. Adjacent to the utilization of a scientific theory is the utilization of the scientific process itself that it enables: an intervention should be created by testing assumptions through public engagement and iterating based on it [4, p. 24]. Furthermore, of the 101 articles of a literature review on sustainability communication research, 76 of them had a theoretical approach. [20] While the popularity of an approach does not necessarily indicate it is the correct one, applying theories on communication and decision making to sustainability communication at least has a significant scientific precedent.

3.4.5 Prioritize Hope Over Fear (SC5)

A vital element of effective communication (reaches the audience, achieves its objective) is for the recipients to believe they are empowered to make a change, and this change is seen as desired and valued. Sustainability communication using fear should be used with caution. [4, p. 285] Instead, it is suggested to utilize hope. Inducing fear has been overused and found to cause rejection and desensitization of the message and distancing from the issue. Inducing fear is conducive to the promotion of wider range of thoughts, action and increased motivation for behavior change. [4, p. 286]

There is research indicating that fear can be ineffective for SC due to the large amount of previous communication attempts about a threat that never materialized for them. As the threat of climate change is vague, human beings have trouble responding to it appropriately. Fear can also produce apathy, especially if the infrastructure for sustainable behavior in response to it is lacking. [20, p. 13] This advice is repeated in many guides on account of the importance of denying the fearmongering that has been a prevalent, intuitive approach to SC [25]. Being less problem oriented and moralizing, and instead

focusing on being more encouraging of proactive and future oriented action should be a guiding principle for all sustainability campaigns [4, p. 25]. The body of sustainability stories of popular culture focuses on cautionary tales and is distinctly lacking in depictions of sustainable futures and the process of reaching them [4, p. 156]. Such psychological barriers for sustainability behavior will be further analyzed in Chapter 4.

3.4.6 Use Two-way Communication (SC6)

One-way communication seems like the prevailing method of SC [20]. The Sustainability Communication Reader emphasizes that one-way public communication of sustainability knowledge does not lead to behavior change, and that even intention to act is not an indication for behavior change [4, p. 21]. Arguing less with moralization and instead focusing on enabling dialogue and reflection on values and attitudes should be a guiding principle for all sustainability campaigns [4, p. 25]. Two-way communications are related to communication *about* sustainability, enabling increased discussion about the subject through feedback loops [17, p. 145]. Social, interactive media is a powerful tool for two-way communications, be it for community forming, political participation, or coordination of action by a large group of people [16].

3.4.7 Help Recipients Reason by Themselves (SC7)

There exists a risk in targeting the specific actions of individuals. Sustainability risks being reduced into something solvable by simple activities, which does not address the context in which these activities happen. [4, p. 75] Furthermore, individual lifestyle changes are not enough to achieve sustainability [16, p. 8]. Instead, an intervention might want to focus on building up the capability of recipients to take appropriate sustainable action as the situation changes, similarly to how the concept of sustainability is defined as an ongoing process rather than a set set of goals. SC7 can also be used for the SC paradigm of targeting specific actions by increasing recipient engagement in understanding the desired behavior.

In any case, the recipients should not be thought of as passive receivers of information,

but rather as conscious actors who believe they are empowered to make a desired, valued, and necessary difference [4, p. 588–589].

People are generally motivated to understand things over being confused, want to feel competent and answer their own questions [20, p. 15]. This guideline emphasizes the ineffectiveness of simply stating out information and chains of logic without participating the recipient in the chain of logic in some way. On top of letting people reason themselves being a method for effective message retainment, building up the capacity for people to be capable of this reasoning is suggested to be an important goal by the literature [4, p. 25].

At least when it comes to sustainable consumption, fundamental changes in how consumers act are recommended. For sustainability communication with such goals, the way change is manifested across societies, the meanings change has, and the purposes for consumption has to be analyzed. A collaborative, peer-to-peer solution of mutual social learning might be more effective than traditional communication. [4, p. 270] Related concepts: two-way-communication, communication ABOUT sustainability, capacity building for adaptive and participatory decision-making. As an example of capacity building, a study on a Hungarian low-medium income community was taught of the sustainable actions already present in their lifestyles. This increased their pride, understanding, and amount of sustainable practices through higher order learning [4, pp. 271–272].

A possible paradigm utilizing SC7 is treating sustainability as a "social imaginary", something requiring a society level push to improve the imagination of individuals to break from normative conditions. A possible way to achieve this is to feed public imagination with innovative visions of a never-before-seen world [4, pp. 80–81].

When it comes to sustainability education, the competence approach is favored by scholarly circles. It has not been translated into practice, however. [17, p. 145]

3.4.8 Utilize Storytelling (SC8)

This method is heavily linked with engaging emotions. Storytelling is said to be effective, especially for conveying emotion [4, p. 90]. It is cited as common advice from SC

consultants [4, p. 3]. One way to achieve this is a Transmedia Narrative Transportation (TNT) approach. It is a fusion of transmedia storytelling and narrative transportation theory. Transmedia storytelling consists of a unified story told through multiple media, through multiple story tellers, with unique contributions from each media.

This approach works as a framework for creating story-based facilitators for behavior change. However, a key part of this framework is the creation of an initial message, creating the outline of a storyworld, followed by the bulk of the messaging being provided by people who began as consumers of the message. [4, pp. 96–100] As hard as getting consumers to organically engage with content already is, this aspect of the framework also takes away control from the original communicator. The creation of multiple controlled pieces of transmedia within a single storyworld should be considered.

The Transportation Imagery Model focuses on how stories can create a measurable experience of narrative transportation. Related to this concept is narrative persuasion. It has the goal of evoking a favorable psychological state from a story that prompts them to adopt certain attitudes and intentions. This can be achieved through three elements: a person processing a story, a person being transported into the story, and finally, losing track of reality while transported. [4, p. 94] Another effect of transportation while being focused on the narrative is the reduction of mental resources available for counterarguing with the message, facilitating persuasion [4, p. 124].

Stories are narratives, representations of arranged events, and people with motivations and emotions. Stories can be fact or fiction, which, according to some research, does not change the impact of a story. [4, p. 124] This might be explained through how, in some theories, the narrative consistency of a story is more important than correspondence with the real world, and in some the narrative of a story showing the state of things rather than arguing for it causes counterarguing to fail as a mechanism: there is no argument to argue against. This can be achieved through thorough engagement, making the consumer of the story shift their line of thinking to go along with the one of the storyworld. Studies on the effects of different narratives for environmental sustainability produce results from unchanged to more pro-sustainability attitudes. Interestingly, according to one study,

watching a certain catastrophe movie heavily featuring impossibly catastrophic weather events actually lowered the perceived likelihood of drastic climate changes [4, p. 135]. However, evidence of stories achieving the notoriously hard to achieve behavior change effect exists. Two entertainment-education radio series on farming practices measurably increased the sustainable behavior of their recipients. [4, pp. 124–133]

4 Behavior Change and Psychology

This chapter will compile guidelines from behavior change intervention frameworks, behavior change theories, and psychological barriers for environmental behavior.

This is the second of three chapters introducing an area of research used to form a framework in Chapter 6. The chapter concludes with a list of guidelines for behavior change interventions, which draws on all the psychological concepts analyzed in this chapter.

4.1 Theories of Behavior and Interventions

The aim of communication is to influence those involved in some manner. This influence means affecting their awareness, attitudes, or behavior. Behavior change can be considered the ultimate goal of sustainability communication [4, p. 285], making the research showcased in this chapter well applicable to all VR experiences for environmental sustainability communication.

Behavior change interventions are used to resolve or improve issues by changing the behaviors of a person, organization, community, or even a society [32]. Commonly, these theories are used for interventions targeting health [33], which has caused many of the most popular theories to be tailored for this use case. Finding commonalities between the more generalized behavior change theories should provide us with a balanced view of how behavior can be affected.

Not all interventions are based explicitly on theory. Research on the effectiveness of theory based interventions provides mixed results, ranging from positive to neutral to even negative when compared to interventions not based on theory. The same research suggests

that the reason these wildly varied results include negative results is an inappropriate use of theory. Examples of this include the unreliable way theory has influenced the creation and analysis of each intervention, the poor selection of an appropriate theory, and the lacking reporting on intervention content. Additionally, interventions reportedly unbased on theory tap into similar mechanisms as theory based ones, which can result in positive results. [34, p. 87] [35] There is growing recognition that interventions should draw on theories of behavior and behavior change [32] [35] [36, p. 20–22], and doing so systematically furthers our understanding of relevant scientific areas. These provide ample reason to base interventions in theory.

Behavior theories include, explicitly or implicitly, theories of behavior change within themselves. This can be supposed because these theories innately claim constructs, that is, key concepts in the theory, affect certain behaviors. Therefore, causing a change in these constructs should influence behavior in a predictable way. [37] Creating a chain of logic from how these constructs are changed, to how these changes affect behaviors is called a logic model [32].

As using a theory or framework of behavior change allows us to robustly approach issues and examine the effectiveness of explicitly defined ways of communication, theory-based communication and interventions seem like the most reliable way to further our understanding of the creation of sustainability communication applications as well.

4.2 Creating an intervention

A one-size-fits-all solution for interventions is impossible, even if the scope is limited to just sustainability interventions through VR. The specifics of the situation, such as the target audience and the communicated sustainability information can vary greatly, requiring vastly different approaches. General frameworks for creating interventions can aid in the creation of tailor-made interventions, ensuring the problem is confronted in a systematic manner. This chapter uses such frameworks to both provide such a framework, and to introduce relevant psychological concepts for its phases.

A framework of key tasks for developing BCIs is provided by and article by Hankonen and Hardeman in their article, "Developing Behavior Change Interventions" [38]. It is formed from overarching principles in two influential BCI frameworks and two influential reviews of frameworks, making it a highly comprehensive look at the subject. The tasks are as follows:

1. Identifying and analyzing the problem.
2. Designing the solution, which includes deciding on the content and delivery modes and designing a logic model or program theory.
3. The development of intervention materials and technology.
4. The empirical optimization of the intervention through early testing.

Abraham and Denford provide an alternative organization of tasks in a book titled *The Handbook of Behavior Change* [32]. Their tasks will be explored along with the tasks of Hankonen and Hardeman. Both frameworks recommend to not follow a waterfall model of development, but rather to iterate through earlier tasks as needed.

4.2.1 Identifying and Analyzing the Problem

An intervention is created as a solution to a problem, which must be clearly defined for the intervention to be effective. This definition includes determining what ecological levels (individual, organizational, societal) it will be administered at. The chosen levels determine the intervention targets, whose behavior, needs, and affecting factors must be understood in their context. [38] If population-level effects are expected, the intervention should be part of a comprehensive strategy spanning multiple ecological levels [32].

Clearly defining the target behavior can lend from models of behavior. The social ecological model for behavior sees interventions as events in a system that are reinforced or dampened by other factors within it, rather than as existing in a vacuum. [39, p. 9]. These socio-ecological factors can be divided into biological, psychological, and behavioral interrelationships between individuals, and the physical, social, and cultural aspects of their environments.

Categorizational assessment of the target behaviors should be clearly defined. For example, rather than assessing recipient willingness for sustainable actions in general, specific actions should be evaluated separately. For example, interventions toward better weatherization, improvements in heating, ventilation, air conditioning systems, low-flow shower heads, and energy-efficient appliances were better received than ones targeting carpooling, other driving habits, and line-drying laundry in the United States [40].

Additionally, best practice should be to first assess the desirability of an intervention on ethical grounds and to consider potential unintended consequences [15]. Hankonen and Hardeman recommend forming a preliminary logic model at this stage as well.

4.2.2 Designing the Solution

The next task is understanding the behavior contributing to the problem through a logic model, and designing a solution. A robust logic model reliably explaining the cause and effect surrounding a behavior might be impossible to form in some situations. Behavioral antecedents and potential determinants of the behavior can be used instead [34], including factors that reinforce rather than cause the behavior [32].

An existing logic model may be used to help form a robust model. The *COM-B* model is one such logic model, postulating that behavior is derived from the target group having the capability, opportunity, and motivation to do so [34, pp. 59–86].

Lastly, the delivery medium of the intervention must be chosen, based on feasibility and the preferences of those involved. [38]

4.2.3 Development of Intervention Materials and Technology

The practical specifics of the intervention are planned at this stage, often parallel with task 2. Key features to consider include attractiveness, clearness, relevance, and ease of use to end users. Abraham and Denford recommend pilots or pretests to identify issues such as whether an intervention's idea is accepted and used by the selected group(s).

4.2.4 Empirical Optimization of the Intervention

Finally, interventions should be iteratively refined based on empirical results.

Abraham and Denford recommend assessing how the environment and specifics of the target group might have affected the changing of targeted antecedents and behaviors, and finally evaluate effectiveness by testing the intervention in new contexts and scaling up to target new groups or populations.

4.3 Models of Behavior

Behavior is influenced by an extensive network of factors, which models of behavior fail to capture in its entirety. This is by design, as complex and comprehensive models do not enable establishing valid and reliable correlations and causal relations between factors. Instead, models employ a set of factors seen as the most relevant, influenced by differences in academic viewpoints and the applied context. [41, pp. 17–21] Forming a new model for the context of VR sustainability interventions is not the goal of this thesis, but rather to explore overarching factors and behavior change techniques in key theories, and guide toward specific theories if using this thesis as a guide. A varied outlook is warranted as studies suggest that using multiple behavior change techniques underpinned by a theory of behavior change is more effective than only focusing on one technique [42].

A systematic literature review of behavior change theories is not within the scope of this thesis. The selection will therefore be limited to theories with a wide influence, or clear applicability in the context of this thesis. A network analysis of 83 different theories of behavior change identified four theories as the most central [43]. These theories are *social cognitive theory*, *the health belief model*, *the theory of planned behavior*, and *self-efficacy theory*. The book *ABC of Behaviour Change Theories* by Michie et al. [36] provides an analysis of the frequency of theory use in a large collection of articles behavior change articles. The most used theories were *transtheoretical model of change*, *theory of planned behaviour*, and *social cognitive theory*. The health belief model and transtheoretical model of change have been left out of this thesis due to being specifically tied to

health behavior change interventions. The other theories will be covered and analyzed for behavior change techniques. Social-norm and social-tipping interventions are included as well due to existing research on their applicability in a sustainability behavior change context.

4.3.1 The Theory of Planned Behavior

Michie et al. [44] describe the theory of planned behavior (TPB) as a logic model of purposeful behavior: behavior comes from intentions, which are formed from attitudes, subjective norms, and perceived behavioral control. When using the theory, on top of defining the action to be influenced, the action's target, context, and time frame should be defined as well.

A literature review of *green purchase behavior* (GPB) covering the years 2000 to 2014 identified TPB as one of the main theories used throughout the body of research. The review states, however, that TPB was not considered suitable for explaining ethical behavior and was often expanded with additional dimensions. Reasons for this include the theory not including affect (emotions), buying habits, or situational factors as factors contributing to behavior. [45] It is possible that beliefs may not always be reflective of their direct measures, as TPB postulates. Shaw and Siu suggest adding structural equation modeling on top of the more commonly used regression analysis to form chains of causal links from beliefs and to allow the specification of latent factors, or cognitive constructs underpinning the model. In their study, the inclusion of these two dimensions significantly improved the explanatory ability of the model. [46] As seen from the examples above, the theory of planned behavior might be insufficient for the formation of a logic model explaining sustainable behavior, unless expanded upon with additional concepts.

4.3.2 Social-norm and Social-tipping Interventions

Theories of behavior change can raise social norms as the key factor affecting certain behaviors, which is the case when employing social-norm and social-tipping interventions. Social norms mean behavior patterns or values that depend on expectations about what

others do and/or think should be done. They are also defined as interdependent and self-enforcing.

Social-norm interventions can be used when existing norms are sustainable, but widely unknown. Simply being made aware of the sustainable actions of others can rectify misconceptions and guide people to act in tandem. Conversely, being made aware of the sustainably problematic behaviors of others can reinforce these behaviors.

Social-tipping interventions can be used when existing norms are unsustainable. Getting a subset of a population to accept non-normative beliefs or behaviors via localized intervention, then applying coordination or conformity incentives can lead to a wide-scale adoption of the beliefs or behaviors, once a critical mass has adapted them.

An individual aligning their actions with social norms may benefit them by, for example, satisfying a desire to fit in, avoiding a social or material sanction, allow for easier co-operation, or reduce the need to think about whether their actions are socially acceptable or not. Such influences reinforce collective behavior patterns.

It is suggested that of the ecological levels, interpersonal, organizational, community, and societal, interpersonal acts as the most important determinant. A review on research about green purchasing behavior also found parents and peers, or the interpersonal ecological level, as acting as role models and possibly a trustworthy information source for sustainability information. [47]

The abstractness and uncertainty of human estimates of the future also extend to climate change data in general, as the studied systems are extremely complicated and results abstracted behind layers of probabilities and conditionals. Acting according to heuristics, such as social norms, helps people make decisions in uncertain situations, making sustainable development a viable target for the application of a social norm intervention.

4.3.3 Social Cognitive Theory

The central proposal of Social Cognitive Theory is that behavior, personal environment, and personal factors all interact to determine each other. Additionally, cognitive processes

are seen as emergent activities of the brain, irreducible to its components but providing deterministic influence on actions [48]. Personal factors include cognitive capabilities, which consist of, according to the theory [36, pp. 360–361]:

- Symbolizing capability, for representing experiences with mental models that can be used to ascribe meanings and more easily compare them in action outcome evaluation. For example, The experience of a single sustainable purchase can be represented with the symbol of "sustainable purchase" and compared to experiences symbolized by "unsustainable purchase" in the mind of a person.
- Forethought capability is used to regulate behavior based on the evaluation of future outcomes.
- Vicarious capability, or learning from imitation, which is stated to be more effective than learning through action.
- Self-regulatory capability, which is the ability to reduce the dissonance between standards and behavior. This can occur through behavioral adjustment alone or the personal organizing of environmental conditions.
- Self-reflective capability refers to the ability of modifying knowledge and standards through self-reflection.

Environmental factors are likewise divided in three factors [48]:

- The imposed environment the person cannot reasonably choose to reside in or majorly influence.
- The selected environment the person chooses to reside within.
- The constructed environment the person has built themselves.

The interplay of these two types of factors influence behavior, and behavior likewise influences them.

4.3.4 Self-Efficacy Theory

There exists a psychological mechanism where belief in being capable leads to changed behavior. This is a central factor in determining the initiation and persistence of certain behaviors, according to self-efficacy theory [49, p. 4]. Four sources of information contribute to this belief:

- Personal experience of success.
- Vicarious experience of success, meaning the observed success of others from performing the behavior.
- Verbal persuasion about capability.
- Emotional arousal, meaning the reduced capacity for belief in oneself during some demanding and stressful situations.

Self efficacy beliefs have three dimensions: magnitude, or the complexity of the task a person feels they can perform, the strength of this conviction, which indicates persistence through failure, and generality, for how wide a range of actions this belief covers. [36, pp. 329-334]

As the theory was first created to explain fearful and avoidant behaviors, [36, p. 330], these might be the most suitable behaviors for this theory to affect in an intervention. The theory is best used for self-efficacy beliefs regarding specific behaviors, rather than general belief in oneself [49, p. 8].

4.4 Psychological Barriers of Environmentally Sustainable Behavior

Finding behavioral determinants for sustainable behavior is one of the main focuses of this chapter, but for a more optimal intervention with less chance of rebound effects, specific psychological barriers that work against such determinants should be considered as well [18]. A brief overview of two important barriers will be covered in this section.

The non-immediacy of many ecological problems makes people less able to perceive these issues. In other words, having degrees of separation from the space, time, and typical experienced life of a person causes issues in comprehension. For example, a mathematical model predicting climate change in the future on the scale of the planet is separated from the everyday life of regular people. The costs of climate actions fall on the people of today, while the positive and negative impacts fall on future generations. This incongruence gives rise to psychological barriers for people to take action. This can happen through the human tendency to discount the future and phenomena that fall on socially or geographically distant communities. [50] [51] [52] [53] Discounting the future should not be seen to be purely due to ignorance, as the immediate demands of the present, and uncertainty of future events can reasonably lead people to prioritize current events.

Habits are a potential psychological barrier. For example, the sustainable behavior of reducing meat consumption has been marred by habits of eating meat as its most significant barrier [18].

4.5 List of Guidelines for Behavior Change Interventions

This chapter introduced psychological concepts and barriers relevant to behavior change interventions for environmental sustainability as well as some of the most relevant models of behavior change and behavior change intervention types. In this section, the most important findings and commonalities between these are used to form a list of guidelines, used in Chapter 6 to explore potential synergies with the guidelines derived from sustainability communication and virtual reality research. The table below acts as a summary of these guidelines related to behavior change, followed by more thorough explanations.

Table 4.1: List of behavior change guidelines

Tag	**Guideline**
BCI1	Follow a BCI Framework: Utilize a Logic Model and an Iterative Process
BCI2	Utilize Multiple Behavior Change Techniques, Consider Actions Beyond the Intervention
BCI3	Improve Comprehension
BCI4	Affect Perceived Capability
BCI5	Apply Social Pressure

4.5.1 Follow a BCI Framework: Utilize a Logic Model and an Iterative Process (BCI1)

Frameworks for creating behavior change interventions were introduced in Section 4.2. Of the many considerations, forming a logic model, and an iterative creation process involving end users should be emphasized.

As a part of logic model creation, the target behavior and the supposed mechanism of its change are clearly defined, aiding in the creation of robust studies with cross-comparable data. A pre-existing logic model can be used, such as the COM-B model in exploring avenues for change. Agnostic of the theory used, it can be said behavior change cannot reliably happen without sufficient capability, opportunity, and motivation. [34, p. 59] Capability might be physical (physical conditioning needed for walking over car use), or psychological (understanding sustainability concepts well enough to conclude CO2 emissions are harmful). Opportunities can be physical (having the necessary gear for walking) or social (having company while walking). Motivations can be reflective (logically concluding walking is better than driving) or automatic (immediate negative affect toward walking). [34, p. 63] The COM-B model is one possible tool, but a logic

model should be formed to suit the situation.

The main contributing factor for sustainable behavior is when both internal and external factors act synergistically, but the field of sustainability behavior change is so large that any all-encompassing theory is less apt than one fitting each specific situation. [51]

As instructed by the frameworks introduced in this chapter, intervention creation should be collaborative and iterative. When harnessing social norms for climate action development should likewise be done adaptively in collaboration between academics, practitioners, and end users [15]. End users may be analyzed as individuals or sometimes as a community. More practical considerations for an intervention involving communities include: [39, pp. 10-11]

- Recognizing the partner community as a unit of identity
- Building on community strengths and resources
- Facilitating collaborative and equitable decision making
- Fostering colearning among the community
- Balancing knowledge generation with community benefit
- Focusing on local issues
- Disseminating information, results, and benefits to the community
- Developing commitment to a long-term process

4.5.2 Utilize Multiple Behavior Change Techniques, Consider Actions Beyond the Intervention (BCI2)

A varied strategy is beneficial, as utilizing multiple techniques as opposed to just one is more effective [42], and a sufficient level in all of capability, opportunity, and motivation are all needed for behavior change according to the COM-B model. This must be balanced with simplicity, as clearness and ease of use by the end users, and the utilization of an unconvoluted theory have been introduced as beneficial for BCIs in this chapter.

Both BCI frameworks introduced in this chapter emphasize understanding the context surrounding the behavior, as well as the behavior change theories, to varying degrees. The complex interplay of different factors, each possibly requiring their own set of techniques, is especially emphasized in social cognitive theory (see Section 4.3.3).

Beyond just utilizing multiple techniques within one intervention, integrating the intervention itself into a multi-ecological level campaign is suggested by some behavior change models (e.g., *the social ecological model* [39, p. 9]) and the framework by Abraham et al., if population-level effects are expected. Even on the ecological level of individuals, it should be understood that even the most effective motivation increasing intervention will not be effective if the surroundings of the individual are extremely unconducive for the target behavior change. Therefore, actions outside simply affecting the recipients should be considered in tandem with the intervention.

4.5.3 Improve Comprehension (BCI3)

As the information deficit paradigm has proved ineffective in explaining the lack of sustainable behavior in intervention recipients (see Section 3.1), simple informing should not remain as the sole behavior change technique. However, as at least a minimal level of sustainability knowledge is required and sustainability concepts can be complex, fostering understanding can be beneficial. Comprehending future results of behavior is heavily linked with the construct of *symbolizing capability*, introduced in Section 4.3.3. Enabling recipients in forming simple symbols of sustainable behavior in their minds, such as "actions highly effective in fighting climate change in the long run" could be an effective strategy of improving forethought capability.

The non-immediacy of issues is a major barrier for sustainable action, as explained in Section 4.4. Presenting these issues in a way that is more immediate, physically closer, or more comparable to the everyday life of recipients are effective ways of improving comprehension.

4.5.4 Affect Perceived Capability (BCI4)

Improving perceived capability is the core factor behind behavior change in self-efficacy theory and an important factor in the theory of planned behavior. According to self-efficacy theory, the most important method of achieving a higher level of perceived capability is through personal performance accomplishments. Other factors that affect the heightening of perceived capability include the level of skill the recipient feels from performing the task. If a task is easy, but not due to chance, a recipient is more likely to feel they are skillful than if it was hard or a matter of luck. [36, p. 333] Self-efficacy theory provides techniques for improving perceived capability through each of its sources [36, p. 333]:

- For personal experience of success, a recipient can get used to performing the behavior through repetition. An intervention could focus on providing a sense of accomplishment from performing the desired behavior while proving perceived negative sides of the actions to be lesser than assumed.

- Verbal persuasion about capability could be induced through encouragement, or even through the recipient self-instructing themselves through a process.

- Emotional arousal negatively affecting self-efficacy through stress could be lessened by desensitization to the behavior, or through relaxation techniques such as biofeedback and meditation. Attribution, where factors in performance are correctly attributed to internal and external sources may also be used.

Theory of planned action has the related construct of perceived behavioral control, that consists of factors that help or hinder in the behavior [36, p. 434] Social cognitive theory calls perceived self-efficacy the most influential self-reflective thought for behavior. It influences chosen behaviors, perseverance and effort, and the level of confidence and anxiety when performing behaviors. [36, p. 361] Additionally, self-efficacy has been found to promote prosocial orientation related to cooperation [48].

4.5.5 Apply Social Pressure (BCI5)

The most fitting model of behavior change for this guideline is the one utilized by social-norm and social-tipping interventions, introduced in Section 4.3.2. Similar constructs exist in other theories as well.

The theory of planned action calls the related construct *subjective norm* a product of *normative beliefs*. Defined more precisely, the most meaningful factors are the perceived approval of important others and a motivation to comply with them for a person. [36, p.434]

People are sensitive to information on how behaviors are changing over time, on top of the more obvious sensitivity to existing social norms. This means information about the emergence of new norms can act as the starting point of an intervention. Generally, social norms spread through complex contagion processes, where only social reinforcement from multiple sources can convince people to change their behavior. This can be practically condensed into three requirements for social-tipping interventions to work [15]:

1. Critical Size: The subset must be of a large enough size
2. Clustering: The subset must be clustered together within the social network
3. Wide bridges: The subset must be connected to many other communities within the population

On top of purely social pressure, social constructs can be used to pressure recipients to act in normative ways. In conserving resources for the future, democratic voting seems to provide a remedy against selfishness and other reasons to discount the future. If a median amount of resources to be consumed by everyone involved is decided by a democratic vote while decision makers are aware of possibly negatively affecting people in the future if they take too much of the resource, more sustainable choices are made. This is partially due to ruling over “defectors” who would take too much without the vote. This effect is massively weakened if the vote only affects a subset of the decision makers. [50]

5 Virtual and Extended Reality

In this chapter *virtual reality* (VR) is analyzed in its context within *extended reality* (XR). *Augmented reality* (AR) will be analyzed as well, as contemporary VR technology employs its features as well.

After discussing XR, virtual reality will be discussed at length regarding what makes for a high-quality VR experience, and what possibilities VR offers compared to other mediums, such as real world implementations and non-immersive digital methods. These possibilities are analyzed through the lens of *affordances*. Then, after discussing some limitations of VR, the limitations and affordances are used to form generalized guidelines about the utilization of VR.

5.1 Extended Reality

Multiple conflicting definitions exist for extended reality terminology. The terms *extended reality* (XR) and *mixed reality* (MR), and immersive technologies are sometimes used interchangeably, but XR is typically considered an umbrella term for all technologies that merge real and and virtual worlds [54]. In the context of this thesis, a virtual world refers to a software-created environment, where navigation typically happens in two or three-dimensional space. A very influential taxonomy by Milgram and Kishino [55] consists of a continuum ranging from real to virtual environments, as seen in Figure 5.1.

In the taxonomy, MR excludes fully virtual and fully real environments, and can be interpreted as excluding VR as a completely virtual environment. In *augmented virtuality* (AV), the virtual world is augmented with real world content, but it has not become a

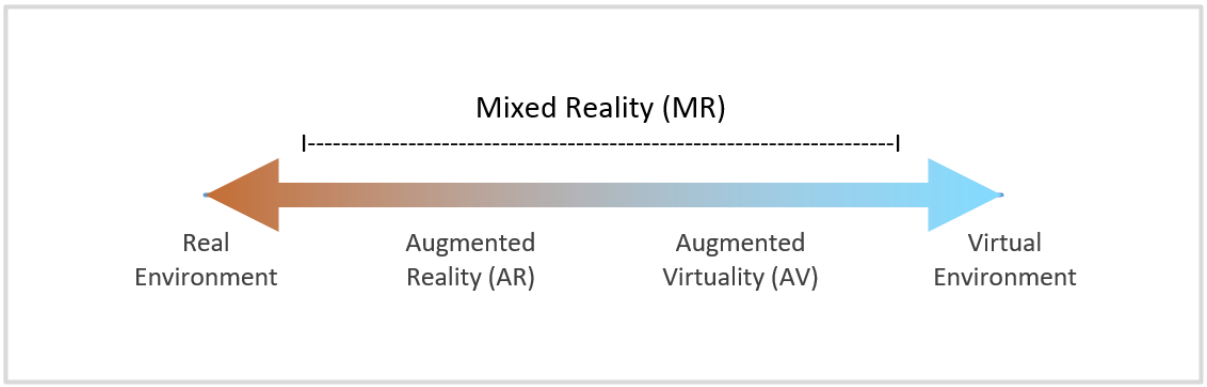

Figure 5.1: Milgram's Virtuality Continuum

commonly used term, unlike *augmented reality* (AR). AR is defined in the taxonomy with the operational definition of any case where the real world is augmented using computer graphic objects. Milgram and Kishino describe VR in the conventional sense being a completely virtual immersive environment, placing it at the far right of the continuum and excluded from MR in that regard. However, the immersiveness of VR and the way displayed virtual objects can have strong ties to the real world can be seen as locating it between real and virtual environments as well. The way this continuum fails to capture the totality of VR is further emphasized by other dimensions of mixed reality displayed in the paper. The dimension of the extent of world knowledge emphasizes how ties of content to the real world can differ. Content might be directly scanned from the real world without their location or contents being directly mapped by the virtual world (e.g., 360-degree stereoscopic images being used as a backdrop), or everything might be completely modeled, allowing for perfect tracking of the "where" and "what" of contents. This modeling typically comes at the cost of labor and can reduce reproduction fidelity if done without a proficient budget or expertise. This fidelity is another dimension, ranging from the simplest of wireframes to models perfectly fooling the sight of the user. Fooling the senses is at the core of extended reality technologies, emphasized by the inclusion of the *Extent of Presence Metaphor dimension*. [55] The concept of presence, the subjective sense of existing in the virtual world, is ever-present in extended reality literature and will be analyzed more closely later in this chapter. These dimensions give form to the breadth of extended reality technologies and their relevant concepts. Milgram and Kishino do not

use the term XR in their paper, however. Extended reality was first introduced in an article by Mann and Wyckoff in 1991 [54] as "any combination of a virtual environment with reality where the virtual environment is responsive to a real or complex-valued output from reality, by way of real-time computation". A disclaimer is added to this definition: some kind of aligning or strong coupling with reality should remain. [56] In practice, the usage of XR terminology has been quite inconsistent. This is exemplified by a taxonomy created for the categorization of extended reality medical dentistry training methods, created to bring consistency to the terminology. The taxonomy was published in 2024, but is largely based on Milgram's Virtuality Continuum created 30 years prior. [57] Operational definitions are employed in this thesis for both augmented reality and virtual reality.

5.1.1 Augmented Reality

As AR and VR share many similarities, it can be valid to consider both together [54, p. 151]. One operational definition for AR, applied in this thesis, is a real environment augmented by virtual content in a way that is interactive in real time, and three dimensional [3]. This real environment does not include virtually recreated real-world environments, such as ones created through utilizing stereoscopic 360-degree imagery, as these are fundamentally virtual environments and therefore belong to VR. A real-time composite recreation of the environment immediately outside a *head mounted display* (HMD) equipped with cameras, however, would be considered AR. Moving between real and virtual environments is possible with contemporary HMDs, allowing us to utilize the benefits of both. Both environments utilize virtual content that need not follow the laws of physics. AR can additionally borrow the context of the real world, allowing users to interact with impossible actors within what feels like their real-world context, and additional information can be attached to real-world actors. Additional issues brought on by AR include the use of complicated algorithms and the proper lighting to correctly anchor virtual content to the real world, and matching the visual fidelity of the real world with the virtual creations, lest the sense of presence suffers.

5.2 Virtual Reality

The operative definition for VR used in this thesis is that it is something that immerses the user in a virtual environment, excluding them from the physical environment [3]. This is typically done through the use of HMDs, used along controllers utilizing hand tracking, or optical hand tracking, both allowing for *embodied interaction*. As an important distinction, this is the VR system that is the main focus of this thesis. Other VR systems exist (e.g., CAVE Automatic Virtual Environments and other projection based immersive experiences), or may come to exist (e.g., fully immersive systems utilizing all senses), undoubtedly sharing many features of VR discussed in this thesis but with technical and other limitations of their own. These shared features should allow the research in this thesis to be somewhat applicable, but the breadth of design possibilities for VR cannot be fully accounted for by the scope if this thesis.

For all VR technology, *immersion* and *presence*, or *sense of presence* are central concepts that showcase the psychologically unique advantages of VR. These terms are often used interchangeably. The seminal article by Milgram and Kishino, introduced earlier, introduced this same concept as the Extent of Presence Metaphor. The book *Virtual Reality Methods* by Jones et. al. distinguishes immersion from presence [2, p. 13]. Immersion is defined as a more objective measure, a sense of being located in the virtual world brought forth by both hardware and software. Presence is a more subjective measure, affected greatly by differences between individuals. The exact list of features that presence consists of is contested, but among the argued for ones are the subjective feeling of 'being in the virtual world', realness, interactivity, the concept of immersion, and a division between social, physical, and self-presence [58, p. 117, p. 120]. As VR is sometimes referred to as "immersive technologies", the concepts of immersion and presence are very central. It could even be argued presence forms the very core of VR, distinguishing it from other virtual media. The features, limitations, and methods of utilizing VR listed in this chapter can be seen to all stem from a need to create the feeling of presence, or directly benefiting from its inclusion.

5.2.1 Development of VR Applications

The creation and implementation of immersive virtual worlds has a number of considerations regarding contemporary technologies. The book *Virtual Reality Methods: A Guide for Researchers in the Social Sciences and Humanities* calls the game engines *Unity* and *Unreal Engine* the default tools for building VR content from scratch [2, p. 118]. Another potential alternative for researchers and creators of behavior change interventions is using pre-existing VR content. The immature industry has not produced commercial experiences for as many purposes as non-immersive virtual media, but this practice has precedent [2, p. 61], and removing development costs can be a substantial benefit. These development costs can be higher than for comparable non-immersive virtual interventions. The creation of VR content requires expertise beyond the creation of traditional games projected onto a single two-dimensional screen due to having been less used, and therefore having less learning materials and other development resources available. Similarly, issues can stem from development environments being accessed through 2D, non-immersive screens, necessitating constant testing outside these environments.

Many VR controllers offer more conventional game controlling options on top of hand tracking, such as buttons and joysticks. A key characteristic difference between hand tracking and conventional control scheme is their degree of embodiment. Degree of embodiment refers to how well they contribute toward awareness of joint and body part movement, their positions, and a sense of self movement and balance. [59]

A unique challenge comes from creating content that runs using an HMD's own processing power: the hardware is similar to smartphones, but as VR content can be extremely resource intensive, well-optimized content becomes a necessity. This is especially true for graphical content, as rendering a high resolution image for each eye is a must.

On top of development challenges caused by hardware, the cost of VR HMD technology has had a direct effect on its lack of use, becoming more widespread with decreases in cost [60]. While still not ubiquitous, the increased likelihood of users having tried VR before comes with the advantage of improved user familiarity, but also the possible disadvantage of reduced novelty.

5.2.2 Affordances of VR

Affordance originates from ecological psychology as a concept [3] [61], but has evolved a wide range of meanings on the border of usability and user capability. Affordance often refers to functional and perceived affordances, which can be succinctly called perceived action possibilities [62], meaning they act as a relation between technical features and user abilities. In some literature, the usage of the term affordance emphasizes its *possible* uses rather than its *intended* uses, which has been utilized to explore the possible uses of technology [63] [64]. This is how the term will be used in this thesis, as ways in which the advantageous and disadvantageous features and potential effects of VR guide toward certain ways to utilize the technology. This includes guiding features such as chosen content and interaction methods, as well as use-cases in a way that is best suited for VR. *Sustainability Communication reader*, the main source for sustainability communication theory in this thesis, notes that creative ways to engage people are a welcome addition for environmental communication, and the affordances of technologies are underutilized [4, p. 40]. Utilizing affordances can result in systems being appreciated and accepted by users [65].

In practice, the varied way the term affordance has been used makes it difficult to synthesize scientific findings of the affordances of VR, but certain concepts and findings are common throughout the literature. A study from 2017 [65] studied affordances related to learning in VR, and a literature review of 151 VR articles from 2022 [66] found a number of focal technology affordances and enablers of HMD-based immersive VR. The most notable affordances found by these relatively contemporary articles were:

- Presence and immersion
- Empathy
- Embodiment/Interactivity
- Create-ability

Presence and immersion have already been discussed as key concepts in VR that enable

other features. As such, it is better examined through its interaction with specific use-cases and methods, rather than an affordance in itself.

Empathy is related to presence in that it is enabled by being able to understand how other people feel. VR technology has regularly been described as empathy machines, meaning technological means to evoke empathy. Empathy is characterized as either an involuntary, unconscious understanding of the mental state of another, or experiencing the feelings of another as your own. [67] Counterarguments for VR technology as empathy machines include the claim that experiencing the perspective of another forces your perspective to become theirs, rather than fostering the act of understanding truly outside perspectives. Additionally, these perspectives can never capture everything from the subjective experience of another. [67] The former of these claims remains unproven to be an issue, and the latter is likely to be an unsolvable limitation for all media.

Embodiment refers to the tendency for users to perceive their virtual body as their own, which is also close to the concept of presence. Practical uses of this affordance include potential for extremely intuitive user interfaces, where virtual objects are manipulated almost identically to their real world counterparts. This embodied interaction, enabled by hand tracking or other devices such as walking tracks, can be intuitive, memorable, and highly enjoyable [3].

Create-ability goes by many names in the literature, but creating realistic content and environments unfeasible in the real world is consistently listed as an important feature of VR [68] [3].

Features to actualize these affordances include AI-based agents, full-body motion for navigation and orientation, invoking senses and emotions, and interacting with agents, avatars and virtual environments. [66]

In addition to the affordances of VR themselves, 3D virtual learning environments have affordances that virtual reality can enhance. Spatial knowledge representation, experiential learning, engagement, contextual learning, collaborative learning, control of environment attributes, are all such affordances, enhancable by a construction of identity, a sense of presence and co-presence, embodied actions, control of environment attributes

and behavior, and features increasing representational fidelity. [69]

The disadvantages and limitations of VR

Contemporary VR solutions still clearly lack in immersion compared to the real world. This is due to limitations in, for example, haptic clarity and visual fidelity. [3] Perhaps the first thing to question before implementing something in VR is whether it would be feasible to implement in the real world instead.

On the other hand, the immersion and impactfulness of the VR experiences brings forth a potential issue: extremes of experience might overwhelm users. Realistically experiencing emotionally taxing events through VR might be unpleasant to an unethical degree for some users. [2, pp. 49-54] In such situations, it may be necessary to implement the solution in a less immersive manner.

A concept enabling better immersion for VR is vection, or self-motion illusions [70]. A simple example and use case for these illusions is the movement of virtual elements creating the feeling of movement for the user without any real world movement, which can feel much more realistic than in non-immersive environments. This creates a discrepancy between non-vision based methods of detecting acceleration, which is a major contributor to what is known as *cybersickness*, or *VR sickness*. Cybersickness refers to a multitude of ill-feeling physiological sensations ranging from dizziness to eyestrain to nausea[71]. While cybersickness caused by vection is quite similar to motion sickness (discrepancy between sight and other senses related to sensing acceleration), it is often a result of many contributing factors, specified in Section 5.4.4.

5.3 VR and psychology

Virtual reality is an inviting implementation medium for psychological treatments. It has been proven effective in certain psychological treatments [2, pp. 60-61], such as the treatment of stress disorders [3] [58, pp. 95-124]. Multiple studies have found a connection between the reactions of individuals to real-world scenarios and corresponding VR

scenarios [2, pp. 119-121], including stress responses. This has been largely utilized in the form of VR exposure therapy. Traditional in vivo exposure therapy consist of exposing a patient to what causes them anxiety in the real world. This real-world exposure method suffers from many limitations: cost, availability, adherence, privacy issues when done in public, and general impracticality of inducing some exposure in the real world. For example, fears of sea creatures and large audiences can be highly impractical to be exposed to in the real world. [58, pp. 95-124] The therapy works through extinction learning, where fear structures in the brain are activated to desensitize the person to the stimuli. An important mediating factor for these same structures activating is the sense of presence [58, p. 118]. Affective contents have a significant effect on the sense of presence in VR, and sense of presence seems to mediate some emotional responses as well, such as anxiety [72].

In VR, more empathetic people have been found more likely to help a virtual characters in need [73]. This seems to indicate great potential in studying the realistic behavior of people in specific situations using VR.

5.4 List of Guidelines for Virtual Reality Experiences

Using the affordances and limitations of VR introduced in this chapter, a non-comprehensive list of VR usage guidelines was gathered. The guidelines are summarized in Table 5.1, and explored more comprehensively later in this section.

Table 5.1: List of VR usage guidelines

Tag	**Guideline**
VR1	Explore Environments and Scenarios Unrealistic for the Real World
VR2	Utilize Embodied Interaction/Learning by Doing
VR3	Utilize Empathy and Emotions
VR4	Minimize Cybersickness
VR5	Take Advantage of the Total Control of the Environment
VR6	Utilize the Social Possibilities of Digital Environments

5.4.1 Explore Environments and Scenarios Unrealistic for the Real World (VR1)

Compared to traditional media, VR has the potential to feel exceedingly real. Compared to many potential experiences in the real world, VR can be exceedingly cheap, realistically available by a greater number of users, and much safer. These facts enable a unique affordance for VR at their cross-section: realistic feeling experiences that would be unfeasible in the real world.

Some sources go as far as to name this the main reason for the use of VR or its main selling point [74] [2, p. 48], with many others agreeing about it being an important affordance [68] [3] [60].

Reasons for a real world implementation being unfeasible include complete inaccessibility through spacial or temporal limitations: past historical events and faraway cosmic

bodies can be accessed through VR recreations. A scenario might be too dangerous for the users or others, such as fire fighting and surgery training. [74]

As noted in Section 5.3, VR scenarios have the potential to inform us of user actions in similar real-world situations as well, uniquely enabling explorations of human behavior in scenarios that would be dangerous or costly otherwise.

5.4.2 Utilize Embodied Interaction/Learning by Doing (VR2)

According to constructivist learning theory, people learn the best when performing actions by themselves, in a way where they can experiment and experience success and failure [68]. The better these actions correspond to the real world issues and use cases of what is being learned, the greater the learning. [75] This effect is further amplified by the fact that multimodal stimulation can amplify the concretization of concepts [60], making an embodied interface and an audiovisual immersive environment very suitable for understanding complex issues. Embodied user interfaces can also be used for training purposes, such as recreating scenarios where certain actions are expected of users, letting them engage with the scenario to have experience before encountering it in the real world. More embodied interfaces can also increase engagement, enjoyment, and realism [59]. A freedom of action that should be taken into consideration is the user being able to freely choose their framing. This means the user of an HMD can choose what to look at by turning their head, similarly to 3D virtual experiences on a computer screen where the camera can be turned through unembodied controls, such as a mouse. However, the embodied control of HMDs should allow for a slightly less prohibited turning of the camera, and the framing inherently present in a rectangular computer screen does not exist. This increased user agency can lead to the experience feeling less constricting and more personal, but also lead to issues in managing what the user focuses on.

5.4.3 Utilize Empathy and Emotions (VR3)

VR has been documented being very effective at evoking empathy as a digital medium [76]. On top of empathy, VR has been documented being particularly effective for evoking

specific emotions as well, including fear and positive emotions [2, p. 51]. Emotions are co-reinforcing with presence [72] and empathy [76], making a focus on all three worthwhile for VR. Utilizing emotions can be seen as a method to actualize other affordances as well [66].

In addition, as the creator of the VR experience has great control over the utilized assets, it is possible to modify their affect, or the way they are emotionally experienced [66].

5.4.4 Minimize Cybersickness (VR4)

It might be impossible to prevent every user from feeling the effects of cybersickness, but diminishing its ill effects should be taken into consideration for all VR experiences. A high degree of cybersickness can make an intervention unethical to administer, or at the very least reduce its completion rates [2, pp. 54]. Additionally, some research has found user experience a priority feature to focus on in VR learning environments, with cybersickness contributing to it greatly [65]. An impressive amount of research has been done on the contributing factors to cybersickness, and with the evolution of the field it might be best to look at literature on the subject outside this thesis when creating a VR experience. For a non-comprehensive list of ways to reduce cybersickness, creators can: [77] [2, pp.54]

- Reduce the degree of vection, expecially multi-axis or rotatory movement, or provide fixed visual stimuli. Vignettes limiting field of view when moving and teleportation control schemes have proven successful.
- Reduce the duration of exposure to VR.
- Allow the user to remain in control of their movement as much as possible.
- Improve visual fidelity, including even unnoticeable increases to display refresh rates.

- Using a third-person viewpoint instead of first-person. However, it would stand to reason that this decreases the sense of presence.

5.4.5 Take Advantage of the Total Control of the Environment (VR5)

In certain cases, such as with experimental science, it is desirable for experiences to be balanced for both experimental control and realism to the situation being tested. The virtual worlds inside VR are more closely manageable than real-world implementations, and more realistic compared to non-immersive digital worlds, making them very fitting for this use case. [73] It is likely that the way VR closes the user from the outside world helps focus their concentration: visual stimuli are closed off, a well-fostered sense of presence can create the feeling of existing in a world separate from the real world with its distractions [3]. However, as noted in Section 5.4.2, HMD environments usually provide a freely framed experience for the user. Forcing a certain viewpoint may lead to discomfort, while unrigorous methods of leading the focus of the user may lead to great variance between experiences. A wide range of no-latency stimuli can be experienced in the real world, proving advantageous in some situations, but disadvantageous when distracting from the desired focus of the experience [3]. Seductive, irrelevant details can also greatly worsen the retention of information in educative multimedia [78], making this guideline both an affordance and limitation to keep in mind.

5.4.6 Utilize the Social Possibilities of Digital Environments (VR6)

Digital environments have the affordance of collaborative learning [69], which extends to virtual immersive environments as well. As distance between communicators has become less of an issue since the invention of radio waves, the still lacking aspect of communication fidelity can be supplemented by a realistic environment that enables conveying body language. Applying social pressure is a suggested possible paradigm for using interactive media for sustainability [4, p. 75]. The sense of presence that VR technologies enable has been utilized in the creation of social experiences, similar to online chat rooms or

platforms for corporate communications. [79]. Additionally, the socializing possibilities of virtual worlds can add value to an experience in and of themselves by enhancing the social lives of users [73].

6 Combined Framework

The combined framework summarized in this chapter will act as a guide for the creation of virtual reality behavior change interventions for environmental sustainability. The full framework can be found in Appendix A and additional context and synergies between its items can be found in Appendix B. The framework is complementary to the frameworks, theories, and practices from prior literature introduced in the earlier chapters. It provides the most important guidelines to keep in mind when designing a VR sustainability experience or intervention, as well as helping explore the design space of such interventions through design questions. These design questions are considerations that designers can ask themselves to make sure they are taking full advantage of the affordances of VR, and the best practices of sustainability communication and behavior change interventions.

The framework will be further analyzed by comparing it with a VR intervention study described in chapters 7–9.

The combined theory is formed through the formation of synergy tables, forming design questions by looking for synergistic overlap between guidelines. Seeking these synergies will be referred to as triangulating, and overlap is sought from, for example, practical, psychological, and conceptual features.

First, the guidelines gathered from Chapter 3 and Chapter 4 were triangulated with each of the guidelines from Chapter 5 to form two sets of synergy tables containing design questions. Lastly, both sets of design questions were further triangulated with the remaining area of research. As an example of the entire process, triangulating VR2 (Utilize Embodied Interaction/Learning by Doing) with SC8 (Utilize Storytelling) gave us the design question: "Can an interactive story be utilized?" This design question was

triangulated with each BCI guideline, finding, for example, that learning by doing and stories can both improve comprehension (BCI3), a three-way synergy between all areas of research. Finding these three-way synergies, especially multiple ones, may indicate important design questions.

The following terminology will be utilized: *The experience* refers to the application being designed, be it explicitly an intervention or an unspecified experience for communication. *Recipients* refers to the people/group receiving the intervention. *The situation* refers to the context surrounding the sustainability concepts explored. *The message* refers to key communication objectives of the experience. *Stakeholder* refers to a wide range of people related to the experience who are not the recipients, such as entities funding and creating the intervention, and people related to the situation. For example, fishers whose livelihood is reliant on sustainability regarding the sea are considered stakeholders for interventions with related goals.

6.1 Framework Summary

In this section, the framework will be summarized guideline by guideline by exploring the features of synergies they are involved in. These synergies include the design questions themselves (guideline × guideline), as well as guideline × design question synergies. For example, the design question "Can different behavior change techniques be evaluated in relative isolation in VR?" was found to synergize with guideline SC4 (utilize scientific theory), as the former enables the scientific method the latter suggests to use. These three-way synergies indicate that following these design questions and guidelines is an effective way to follow the best practices of all three areas of research. The summary will focus on the most interesting and meaningful findings found through triangulation, such as certain guidelines being involved in multiple synergies, being involved in a predictable or surprising manner, and not being involved in many synergies.

6.1.1 Sustainability Communication Guidelines

All sustainability communication guidelines contribute to design questions with four to five of the possible VR guidelines, save for SC6 that synergized with two guidelines.

Use Innovative Alternatives to Mainstream Communication Methods (SC1) All but one guideline involved with SC1 are related to increasing interest in the experience. Interesting environments and scenarios, novel actions such as VR communications and embodied interaction, and the possibility of an emotional experience can all raise interest in the intervention. One danger was found in finding the balance between novelty and causing cybersickness. For example, a virtual roller coaster ride is likely to be novel and sickness-inducing.

The search for synergies with design questions derived from BCI guidelines did not reveal additional synergies. Increasing the outreach and enjoyment of the experience has obvious advantages for behavior change interventions as well, but all potential synergies were repeating findings made in the VR × BCI design questions. This calls into question the low level of specificity of this guideline.

Understand the Recipients and Tailor the Content to Them (SC2) Following this guideline should ensure the contents of any kind of experience are effective on the recipients, but the less obvious synergistic possibility of VR meetings between stakeholders and recipients should be highlighted from the design questions.

Synergies with VR × BCI design questions revealed an elevated need for early testing when the contents of the experience rely on uncertain or subjective features, such as evoking emotions and targeting gaps in their knowledge.

Uphold Accuracy and Truthfulness (SC3) Two of the five design questions were dangers related to design pressures running counter to this guideline. Stripping the experience of tertiary details or applying emotional persuasion risk giving a distorted view of the situation. This possibly indicates a fundamental danger for VR experiences, with their potential to be highly focused and intense experiences.

On the other hand, many techniques and features of VR can be used to increase comprehension, in line with this guideline. Framing, social experiences, stories, embodied interaction, and the accurate recreation of real world environments are all potential tools for this purpose, as the synergies with VR × BCI design questions find.

Utilize Scientific Theory (SC4) This guideline refers both to making science communication theory-based and applying the scientific method when developing and applying the experience. The design questions involved with it are mostly based on the exploration of theories the experience is based on: communication theories and behavior theories may all provide helpful concepts and mechanisms for the intervention.

Making the experience theory-based was found to be an obvious synergy with all BCI guidelines, as they are all constructed according to theories of behavior change. The explored synergies revealed the potential of VR for testing phenomena in isolation. While using an HMD, recipients are closed from the outside world and the outward stimuli they receive can be carefully chosen, providing a unique opportunity for verifying theories of SC and BCI.

Prioritize Hope Over Fear (SC5) Both framing and enhanced emotional responses to VR content were found to be conducive for this guideline.

Synergies with VR × BCI design questions provide more concrete examples of this: scenarios of hopeful features can be concretized with VR, the self-efficacy of recipients can be increased with training or by demonstrating the real effects of their sustainable actions, both of which can be realized with multi-user experiences if applicable groups are found. Examples of such groups include remote training in the sustainable behavior with experts, or meeting people directly affected by the achievements of a sustainability project.

Use Two-way Communication (SC6) Only two design questions were formed using this guideline. This is largely due to its large overlap with VR6, guiding to utilize the social possibilities of digital environments, but a synergy was found in increasing empathy

through VR communications with people involved in the situation as well.

Synergies with VR × BCI design questions provide a much more varied set of possibilities. Multi-user experiences can be used for training, encouragement from experts and people affected by the situation, communications between stakeholders in the sustainability project and recipients directly or indirectly, and applying direct social pressure in the form of social-tipping or social-norm interventions.

Help Recipients Reason by Themselves (SC7) The memorability and easier comprehension of VR contents along with the interactivity of VR lend themselves well to this guideline. Providing realistic environments and scenarios, allowing recipients to manipulate a simulation of the situation, and framing the situation to only the factors that are conducive for reasoning are all among these design questions.

Synergies with VR × BCI design questions largely reaffirm these findings. Additionally, it was discovered that social experiences could benefit from collaborative reasoning.

Utilize Storytelling (SC8) Design questions derived from this guideline highlight the suitability of VR for storytelling: emotional responses and scenarios unfeasible for the real world are both fundamental features of stories, and the interactivity of VR also enables interactive storytelling, a scientific research area all its own. A novel possibility was found in person-to-person storytelling being utilized in multi-user VR.

Synergies with VR × BCI design questions highlight the flexibility of stories as ways to condense information for a desired effect. Recipients could be encouraged by feedback from an interactive story or by convincing them of the effectiveness of their sustainable behavior, mechanisms involving emotions can be utilized effectively. Additionally, multiple scenarios can be used as a cohesive whole, and the engagement and memorability of embodied interactivity can be used to further bolster the effectiveness of messaging in interactive stories.

6.1.2 Behavior Change Intervention Guidelines

BCI2, BCI3, and BCI4 could be used to create design questions with most of the six VR guidelines, while BCI1 and BCI5 could be used with just two.

Follow a BCI Framework: Utilize a Logic Model and an Iterative Process (BCI1) An iterative process is in accordance with agile principles, making it applicable for VR experience development. However, the analysis for specific synergies only provided two design questions. The iterative creation process could be established using VR communications, and that kind of process is an effective way to minimize cybersickness. More synergies could be found if this guideline were more specific, a possible improvement for the framework of this thesis. However, the BCI frameworks explored in Chapter 4 are of a low specificity themselves, and the logic model can look drastically different between different interventions.

Synergies with VR × SC design questions include the two-way communications of an iterative process allowing the direct informing of recipients even before the interventions, while helping the creators of the intervention understand the recipients better for tailored content. Many synergies identify how using a logic model ensures scientific theory is applied robustly, allowing intervention studies to form cause and effect hypotheses for testing.

Utilize Multiple Behavior Change Techniques, Consider Actions Beyond the Intervention (BCI2) While considering the entire breadth of actions available for both participants and creators of an intervention was seen as a valid grouping in Chapter 4, this guideline could possibly be split in two as the synergies found were relatively separate. For utilizing multiple behavior change techniques, using multiple VR scenarios in an experience, possibly in a story, was found as a possible synergy. Isolating these techniques in VR could enable verifying their effectiveness. These techniques are also likely to benefit from the increased memorability and enjoyment of embodied interaction.

When considering actions beyond the intervention, the potential of VR for person-to-person communication and turning complicated concepts into understandable and mem-

orable experiences can enable its use in projects encompassing the intervention.

Improve Comprehension (BCI3) Perhaps unsurprisingly, improving comprehension of the situation was found to have the most synergies out of all BCI guidelines, as it is a fundamental goal of sustainability communication. Scenarios and environments, and social interaction can all be used to improve the comprehension of recipients. More specifically, the framing enabled by VR can be used to provide highly tailored experiences, and seeing the point of view of another can potentially increase empathy.

Synergies with VR × SC design questions include the effectiveness of two-way communication in improving the comprehension of both sides, and the way tailored content ensures both the validity of the chosen subject matter and effectiveness of methods used. The design questions also reaffirm the comprehension improving features of VR such as embodied interaction and framing.

Affect Perceived Capability (BCI4) Guidelines about increasing perceived capability in VR consist of considering providing practice in the target behavior in VR, especially with live feedback, and utilizing multi-user experiences to provide encouragement.

Many VR × SC design questions were found to provide practical ways to realize this training. Stories, interactive simulations, and live connections to experts could be used to give examples of the target behavior being performed and to affirm the target behavior having real effects.

Apply Social Pressure (BCI5) This guideline is heavily tied to social norm and social-tipping interventions, where the sustainable actions of many peers or a small group of highly regarded people, respectively, are demonstrated to recipients. Design questions derived from this guideline highlight two ways to achieve this in VR: direct communication with people acting sustainably, or scenarios that demonstrate it indirectly.

The search for synergies with VR × SC design questions provided more specific ways to achieve this. Multi-user VR experiences can help recipients feel they are in a group where the behavior is expected of them. Stories and other VR methods to increase

comprehension can be used to inform recipients of the existing sustainable actions of others. The feeling of belonging to an in-group is likely to involve strong emotions, so other synergies involving emotions may be utilized in interventions applying this guideline and its related design questions.

6.1.3 Virtual Reality Guidelines

All design questions have already been summarized earlier in the two prior subsections, as they were formed using VR guidelines. This subsection will instead briefly summarize how well each VR guideline synergized and functioned as a part of the framework.

VR1 (Explore Environments and Scenarios Unrealistic for the Real World) and VR2 (Utilize Embodied Interaction/Learning by Doing) are both based on obvious affordances of VR and contributed to many design questions, proving them a valuable part of the framework.

VR3 (Utilize Empathy and Emotions) contributed to the second highest number of design questions. Targeting such subjective feelings might prove difficult, but with the added reliability of theory based communication, following this guideline becomes more realistic for sustainability behavior change interventions.

VR4 (Minimize Cybersickness) contributed to the smallest number of design questions. It might have been less fitting to include in this search for specific synergies than other guidelines, but its inclusion in the framework is still seen as justified. VR4 is an important consideration for user experience, and often applying opposite design pressures than the other guidelines.

VR5 (Take Advantage of the Total Control of the Environment) contributed to design questions based on framing and isolating content. The isolation of content might be an underutilized affordance of VR, usable in never-before-seen studies of isolated concepts to test theories of psychology. Framing, or choosing which sides of a larger context to display for controlled messaging, is something all VR experiences employ to some degree. Realizing this and making sure the message is efficiently delivered requires active effort, where the design questions should prove helpful.

VR6 (Utilize the Social Possibilities of Digital Environments) had the highest number of design questions it contributed to, as synergies were found with every guideline from SC and BCI. Many of these design questions are not generally applicable to any intervention, however. Person-to-person storytelling, VR meetings between stakeholders and recipients in the early parts of the design process, and multi-user experiences in general might take considerable resources to realize, for example. However, the many potential benefits of remote social interaction in a real feeling, high sense of presence environment make this guideline and its relevant design questions attractive considerations in the early planning stages of an intervention.

6.1.4 Usage and Limitations

It is not feasible to follow each guideline and employ every possible synergy implied by each design question in a single VR intervention. Instead, all guidelines and questions should be considered to the extent of their feasibility for any given intervention. As implied by the term "design question", the framework is primarily designed to be used in the design process of the experience. However, as one of the commonalities between SC, BCI, and software development, an iterative, agile development process is recommended where the design phase is visited multiple times. Additionally, some of the design questions touch on preliminary planning, iterating after testing, and even actions beyond the intervention, making the framework somewhat applicable for the entire creation process.

The guidelines were derived from converging results from multiple sources. However, these sources were not gathered through an explicit scientific literature review. Further research must be done to increase the validity and reliability of the framework, including further examination under scientific rigor, and exploring its use with real interventions. This should result in iterating: proving which guidelines and design questions are the most valuable, removing the less valuable ones, and potentially finding additional ones.

A step toward this validation process will be done in chapters 7–9, where it is evaluated for practical and theoretical applicability for a real VR sustainability behavior intervention.

Overall, the framework should prove to be a valuable tool to explore the design space and help validify the scientific basis of any VR behavior change intervention for environmental sustainability. The guidelines were created from converging evidence from multiple sources and a thorough search for synergies between them was conducted. The resulting framework contains many considerations the developers of an intervention can choose between according to their needs. Additionally, the lists of guidelines could be applied separately to their respective areas of research.

7 Pilot Study

Parallel to the creation of this thesis, a pilot study was conducted as part of a university and industrial collaboration project. This *Sustainability Through Information Flows* project [1] had the goal of increasing the flow of sustainability information through the entire Finnish shipbuilding infrastructure. In the study, a VR experience was evaluated, designed to act as a platform for sustainability communication, entertainment, and an intervention on green purchase behavior. It was designed using the framework created in this thesis in combination with green purchase behavior research.

This chapter will describe the study and applicable theory. The following chapters will analyze how well the experience succeeded in its goals, answered its research questions, and most importantly for this thesis, reflect how well the framework is applicable to a real intervention.

7.1 Overview of the Study

This section will give an overview of the experience and the accompanying questionnaire. Due to confidentiality, some details of the experience and questionnaire will be omitted. The research questions of the study will be shortened to "SRQ" to separate them from the research question of the thesis. They were as follows:

- SRQ1: How can a virtual reality sustainability application with a focus on scientifically accurate communication be designed to have a good user experience?
- SRQ2: Can a virtual reality sustainability experience be used as entertainment for cruise guests?

- SRQ3: How can a virtual reality sustainability experience be used to affect sustainable purchase behavior related to cruises?

The target group of the experience was *cruise guests* of family cruises, meaning customers on board. Scientifically accurate communication in this context means that the content is made while upholding accuracy and truthfulness (as per guideline SC3), and is used to communicate a substantial amount of information. The sustainable purchase behavior related to cruises was the purchase of tickets to a greener cruise. The study was done in collaboration with a cruise line company and a shipyard company.

It was a one-shot case study, meaning a pre-experimental single-group posttest-only study. The recipients participated in a standardized experience, which acted as a sustainability intervention. Observational field notes were collected during testing, immediately followed by a survey.

As cruise guests of a relevant cruise type were unavailable, the test group consisted of workers employed to work on such cruises (n = 46) and employees of a shipyard company, with heavy ties to such cruises (n = 24) for a total test group size of 70. Recruitment was primarily done on-board a cruise ship in a late stage of construction, housing workers of both types. Testing was also performed in the facilities of the shipyard company on two subsequent testing sessions. In all cases, workers were invited to take part in the experience by raising their interest in the testing session with internal company communication, and visual aids such as posters and a screen displaying gameplay of the experience. Light verbal persuasion was also utilized.

All three testing locations employed a similar design: two testing stations consisting of Quest 3 VR headsets and controllers on two chairs were available, allowing two simultaneous users. A tester would play through the game for as long as they wanted, approximately taking anything from a few minutes (if they ended the experience early) to half an hour.

The testing situations were also monitored by two to four university researchers and shipyard personnel, who made observations during testing.

The experience itself was an interactive VR story about building a ship and choosing

how it operates, making sustainable or unsustainable decisions along the way. The sustainability was limited to environmental sustainability. More specifically, it was limited to fuel use. As an intervention, it aimed to increase purchase behavior regarding greener cruise tickets.

7.2 Applied Theory

As sustainability communication, the experience could be primarily categorized as communication *for* sustainability, aiming to change behavior. It also employed communication *of* sustainability, as displaying the sustainable actions of the company was also a goal. Communication *about* sustainability was kept to a minimum. Science communication was avoided altogether to keep the experience concise and entertaining.

As an XR experience, a purely single player VR scope was applied. An HMD and a mostly embodied control scheme were utilized in a low-intensity interactive story.

As a behavior change intervention, no explicit theory of behavior was followed. This was partially due to the limited amount of resources and access to end users not allowing for a heavily focused intervention. For example, the capabilities of the recipients and context surrounding the purchase of greener cruise tickets could not be established. Due to this limited reach, an individual ecological level was chosen as its scope. Despite these limitations, the intervention was theory-based. Theory regarding *green purchase behavior* (GPB) was utilized to form a logic model.

Next, the GPB theory utilized will be analyzed more explicitly. GPB refers to buying ecologically sustainable products and services, such as a ticket to a green cruise, seen as a service in this study. The determining factors of GPB include subjective and personal norms, environmental concerns [80], attitudes, environmental knowledge, personal behavioral control, and perceived consumer effectiveness. [45] [47].

As the theory of planned behavior is the most prevalent of theories used among GPB studies [47], personal behavior control might be overrepresented as a factor. At least one study found it to have an antagonistic effect with GPB instead [45]. For these reasons,

it was left out of the tracked and affected determinants of the intervention. Personal behavior control and perceived consumer effectiveness were assumed to be hard to affect and hard to fit into the experience, and were left out as well.

Affecting the level of environmental concern of the recipients could have been realized by focusing on fear-inducing and depressing facts about the environment. This would have run counter to both the experience's value as entertainment, as well as guideline SC5, which advices prioritizing hope over fear. It was therefore tracked for any incidental increases, but was not an explicit target determinant.

As a somewhat obvious but necessary confirmation, multiple studies have confirmed that a lower price and a better product quality often outweighs ethical considerations of GPB [45] [47]. The pricing of greener tickets was not something accurate claims could be made about, but plausible service quality was. Because of this, perceived service quality was one of the determinants to be tracked, and it was an explicit target determinant to be changed as well.

While not listed as a determinant in the logic model of this intervention, attitudes have considerable overlap with personal norms and the level of environmental concern that were used as determinants. Instead of affecting attitudes, one possible avenue is affecting the green attitude-behavior gap, which is a well documented phenomenon in this field as well [47]. Four possible causes for the gap are [51]:

- Having direct versus indirect experience.
- Normative influences.
- Temporal discrepancy between measure of attitudes and behavior.
- Attitude-behavior measurement, or how measured attitudes often have much broader scope than any specific measured action.

Incidentally, immersive technologies like VR should enable more direct experience with scenarios and environments related to sustainability. For GPB specifically, a significant factor in the attitude-behavior gap appears to be the lack of consumer trust in greenness claims [47].

Labeling products as ecological seems to provide limited results as consumers do not understand their validity and meaning [45]. Increasing user trust in green claims, such as the greenness of a greener cruise, is thus one of the tracked and explicitly targeted determinants.

An important factor influencing the effects of sustainability media is existing foreknowledge of sustainability, which seems to correlate with personal interests and educational background [4, p. 327]. A multi-study analysis seems to indicate the importance of mass media in the amount of pre-knowledge people have, but the effects on behavior are unknown, with ambivalent study results [4, p. 328]. Factors like these are well beyond the scope of a VR intervention, and explicit targeting of this determinant during the experience could have compromised the entertainment value of the experience. It was therefore left out as an explicit target determinant, but tracked for incidental changes.

Personal norms, frequently found to be one of the main determinants in GPB, were found to be fully mediated by purchase satisfaction in one study [80]. In other words, the reason why people whose personal norms align with GPB seem to make sustainable purchasing decisions is because it makes them satisfied. This is further supported by a study on the effects of intrinsic motivation on GPB [81]. As personal and subjective norms are very difficult to influence, changes to assumed purchase satisfaction were tracked in the intervention instead. It was also presumed that all other determinants affect assumed purchase satisfaction to some capacity.

Figure 7.1 summarizes the logic model based on the theory introduced in this section.

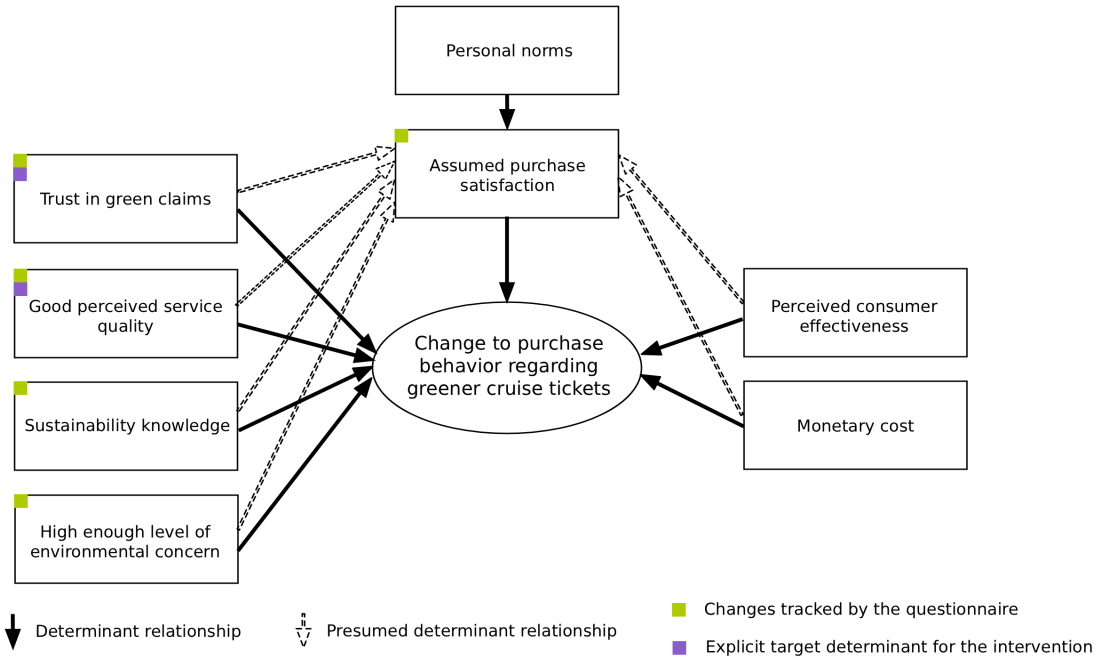

Figure 7.1: Logic model of the behavior change intervention

To further clarify this model, a few disclaimers should be made. Sustainability knowledge refers to overall understanding of sustainability, which the experience presumably affected to some degree for some users, even though the term was only briefly touched on in the experience. For assumed purchase satisfaction, it would be more accurate to say it has a mediating rather than deterministic relationship with personal norms. As all other determinants were presumed to increase assumed purchase satisfaction, it was hypothesized increases would be found in this determinant as the two explicit target determinants increase. The experience applied techniques to increase trust in green claims and perceived service quality. These techniques could not be tested in isolation or contrasted with alternative techniques, thus not allowing to draw certain conclusions about their effectiveness. It is likely this would be impossible, however, as an experience like an interactive story is irreducible to the sum of its components. Techniques for increasing the two indicated determinants are further analyzed in Chapter 8.

7.2.1 The Experience

The context of the experience necessitated evaluation as potential entertainment on board a commercial family cruise. This guided the design of the experience greatly, as usability for a varied audience, engaging contents, and aspects such as aesthetic qualities had to all be realized. The tone of the experience was comedic and light-hearted.

The sustainability communication focused on increased sustainability through fuel use decisions, showcasing current and future methods to save fuel or decrease the greenhouse gases produced by fuel choices. The topic of sustainability can be extremely complex and emotionally taxing, necessitating a brief experience. However, informing recipients enough to reason by themselves is effective for sustainability communication (as per guideline SC7). These two considerations applied conflicting design pressures, which is why sustainability communication topics were limited to just fuel use. It was chosen for contributing greatly to the lifetime greenhouse gas emission of a cruise ship, for the many design decisions for cruise ships revolving around it, and the cruise company having promising statements regarding their future fuel use available.

In the VR experience, the user was transported into a virtual world, an interactive story where an assistant robot takes them through building a ship for the cruise company and choosing how it operates. The process was heavily simplified, as the entertainment value for the target audience would suffer from long technical explanations.

The experience had the player enter computer-generated 3D environments mixed with stereoscopic 360-degree images and videos of the real world. In these environments, they received sustainability information and advanced in the story through simple embodied interaction. This is best demonstrated by the following example:

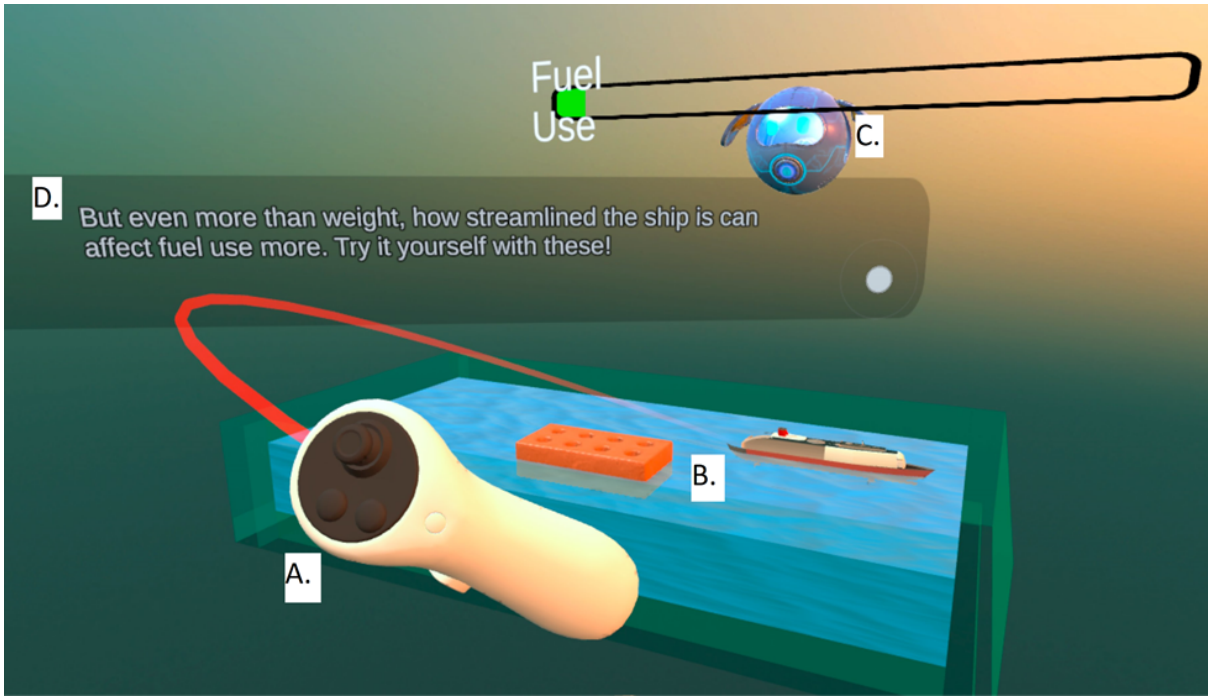

Figure 7.2: Example of the gameplay

The user would see an immersive 360-degree image of a shipyard surrounding them, replaced in Figure 7.2. due to confidentiality. There, they would receive text (D.) and text-to-speech dialogue from the assistant robot (C.) on how the shape of a ship hull can affect fuel use. In the figure, the robot has floated around the user, directing their attention to a set of two shapes in a water tank (B.). The user could use their controller (A.) to experiment with the shapes, noticing they resist movement in the water differently, and moving them has different effects on the Fuel Use meter (C.). This embodied demonstration would act as a supporting part of more extensive dialogue given by the assistant robot.

The experience contained multiple similar simple interactions, but the main method of informing the user was through dialogue given by the assistant robot. Information was divided into mandatory and optional information, allowing users a degree of freedom. Users could make choices, such as whether to view optional information or not, through an embodied interface available for most of the experience. Rectangular plates with text floated around the user, triggering dialogue, registering choices, or advancing in the experience when placed in a 3D-modeled receptacle floating in front of the user.

There were three main areas in the experience that the user advanced through sequentially. These areas corresponded to three types of decisions affecting the fuel use of a ship: hull and miscellaneous fuel efficiency solutions, current and future fuel choices, and operating decisions of the ship. In each, information on the topic could be received through a mixture of embodied interaction and dialogue. At the end of each area, a choice was made between a sustainable and unsustainable option. The dialogue in the game heavily encouraged the user to pick the sustainable option, which "rewarded" the player with positive feedback from the assistant robot. Making an unsustainable option would lead to a narrative anticlimax, which was meant to be comedic in tone. The final area, corresponding to operating decisions, included a small game where the user could steer the ship they had created while receiving dialogue from the assistant robot. After the steering game, and the user choosing between operating sustainably or unsustainably, a summary of the the user's choices was given. Lacking the earlier comedic and lighthearted tone, the results of their choices were given, such as the ship being taken out of service for violating company pollution policy. The user then had the option to make new choices and see different summaries. After this, the experience ended and they were asked to fill a questionnaire.

The experience was created with the development platform *Unity* by a single developer. Development resources did not allow the creation of a commercial-grade product, but effort was put into visual quality to make it comparable to existing entertainment products. It was created to run locally on the Meta Quest 3 headset [82], which applied hardware limitations when compared to VR experiences that use the resources of a PC. Running locally on an HMD was estimated to be considerably less cumbersome to realize as cruise entertainment.

Tutorials were provided as text boxes that appeared when a new action was required for the first time. Unlike dialogue, tutorial text was not read out loud by text-to-speech, but contained a real-world video of performing the required button press and/or movement on the controller. The number of required actions was kept to a minimum, with most interactions performed through an unchanging interface of pointing a laser coming

from the controller at an object, and grabbing it by holding any of the trigger buttons on the lower half of the controller. This enabled moving the object until released. The only other action available for the user was advancing dialogue by pressing any of four different buttons on the controller.

The experience was played while sitting down. This was done for safety considerations, but provided other advantages as well, such as increased comfort and accessibility, and reduced complexity in setting up the use environment in the real world. This posture does have disadvantages as well, namely the amount of locomotion precision, and the limited potential for vection (the illusion of movement) and engagement through embodiment when compared to being allowed to walk around in the real world [59].

The experience was created with minimizing VR sickness in mind, as per guideline VR4. Some of the most prevalent technical causes for VR sickness include display quality, refresh rate of the screen, flickering, and latency. Additionally, VR sickness is affected by the content of the experience, such as the degree of vection, rotatory movement, especially multi-axis, lack of fixed visual stimuli, duration, and lack of control. [77] Compared to older HMDs, the Quest 3 headset has a good display quality [83], which includes low amounts of flickering and latency. The refresh rate of the screens are affected by how computationally intensive the software is. Through optimization, it was kept close to 60 Hz through most of the experience, but sometimes dropping close to 20 Hz. Low refresh rates of the visuals have been found to contribute to VR sickness, even when not noticeable [77], which was assumed to affect VR sickness caused by the experience. The user could not move in the experience beyond head movement, limiting the ill effects of vection, and being moved against their will (lack of control). The experience being relatively long, taking around 20 minutes to complete, was estimated to be a potential risk for VR sickness as well.

7.2.2 Questionnaire

The questionnaire contained the following categories of questions:

- Demographic, including age and gender, familiarity with VR, familiarity with cruise

guests, and work experience.

- User experience, including a short form User Experience Questionnaire (UEQ-S) and questions about VR sickness.
- Evaluation on the suitability of the experience for cruise guests in the form of an estimation UEQ-S.
- Questions on changes to the determinants of green purchase behavior (GPB).

Some questionnaire questions are omitted due to confidentiality. The questionnaire relied on self-reporting, consisting mostly of choosing between options and points on a scale. A small amount of open-ended questions were included as well. Some questions were optional to answer, such as every open ended-question.

Demographic data was gathered to form correlations and potential explaining factors when compared with other results. Experience with VR technology was divided into having no experience, having tried it once or twice, having used it multiple times, using it monthly, and using it weekly. Experience with cruise guests was gauged with a question as well.

A shortened version of the *User Experience Questionnaire*, the UEQ-S [84] was used. It is a self-assessment tool for user experience, consisting of a seven-point scale between eight pairs of opposing adjectives, chosen by respondents based on their intuitive estimation. Four of the pairs on the questionnaire can be used to assess the pragmatic qualities of the experience (usability), and four others for hedonic qualities (enjoyment).

A tailored method for gathering expert-by-experience opinions on suitability for cruise guests was utilized. Respondents were asked to estimate how a guest would rate the experience on a second UEQ-S, referred to as the *estimation UEQ-S* in this thesis. They were also asked to explain why the guests would give such ratings via an open-ended question. The results of these two items in the questionnaire could be contrasted with the UEQ-S they filled for themselves to allow for further estimation on suitability.

VR sickness was evaluated since it is an important factor for user experience and for suitability as cruise entertainment, and deemed an important aspect in guideline VR4. It

consists of varied physiological sensations of feeling ill from VR exposure. Questions for capturing this variance were derived from the symptoms used in the *VR Sickness Questionnaire* [71], which are sorted into oculomotor and disorientation categories, with the addition of nausea from the *Simulator Sickness Questionnaire* the VR Sickness Questionnaire is based on. Easy to understand symptoms assumed to be representative of each category were chosen to be tracked via self-reporting: nausea, headache or eyestrain, and disorientation or dizziness. The full VR sickness questionnaire was not used to limit the overall length of the questionnaire.

As tracking actual changes to green purchase behavior was impossible, alternative methods had to be deployed. As the attitude-behavior gap for sustainable behavior would render direct self-reporting of purchase intentions less effective, a slightly novel method of self-reporting was used instead. Important determinants for green purchase behavior were chosen, and respondents reported on changes to these determinants in the questionnaire.

A selection of determinants affecting green purchase behavior was chosen to be key targets for the pilot as a behavior change intervention. These were assumed purchase satisfaction, trust in green claims, and perception of service quality. Additionally, while not a focus for the experience itself, changes in sustainability knowledge and environmental concern were tracked as well. The reasoning for these choices is covered in Section 7.2. The chosen green purchase behavior was the purchasing of greener cruise tickets. Trust in the greenness of the service was fostered in the experience through a thorough explanation of factors affecting fuel use, helping recipients reason by themselves. Perception of service quality was fostered through assurance that reductions in fuel use do not have to directly impact cruise enjoyability.

8 Results of the Pilot

This chapter will give an overview of the relevant results of the pilot. These results are, as per its research questions, divided into user experience, including VR sickness, suitability as cruise entertainment, and effectiveness in changing the determinants of green purchase behavior. Estimating the user experience of the experience is relevant since enjoyability is a large contributing factor to how engaged users are with it, increasing its effectiveness as an intervention. Interventions also never exist in a vacuum, making estimating its suitability as cruise entertainment a relevant consideration.

8.1 Overall Results

Of the 70 respondents, 79% reported some degree of familiarity with cruise guests, with 37% being very, or extremely familiar with them, as Figure 8.1 illustrates. This top 37% of respondents will be referred to as *experts* in this thesis. 75% of shipyard workers reported some degree of familiarity with cruise guests, with 9 categorized as experts, indicating good overall familiarity. Most respondents were male (77%) and in the 31-50 age bracket (60%), with all but one of the respondents above the age of 21. Around three fifths of the respondents had some prior experience with VR, with 7% using VR at least monthly. 23 respondents ended the experience early, referred to as *early enders* in this thesis. These early enders sometimes gave reasons to the test staff such as running out of time they can spare from work, and a certain scene triggering their fear of heights for two testers, but most often no reason was given. Those finishing the experience will be referred to as *finishers*. A typical playtime of a user was estimated to be 20 minutes.

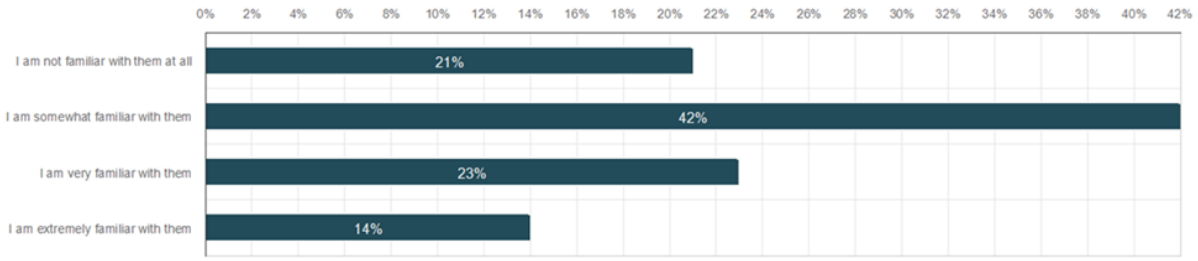

Figure 8.1: Respondent familiarity with cruise guests.

8.2 User Experience

User experience is tracked through the results from the UEQ-S and VR sickness questions, as well as observations made during testing. Some users were observed having considerable usability issues at the start of the experience, unable to use the point-and-grab interface without assistance.

The average of all items is 5.4, which is considerably above the scale midpoint of four. The averages for pragmatic (first four item pairs on the UEQ-S) and hedonic qualities (last four pairs on the UEQ-S) showed no significant difference.

Two factors were found to have a great effect on the average rating given in the UEQ-S displayed in Figure 8.3. Possible reasons for these results will be discussed in Chapter 9.

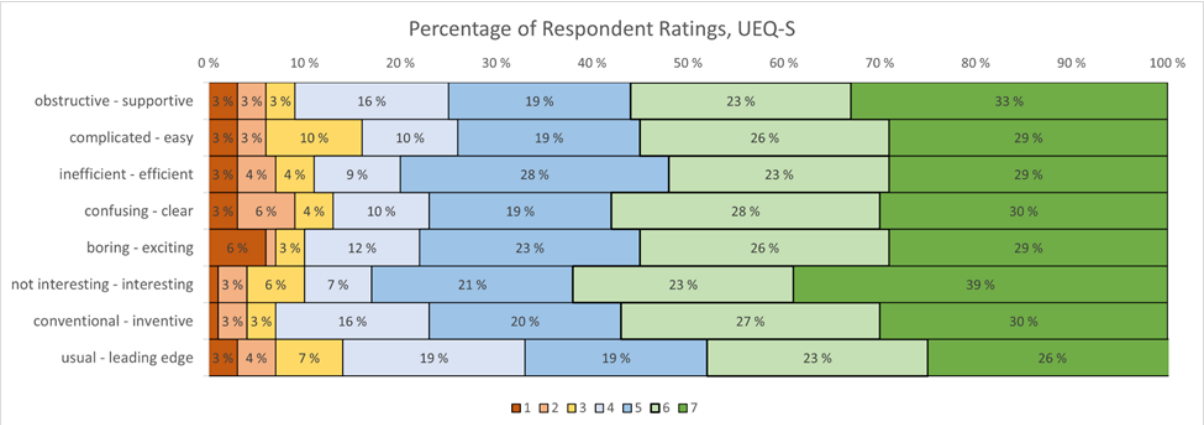

Figure 8.2: UEQ-S results, on a scale between the item pairs on the left.

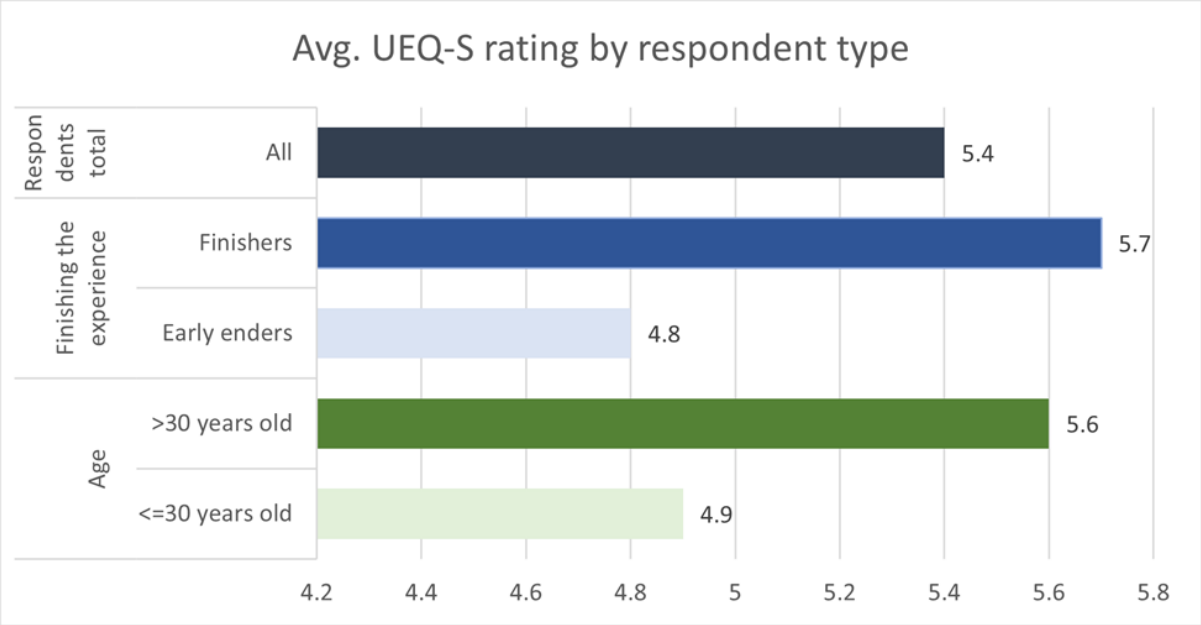

Figure 8.3: Significant factors affecting the average of all UEQ-S items.

8.2.1 VR Sickness

A relatively high prevalence of VR sickness was reported. As Figure 8.4 illustrates, this was particularly the case with nausea. However, even respondents who felt an extreme, or close to extreme level of nausea (rating of 4 or 5) gave a relatively high average rating of 5.2 in the UEQ-S. 85% of those that felt extreme or close to extreme nausea were cruise company employees (base rate 66%). Respondents with no nausea (rating of 1) gave slightly higher UEQ-S ratings (Avg. = 5.6), had no meaningful difference in the GPB determinants, and only had a very slightly higher rate of finishing the experience (71% for the no nausea group, 67% baseline). 32% of the no nausea group had used VR multiple times (20% baseline).

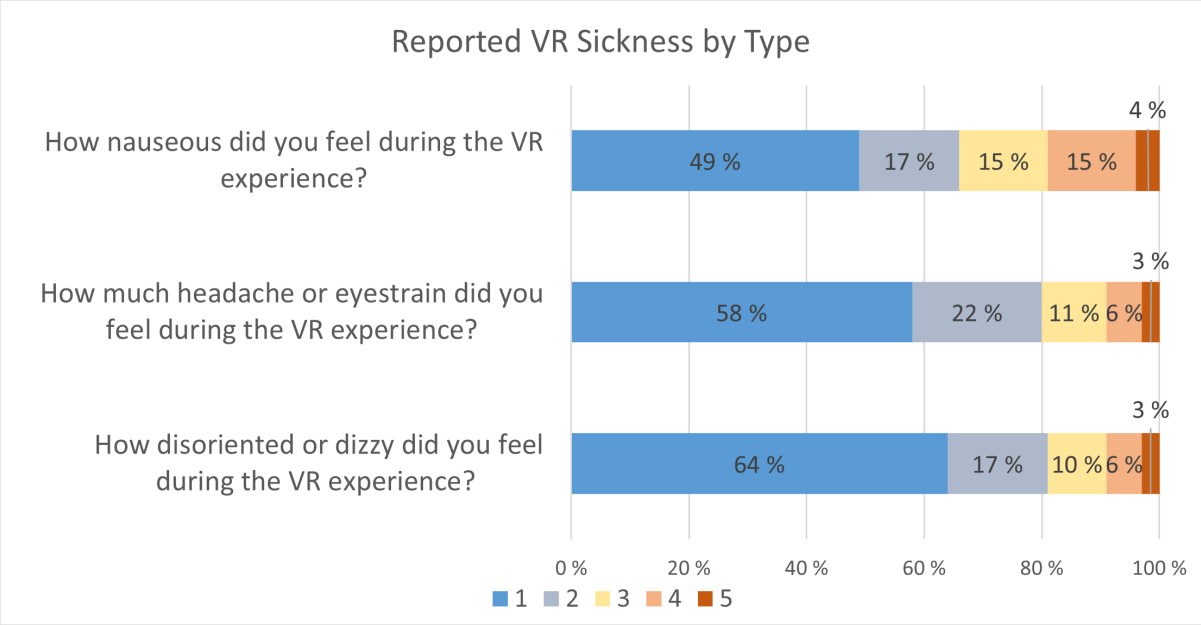

Figure 8.4: VR sickness results, 1 corresponding to "Not at al", and 5 to "I felt this to an extreme degree"

8.3 Suitability as Cruise Entertainment

During testing, observations were made about practical considerations for implementing a similar VR experience on a cruise. Participants were observed communicating with people outside VR, sometimes involving getting near the VR user. A large number of users required assistance with the experience, often during the tutorial for grabbing the plates with text on them and bringing them to the choice receptacle. During testing, one screen displaying gameplay from one HMD was present. This screen filled two roles, both found to be important: allowing test personnel to see what the participant is seeing for troubleshooting, and raising the interest of passersby in the experience.

The overall user experience is a major factor in its applicability as entertainment, the results of which are displayed in Section 8.5.1. The user experience for cruise guests specifically was evaluated using the estimation UEQ-S (second UEQ-S where respondents estimated what cruise guests would answer), displayed in Figure 8.5.

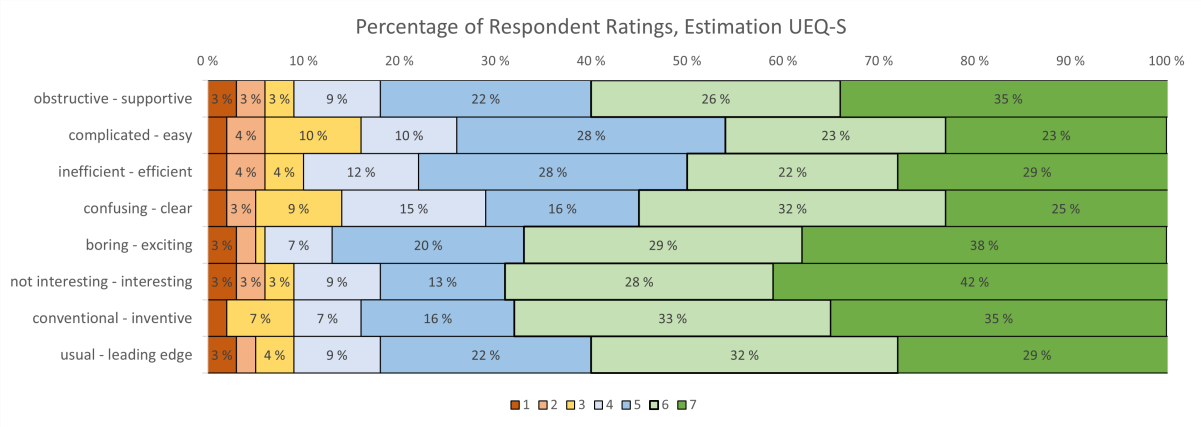

Figure 8.5: Estimation UEQ-S results, on a scale between the item pairs on the left.

The average score for the estimation UEQ-S was 5.6, which is slightly higher than the average of the earlier, typical UEQ-S (Avg. = 5.4). A clear difference in pragmatic and hedonic ratings can be seen here, with an average of 5.4 for the pragmatic quality, and 5.8 for the hedonic quality. 69 responders answered the estimation UEQ-S, 34 of whom also provided open-ended answers as to the rationale behind their rating. These answers had seven responses alluding to something being ill-fitting for cruise guests, and 20 responses giving positive feedback. The most common ill-fitting allusion was that the experience was too complex (four responses).

8.4 Effectiveness as a Sustainability Intervention

The experience could be seen as a way to inform cruise guests of the sustainability efforts of the shipyard and cruise companies, rather than as an explicit intervention. This manifested itself in a focus on the entertainment and usability aspects and in the large number of topics covered by the questionnaire, which limited how thoroughly it could be evaluated as an intervention. Regardless, its evaluation as a behavior change intervention was used as a measure of its success, since behavior change is the most desired goal of sustainability communication (see Section 3.1). Changes to green purchase behavior determinants are illustrated by Figure 8.6.

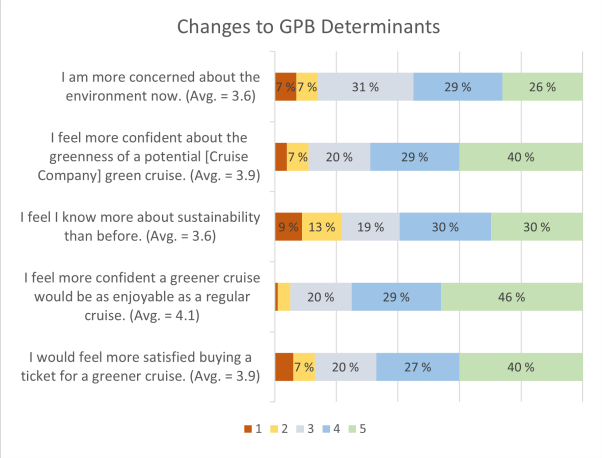

Figure 8.6: Level of agreement with statements on changes to GPB determinants. 1 corresponding to "Disagree", 5 corresponding to "Agree".

Each statement corresponds with changes to one of the tracked determinants, in order:

- Increased level of environmental concern.
- Trust in green claims (Cruise company name replaced with [Cruise Company] in the figure).
- Sustainability knowledge.
- Good perceived service quality.
- Assumed purchase satisfaction.

The greatest changes were reported on the determinants the intervention explicitly targeted (trust in green claims and perceived service quality), and assumed purchase satisfaction that was presumed to increase as all other determinants do.

8.5 Discussion of Questionnaire Results

In this section the results of the questionnaire are discussed further. Each subsection covers one of the three research questions, followed by overall conclusions.

8.5.1 User Experience

SRQ1 was as follows: How can a virtual reality sustainability application with a focus on scientifically accurate communication be designed to have a good user experience?

A focus on scientifically accurate communication meant truthfully relaying a substantial amount of sustainability information. A concession made in the design of the experience was to sacrifice information specificity in favor of demonstrating broad concepts and providing an overview of the most significant factors for fuel consumption. This means the experience was not made to communicate numerical data and difficult to understand concepts typical for sustainability. Careful consideration was put into wording the information accurately, mentioning the sources of claims if they could be contested, and only claiming something as factual if it was abundantly clear it was. It could be argued that the way the experience focused on positive messages and future potential did not give a comprehensive picture of the downsides of fuel use, but this could have hindered its effectiveness as an intervention (SC5). Overall, a focus on scientifically accurate communication was held.

The results from the UEQ-S and VR sickness questions, as well as observations made during testing were used to answer this research question. The story elements presumably successfully made the user experience better, as the UEQ-S ratings were very promising and no negative feedback was received regarding the story itself. The experience was rated as highly interesting, and 12 of the 34 responses to the open-ended question of the evaluation UEQ said it would be “informative”, “interesting” or that cruise guests would be “curious”. The simplified communication in the experience was effective at upholding interest. The experience also employed 360-degree images of the inside of a ship under construction and of the shipyard, a feature alluded by two respondents as specifically interesting.

A considerable number of respondents ended the experience early. Four main compounding reasons are thought to be the main contributors to this: VR sickness, usability issues, the length of the experience, and the limited time some recipients had in the testing situation.

The experience was created with minimizing VR sickness in mind. Users were not permitted to move in the virtual world, thus limiting the ill effects of vection and multi-axis movement. The head movements of the users always turned the point of view in the experience, ensuring control was never taken away. The experience was running inside the headset, ensuring minimal latency. The end of the experience included a ship steering game, where a moving texture and approaching rocks were used to simulate a moving ship, which may have contributed to VR sickness, but a stationary platform the user stood on acted as fixed visual stimuli. The reported prevalence of nausea was surprisingly high regardless. Low refresh rates of the visuals have been found to contribute to VR sickness, even when not noticeable [77]. Optimization issues and limited hardware capabilities caused the frames per second to go below 30 at certain points of the experience. The processing power of contemporary HMDs is a limiting factor on the adoption of VR as a medium for custom-created guest-suited entertainment applications, but an application with less complex 3D models and more resources put toward optimization could alleviate these issues.

Early enders reported slightly higher levels of VR sickness across all categories (Early ender nausea Mdn. = 2, headache or eyestrain Mdn. = 2, disorientation Mdn. = 1.5) compared to finishers (finishers, all categories of VR sickness Mdn. = 1). It is likely nausea caused some users to be early enders, but as prolonged exposure to VR can increase VR sickness, the extent of this might have been confuscated.

Contrary to the findings of Kim et al. in their influential article on the Virtual reality sickness questionnaire [71], nausea was more prevalent than the oculomotor and disorientation categories of simulator sickness. This, along with the high user experience ratings of those who reported feeling nausea, suggest that the negative effects of nausea might have been more limited in practice than the questionnaire results suggest.

Some users were observed having considerable usability issues. The point-and-grab user interface was not as intuitive as assumed. A number of users needed verbal instructions that repeated the contents of tutorials. These problems were not observed on all users, but likely contributed to the number of early enders.

The responses of those ending the experience early were compared to those that did not. 43% of those working on the ship were early quitters, a percentage which only reached 11% for on-shore workers and 25% for shipyard workers. This is evidence toward the fact that some workers had less time for the experience, though other demographic factors may be at play as well.

Early enders rated the experience as more obstructive and complicated in the UEQ-S. Predictably, overall user experience ratings were lower as well (Avg. = 4.8 for early enders, Avg. = 5.7 for finishers).

As even the early enders rated the experience above the scale midpoint of four, with finishers rating it greatly above, the experience had a very good user experience overall. The experience took advantage of certain affordances of virtual reality: the user interface utilized embodied interaction where possible (VR2), and immersive environments were explored that were not accessible by users in the real world (VR1).

It is unclear what caused the lower ratings of respondents under 30-years old seen in Figure 8.3. The difference was seen in both pragmatic and hedonic qualities. Neither gender nor not having any previous VR experience were found to explain these results. Generational demographic differences, such as amount of exposure to similar non-VR technologies (e.g., video games), amount of exposure to different media (e.g., social media) are potential explanations for these findings. As such things were not captured by the survey, further research is required.

Respondents with no prior VR experience were expected to be more impressed by the experience (higher hedonic rating) and have more difficulties using the experience (lower pragmatic rating). However, both groups had the same rating for the pragmatic quality (Avg. = 5.3) and only a slight difference was observed in the hedonic quality (Avg. = 5.4 for first time users, Avg. = 5.2 otherwise).

Overall, some clear issues were found, but the average user experience was good, matching the research question.

8.5.2 Suitability as Cruise Entertainment

SRQ2 was as follows: Can a virtual reality sustainability experience be used as entertainment for cruise guests?

As user experience was deemed an important factor in its suitability as cruise guest entertainment, the answer to SRQ1 is relevant as well. The overall good user experience indicates suitability for entertainment, but the observed issues, VR sickness and usability issues for some users, indicate the opposite. A real entertainment product could have mitigated these issues by, for example, an increased development budget and testing with end users.

The questionnaire employed a novel method for measuring specific suitability for cruise guests: the estimation UEQ-S and its accompanying open-ended question. The results of a novel method should be taken as indicative before its validity is verified through further testing. What these results indicate is that the guests specifically would find the experience entertaining.

The overall rating was higher than respondents gave on the conventional UEQ-S, which remains true when filtering only for the expert responses (expert conventional UEQ Avg. = 5.5, expert estimated UEQ Avg. = 5.7). The greatest contributor to the gap between pragmatic and hedonic qualities visible in Figure 8.5 is likely the usability issues addressed previously.

Only one respondent, a non-expert, said the experience would not be suitable for cruise guests as guests do not care about sustainability. This notion is contested by four expert opinions saying the experience would be interesting for guests specifically. Filtering only for expert responses, five out of nine said guests would appreciate the experience for being new or innovative.

Early enders had a considerably lower estimated suitability for guests on the estimation UEQ-S (Avg. = 5.0). Interestingly, there was no meaningful change to the gap between pragmatic and hedonic qualities compared to the total set, even though early enders reported lower pragmatic qualities on the traditional UEQ-S.

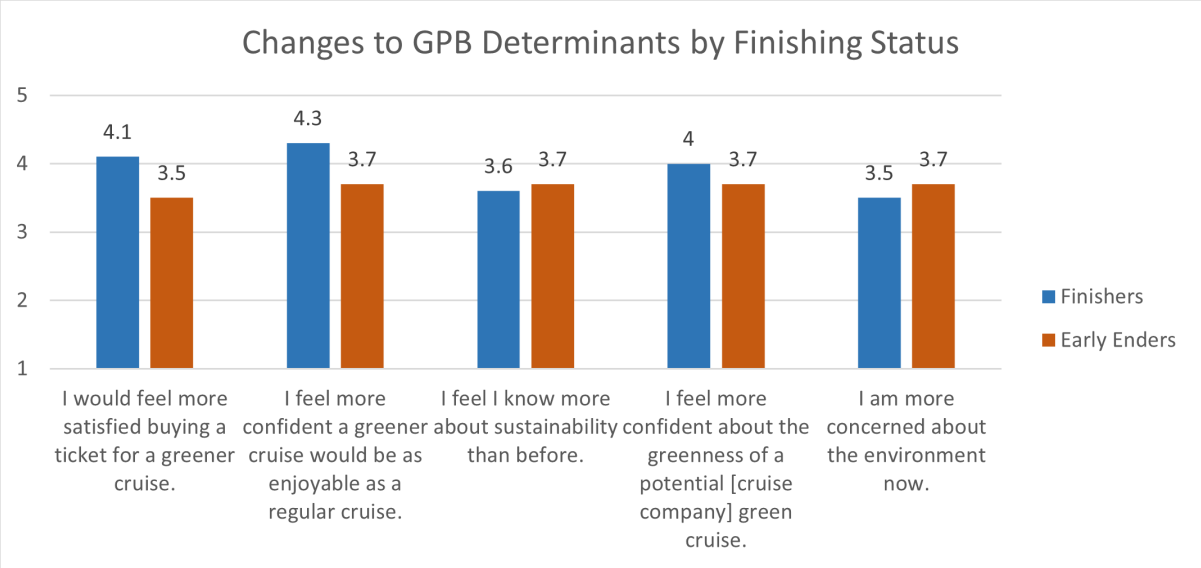

Figure 8.7: Changes to the average rating of GPB determinants. Finishers report higher changes to only purchase satisfaction, perceived product quality, and trust in green claims.

8.5.3 Effectiveness as an Intervention

SRQ3 was as follows: How can a virtual reality sustainability experience be used to affect sustainable purchase behavior related to cruises?

The chosen green purchase behavior was the purchasing of greener cruise tickets. The experience affected this behavior as an intervention, with the aim of increasing this purchase behavior. Direct measures of this behavior before and after the experience were not feasible, thus affectable determinants were sought in the logic model instead (Figure 7.1). Changes to these key determinants were measured by self reporting, providing indicative results. These results displayed in Figure 8.6 are promising. The greatest change could be seen in determinants directly targeted by the experience, service quality and trust in green claims, and in purchase satisfaction that the other two should act as determinants for. Another piece of evidence for the validity of the logic model and success of the experience as an intervention on specific determinants can be found when comparing early enders with finishers. As shown in Figure 8.7, three of the determinants saw more change for finishers.

The experience was tailored to increase only the key determinants, which stand out from other determinants only for respondents who had the intended, complete experi-

ence. This indicates deliberateness and success in the chosen methodology over random variance. The scale in the question ranged from "Completely disagree" (1) to "Completely agree" (5). In all cases shown in this thesis the average was over 3, meaing the recipients agreed more than disagreed. The reason why this is the case even for determinants that were not targeted is presumably the inherent bias in self reporting toward positive feedback.

As for behavior change techniques the experience employed, none were explicitly theory-based, but tapped into similar mechanisms as theory suggests. These are further analyzed in Section 9.2. Trust in the greenness of the service was fostered slightly throughout the experience by providing a comprehensive but non-specific overview of factors affecting fuel use. The main mechanism is believed to be a practical explanation toward the end of the experience, where changes to scheduling can save fuel. This explanation is also the intended mechanism for increased perceived product quality, as the user is assured a greener cruise could have a scheduling change instead of compromising in service quality. This explanation was delivered by the assistant robot while the user was entertained by a ship steering game.

8.5.4 Conclusions about the Pilot Results, Future Work

As the study relied on self-reporting, the results can be bolstered through other venues, such as biofeedback, follow-up studies to track actual changed behavior, and different kinds of expert evaluation. The test group were experts on cruise guests. Confirming the scientific validity and reliability of the research method of using such a test group could be done by studies measuring both the expert evaluation and the final target group themselves. A study on the cruise guests directly could greatly contribute to the findings of this study. Such a study would also reveal more on the practical suitability of a VR sustainability experience as entertainment for cruise guests. Heavily involving cruise company representatives responsible for designing and approving cruise entertainment for future studies can also contribute to this.

Overall, the experience achieved promising results on the metrics used in the study,

while also revealing areas for improvement. Taking part in the maturation of the fields of sustainability communication, behavior change interventions and virtual reality research, this study hopefully provides new insights in these fields and acts as valuable data on the use of specific methods.

9 Discussion of the Framework and Study Results

In this chapter, the framework created in this thesis will be reflected on by analyzing the pilot. Each guideline will be evaluated for suitability for interventions in practice by considering its use in the pilot. For each guideline, relevant design questions formed from the guideline are also evaluated on their suitability for a practical intervention. This single use case enables a more thorough discussion of the framework and its specific items, and a cursory evaluation of it.

9.1 Framework Evaluation: Sustainability Communication

Use Innovative Alternatives to Mainstream Communication Methods (SC1) Evidence was found of the novelty factor of VR raising interest in the experience. Outside the experience, the screen displaying VR footage for passersby was observed to increase the number of potential participants that stopped to observe the testing situation. As for raising interest in the message inside the experience, the experience was rated as highly interesting in the UEQ-S, indicating success. However, conclusions about the determinants of this interest cannot be made without a control group. The hedonic qualities of the experience (including a scale between not interesting and interesting) were rated highly by both first time and somewhat experienced VR users, indicating the rating was not purely the resulf of the "wow-effect" of first time VR use. Weekly and

monthly users of VR reported a noticeably worse user experience (avg. of all items = 4.8) than the total average (avg. of all items = 5.4), a possible indication of the importance of SC1. Only 5 respondents fit these categories, so conclusions about these responses are less certain.

Novel environments and embodied interaction were successfully used in the experience (design questions VR × SC 1.1 and VR × SC 2.1). Direct feedback was received from two respondents about the environments being especially interesting.

Understand the Recipients and Tailor the Content to Them (SC2) The intended recipients, cruise guests, were not available for testing, let alone for the development process. Thus, tailoring was based on assumptions and expert opinions provided by partner companies, shaping the focus of the experience toward easily understandable entertainment. Similar availability issues might be present for other interventions employing this framework. This is likely to considerably raise uncertainty about the effectiveness and desirability of the intervention.

Of the design questions involving SC2, VR × SC 2.2 should be examined. "Are there sustainable behaviors that specifically the recipients can train in in VR?" seems irrelevant for green purchase behavior, where the desired behavior requires no training. The question remains relevant, however, for behavior where discernment is expected of the recipients. This is applicable to even some cases of GPB, where estimating the sustainability of different options is a challenge (e.g., understanding green labeling, see Section 7.2).

Uphold Accuracy and Truthfulness (SC3) This guideline was upheld as per SRQ1, "How can a virtual reality sustainability application with a focus on scientifically accurate communication be designed to have a good user experience" This was discussed in Section 8.5.1, concluding concessions had to be made in the breadth of information communicated to not compromise accuracy. Similar compromises are to be expected in other interventions created using this framework.

This is evidence toward SC3 being a fundamental danger for a VR experience as

supposed in Section 6.1.1. Specific methods derived from design questions were successfully used in the experience. Story elements, the accurate recreation of real world environments (360-degree stereoscopic content) and embodied interaction were all used in service of communication without receiving negative feedback about them, apart for two early enders reporting issues due to their fear of heights.

No methods of confirming that recipients had received an accurate understanding of greener cruise tickets could be realized. This is an example of a consideration that had to be left outside the scope of the study due to the sheer number of other considerations already present.

Utilize Scientific Theory (SC4) GPB theory and the theory to form the framework were all utilized in the creation of the experience. Being a scientific one-shot case study, the scientific method was used to estimate the effectiveness of the intervention. However, no control group, comprehensive set of hypotheses, and repeated experiments were utilized. This is due to the exploratory nature of the study, limited resources, and uncertainties regarding practicalities limiting what was feasible. Such features of a controlled scientific study should be applied if further research is done on this subject. This does raise the question of whether or not interventions with resources for such comprehensive testing are typical, and thus whether this guideline is reliably applicable.

Prioritize Hope Over Fear (SC5) Framing was used to highlight positive sustainability content regarding cruising. This is what lead to the focus on fuel, as hopeful communication of possible future actions regarding it was possible. Visions of a certain sustainable future were seen as compromising SC3, so generalized facts about possibilities and goals were used instead. Emotional responses to VR content were utilized to some degree as well. As the user made sustainable choices, they were rewarded with praise from the assistant robot, aimed to create a positive affect. The result of unsustainable choices was not supposed to result in negative affect, instead being comedic in tone. One responder felt these results were shaming the user, however. This is an example of the danger of utilizing fear and shame, even tangentially.

The end summary describing the negative effects of unsustainable effects was a controlled attempt at using fear over hope. Leaving out the negative effects of unsustainable actions was seen as compromising SC3 and the very concept of environmental sustainability. This is likely to be the case in other interventions this framework is used for as well, hence the wording of "prioritize" in SC5 is appropriate over guiding to never use fear.

Use Two-way Communication (SC6) Two-way communication was used tangentially in the experience. The questionnaire contained multiple open-ended questions, and the results of the study were shared to partner companies. The experience itself was straight forwardly one-way top-down communication, however. Implementing a direct or indirect line of communication between stakeholders and recipients would have complicated the experience to a large degree. This illustrates how such features are not feasible for all interventions, and should perhaps be implemented as an integral part of the experience if at all. Multi-user VR experiences are evaluated further in Section 9.3 in VR6.

Help Recipients Reason by Themselves (SC7) This guideline was upheld to a reasonable degree, as it was enabled but not especially encouraged. Communication in the experience was designed to be simple, and the goal of acting as on board entertainment limited how much effort could be demanded from recipients. Each of the three areas in the experience were chosen to give an understanding of the most important factors affecting the sustainability of fuel use for someone who knows very little about the subject. Some of the information provided was likely to help even more informed recipients reason by themselves. The choices made by recipients allowed for freedom to experiment, especially with the feature to quickly change configurations and see different end summaries.

Design questions related to SC7 are mostly related to framing (i.e., VR $\times$ SC 5.7) or constructing tasks (i.e., VR $\times$ SC 2.7) to assist in the reasoning process. Framing was mainly used in the choice of the three areas related to fuel use and the choice of 360-degree images and videos. These choices were successful in increasing interest and the entertain-

ment value of the experience (see Section 8.5.1), but did not utilize framing for reasoning about sustainability. As the inclusion of this content was seen as a positive feature, it is possible this was the better design decision over focusing purely on sustainability in this instance. This possibility highlights how implementing the maximum amount of design decisions guided by the framework is not the recommended way to use it. Similarly, tasks that assist in the reasoning process were present, but complex simulations were deemed ill-fitting.

Utilize Storytelling (SC8) Storytelling was an integral part of the experience. The interactivity of VR was utilized for an engaging, interactive story, where multiple environments impossible for recipients to visit in the real world were presented as a cohesive whole. Emotions were utilized to "reward" sustainable choices by helping the grateful assistant robot, and to reduce negative affect from the results of unsustainable choices by utilizing a comedic anticlimax. All design questions regarding SC8 contributed to the experience, save for VR × SC 6.8, *Can the experience benefit from person-to-person storytelling?* The flexibility of storytelling should lend itself well to other VR interventions as well, making this guideline and the design questions derived from it valuable.

9.2 Framework Evaluation through the Pilot: Behavior Change Interventions

Follow a BCI Framework: Utilize a Logic Model and an Iterative Process (BCI1) A logic model was utilized, but an iterative creation process involving end users was not. The logic model provided an invaluable way to interpret test results to evaluate the effectiveness of the intervention, with evidence pointing toward it being effective. Testing and data collection were, however, not sufficient to definitively prove its effectiveness at changing green purchase behavior or to prove the validity of the logic model. Likewise, the scale of the study did not allow for an iterative creation process involving end-users. Such limitations may be common for interventions, but this guide-

line should be especially important to keep in mind for such cases. Being aware of the limitations of an intervention allows clearly defining the validity of the results and shows avenues to improve them.

Utilize Multiple Behavior Change Techniques, Consider Actions Beyond the Intervention (BCI2) Utilizing multiple, specific behavior change techniques was not a priority for the experience. One-way communications in the form of an interactive story could be considered a single behavior change technique utilizing informing as the primary technique. This may be the main limitation of the intervention, as the information deficit paradigm has been proven insufficient for sustainability communication (see Section 3.1). Alternatively, the experience could be seen as utilizing multiple behavior change techniques as it did not rely solely on mere informing. For example, informing was used to enable recipients to reason by themselves, bolstered further by memorable embodied interaction and emotional involvement through the story. It is possible the results of the intervention would have been greater and more reliable if more varied behavior change techniques suggested by the guidelines and design questions were utilized. Possibly applicable examples include applying social pressure (BCI5), stronger emotional arguments tailored for the recipients (VR $\times$ BCI 3.2), and methods to increase perceived consumer effectiveness (see Section 7.2).

As issues were already faced regarding the length of the experience, utilizing these techniques in a larger behavior change project beyond the intervention would be a more realistic way of implementing them. As a pilot study done in corporate collaboration such techniques are unfeasible, but they should be carefully considered for a full-scale implementation.

Improve Comprehension (BCI3) As mentioned above, improving comprehension through multiple techniques was the primary behavior change technique in the experience. Changes to GPB determninants indicate this method was effective. The full breadth of design questions derived from BCI3 were not utilized. Social interaction, being able to assume the point of view of another for empathetic understanding, and strictly chosen

framing to maximize comprehending the situation were left out of scope.

Affect Perceived Capability (BCI4) Affecting perceived capability was found ill-fitting for GPB, as it is rarely a matter of capability. Increasing perceived consumer effectiveness would have likely been effective, but no facts were available to reliably prove the effectiveness of the target behavior. If such facts were available or the target behavior was affected by capability, an environment with fitting tasks could have reasonably been fit into the experience. This possibility indicates this guideline fitting the framework.

Apply Social Pressure (BCI5) This guideline is one of the potential behavior change techniques the experience did not utilize, save for the possible social pressure-like effect of the assistant robot placing expectations on the user. When resources constrain the extent to which peer groups, and people affected by the target behavior can be involved in the intervention, understanding this use of non-player characters for social pressure has great potential. The synergy between this guideline and VR × SC 3.8 suggests the utilization of pride in being part of an in-group that performs the behavior, a technique that could also have been utilized.

9.3 Framework Evaluation through the Pilot: Virtual Reality

Explore Environments and Scenarios Unrealistic for the Real World (VR1) This was a key part of the experience, reaffirmed as an important affordance of VR. It provided a guideline to design the experience around and was regarded as interesting in the feedback. The shipyard and fuel tank were environments that recipients could not access in the real world, and choosing how the ship operates and seeing the effects of absurdly unsustainable choices in the ending were cases of unrealistic scenarios.

Utilize Embodied Interaction/Learning by Doing (VR2) This guideline was applied successfully to increase interest in the experience. Definitive conclusions can not

be made without a comparison group, but it is highly likely the almost fully embodied user interface increased engagement and memorability. These interactions were basic, but were not tutorialized appropriately as evident by the observed user issues. Interventions that users cannot finish due to unfamiliar VR control schemes are obviously counter to increasing comprehension and engagement, a lesson demonstrated by this pilot study. Learning by doing was not utilized to its maximum potential, as most of the experience consisted of dialogue from the assistant robot. Despite this, a very good user experience and noticeably increased key determinants of GPB were observed.

Utilize Empathy and Emotions (VR3) The ways in which emotions were used and could have been used are already discussed in Section 9.1 and Section 9.2. Regarding empathy, it is possible the assistant robot filled a similar role to real social actors. In that case, it is possible the expectations, and positive and negative feedback from it guided users toward preferring sustainable behavior, but this remains to be proven. Overall, it seems this guideline was utilized successfully, but proving success regarding this subjectively experienced guideline is difficult.

Minimize Cybersickness (VR4) Even though this guideline contributed to but three design questions, the importance of including it in the framework is demonstrated by Section 8.2.1. Many considerations and techniques for minimizing it were utilized, but it proved to be a potential issue regardless.

Take Advantage of the Total Control of the Environment (VR5) Framing was successfully used to focus on information relevant to fuel use. In practice, a total disconnect from the real world was not observed. Coworkers interacted with users from outside the experience, and many users had to break their sense of presence in the virtual world while receiving help from test personnel. This guideline was used to form design questions related to studying concepts in relative isolation. As the study was closer to a field than a laboratory study, highly controlled test situations with randomized control trials with control groups were not considered. This application does highlight an issue

with isolating phenomena regardless: experiences are irreducible to their components. Comedy was used as well as an interactive story, likely having an effect on recipient GPB. Designing a test scenario where the same humor and the same interactive story are applied in isolation from each other would be impossible, making the application of these design questions limited.

Utilize the Social Possibilities of Digital Environments (VR6) Social possibilities were not utilized in the experience. The main reasons for this are fourfold: their inclusion would make the experience more complicated, longer, would use more development resources, and the simple fact that not all design possibilities can be realized at once. Complications include securing a reliable internet connection in the testing situation. The main development resources lacking were development time for the considerably more complicated multiplayer experience, and limited communication opportunities with stakeholders. These are likely to be issues with other VR interventions as well.

9.4 In Summary

All guidelines could be evaluated by reflecting on them through the pilot, to a varied degree. Six of the eight sustainability communication guidelines were fully utilized (SC1, SC3, SC4, SC5, SC7, and SC8) and one was partially utilized (SC2). This speaks to the general nature of the guidelines as well as their influence on the chosen form the the pilot. The application of behavior change intervention guidelines was more limited, as only one guideline was fully utilized (BCI3) and two out of five guidelines were partially utilized, namely, BCI1 and BCI2. It is possible the experience would have benefited from a more complete utilization of these two guidelines, but results indicate it is effective in its current form. Overall, BCI guidelines and related design questions often lean heavily on other literature (BCI frameworks, specific theories of behavior), making them more cumbersome to apply than other parts of the framework. This can either be a point of improvement for the framework, or a necessary concession to keep the framework simultaneously flexible and drawing from valid behavior change intervention practices. BCI1 and BCI2 are

among guidelines and design questions that had to do with practical arrangements, which could only be partially implemented due to resource limitations. Resources would have limited how much social possibilities (VR6) and two-way communication (SC6) could be implemented, but it is also a design direction the experience simply did not happen to take. Three of six virtual reality guidelines could be fully utilized (VR1, VR2, and VR4) and two could be partially utilized (VR3 and VR5). These are similar results to the sustainability communication guidelines, indicating good fit for real-world interventions. More comprehensive conclusions on the framework can be found in Chapter 10.

10 Conclusions

In this thesis, an exploratory framework was created and evaluated using a practical example of a virtual reality behavior change intervention for environmental sustainability. This was done to answer three research questions, answered more explicitly in this final chapter.

RQ1 was as follows: "In the context of virtual reality behavior change interventions for environmental sustainability, what are the best practices of sustainability communication, behavior change interventions, and virtual reality experiences?"

The answer was sought by an exploration of relevant literature of each of the three areas of research in chapters 3–5 to form guidelines which were further verified by answering RQ3. Chapter 3 explored sustainability communication. It was brought to question whether sustainability communication should be thought of as a separate area of research from other communication research. The guidelines somewhat reflect this since, at a surface level, they may seem to be generally applicable advice for any communication (see Table 3.1). However, they are largely derived from lessons learned from practical applications, and paradigms that proved effective in this specific context through validation by reflecting on the practical intervention.

Potential best practices from behavior change interventions (see Table 4.1) gathered in Chapter 4 were successfully used to partially guide the design of the practical intervention and to form design questions. These guidelines lean more heavily on outside literature than expected, making these guidelines more cumbersome to use. It is likely these practices fill their purpose as a valuable part of the framework for their flexibility.

Potential best practices for virtual reality experiences (see Table 5.1) were gathered in

Chapter 5. While the ways in which the literature categorized the affordances of VR was quite varied, some trends did emerge. Particularly guideline VR1, explore environments and scenarios unrealistic for the real world, was found as something almost all explored literature converges on as one of the main reasons to use virtual reality.

Their practical effectiveness was demonstrated further in Chapter 9, in the service of RQ3.

Overall, potential best practices of each area of research could be identified. They were partially validated, but for practically usable sets of best practices, further iteration through their practical application is required.

RQ2 was as follows: "Can overlaps and synergies be found from these best practices to create a framework for creating aforementioned interventions?"

A framework was successfully created, found in Appendix A, supplemented by Appendix B, and summarized in Chapter 6.

Three-way synergies could not be included in the framework proper, save for design questions that overlapped to such a degree they could be combined into one. This is not seen as an issue as the supplementary Appendix B filled three relevant purposes: provided the desired three-way synergies, clarified the succinctly worded design questions, and provided practical ways to realize them in an intervention.

As parts of an exploratory framework, all guidelines filled the purpose of being used to find synergies between the three areas of research, save for VR4 (minimize cybersickness). This guideline proved itself valuable as a practical consideration through reflecting on the practical intervention, as there was indication that the experience caused cybersickness.

RQ3 was as follows: "What features of the framework can be validated by creating and reflecting on a practical, aforementioned kind of intervention?"

As was the intended usage of the framework, not all guidelines and design questions were utilized for the intervention described in Chapter 7. Even for guidelines that were not utilized, their validity could be reflected on by examining their feasibility for a potential, similar intervention project.

A framework was successfully formed, used to assist in the creation of an intervention

of the specified type. Chapter 8 provided indicative results of the success of the experience as an intervention, and Chapter 9 evaluated the degree at which each guideline and related design questions contributed to this. As the guidelines are based on overall best practices and the most promising design directions found, many of them contributed to the practical intervention. The design questions are more exploratory in nature, and a much smaller percentage of them were applicable to the practical intervention.

The sustainability communication guidelines and design questions were utilized to a large degree for the intervention. For example, storytelling, prioritizing hope over fear, and upholding accuracy and truthfulness were all utilized. The design questions that focused on social aspects, the communication of complicated information, or had to do with thorough testing with end users were not utilized. Each of these three types of design directions would have complicated the creation process, and first two would have made the experience itself more complicated for end users. It remains to be seen how viable considerations these are for interventions in general.

As mentioned in Chapter 9, the guidelines and related design questions for behavior change interventions take more work to utilize as they lean on outside literature. Thorough testing of theories on a well understood test group was not possible, a category of design questions that was quite prominent. As an exception, the utilization of a behavior change model was successfully utilized and provided a valuable, testable hypothesis about the results of the intervention.

The affordances and limitations of VR were successfully utilized in the design of the practical intervention. The limitation, cybersickness, was indicated to be a potential issue. Almost all other guidelines were suitable as well: scenarios unsuitable for the real world and embodied interaction raised interest and likely improved comprehension, framing was used to focus on hopeful aspects, and emotions such as amusement and pride were utilized to a light degree, though this was not verified. The social possibilities of digital environments were not utilized as they would have taken considerable resources to implement.

It remains to be seen whether the reflections on this intervention are representative

of intervention projects in general, particularly for the guidelines and design questions that were not utilized. The results that were gathered indicate the framework providing valuable considerations for creating the intended kind of interventions.

Further work can be done on any level of the framework to further verify its effectiveness: the guidelines and design questions could be explored further by consulting experts of relevant fields or by doing more thorough literature searches. The cascading changes to the framework from changing the design questions could prove cumbersome, as the search for synergies and three-way synergies is a multi-stage process. The resulting comprehensive nature of the framework should make this work worthwhile. On a practical level, it would be valuable to evaluate the framework through more interventions, either formed using the framework, or to evaluate it through pre-existing intervention studies. Studying its use by designers other than its author would also be invaluable.

All in all, a thorough exploration of the the synergies between the three areas of research were used to form a framework that allows exploring a wide breadth of the design space of virtual reality behavior change interventions for environmental sustainability. Both research questions could be answered, albeit not conclusively, as is the case with most research. The framework was used in the creation of an intervention that worked as predicted and indicative results point being successful. The framework should prove to be a valuable tool for anyone seeking to create an intervention of the specified type, and the work done toward it contributes to advancing the research areas of sustainability communication, behavior change interventions, and virtual reality experiences.

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Appendix A The Framework

This appendix contains the framework for creating virtual reality behavior change interventions for environmental sustainability. It will first introduce the guidelines formed from three areas of research: sustainability communication (SC), behavior change interventions and psychology (BCI), and virtual reality (VR). More thorough explorations of these guidelines can be found in Chapter 3, Chapter 4, and Chapter 5 respectively.

Then, design questions formed from synergies found between guidelines are introduced, first between VR and SC, then between VR and BCI. Both are preceded with summary tables (Table A.4 and Table A.12) before listing all the design questions found. More information on the formation of these design questions can be found in Chapter 6. Table A.4 lists all VR $\times$ SC design questions found, including those that have been removed from the SC design questions and combined with overlapping BCI design questions. The original versions of these design questions can be found in Appendix B.

Appendix B also contains additional cross synergies between guidelines derived from SC and BCI. When using this framework, it is recommended to examine these additional cross synergies for design questions intended for the experience in question. This helps to better understand the questions, and allows for more efficient exploring of the relevant design space.

The design questions will utilize the following terminology: *The experience* refers to the application being designed, be it explicitly an intervention or an unspecified experience for communication. *Recipients* refers to the people/group receiving the intervention. *The situation* refers to the context surrounding the sustainability concepts explored. *The message* refers to key communication objectives of the experience. *Stakeholder* refers to a

wide range of people related to the experience who are not the recipients, such as entities funding and creating the intervention, and people related to the situation. For example, fishers whose livelihood is reliant on sustainability regarding the sea are considered stakeholders for interventions with related goals. When something potentially unsynergistic is discovered, it is preceded with *Danger*.

A.1 Guidelines

Table A.1: List of sustainability communication guidelines

Tag	**Guideline**
SC1	Use Innovative Alternatives to Mainstream Communication Methods
SC2	Understand the Recipients and Tailor the Content to Them
SC3	Uphold Accuracy and Truthfulness
SC4	Utilize Scientific Theory
SC5	Prioritize Hope Over Fear
SC6	Use Two-way Communication
SC7	Help Recipients Reason by Themselves
SC8	Utilize Storytelling

For more information about the guidelines in Table A.1, see Chapter 3.

Table A.2: List of behavior change guidelines

Tag	**Guideline**
BCI1	Follow a BCI Framework: Utilize a Logic Model and an Iterative Process
BCI2	Utilize Multiple Behavior Change Techniques, Consider Actions Beyond the Intervention
BCI3	Improve Comprehension
BCI4	Affect Perceived Capability
BCI5	Apply Social Pressure

For more information about the guidelines in Table A.2, see Chapter 4.

Table A.3: List of VR usage guidelines

Tag	**Guideline**
VR1	Explore Environments and Scenarios Unrealistic for the Real World
VR2	Utilize Embodied Interaction/Learning by Doing
VR3	Utilize Empathy and Emotions
VR4	Minimize Cybersickness
VR5	Take Advantage of the Total Control of the Environment
VR6	Utilize the Social Possibilities of Digital Environments

For more information about the guidelines in Table A.3, see Chapter 5.

A.2 Synergies Between Sustainability Communication and Virtual Reality

The synergy tables in this section triangulate the guidelines of sustainability communication and virtual reality research.

The sustainability communication guidelines can be found in Table A.1. The summary synergy table, Table A.4, summarizes synergies found, displayed explicitly from Table A.5 to Table A.10 for each VR guideline.

The numbering displays the number of the VR guideline first, the other area of research second. For example, design question VR × SC 2.1 combines the guidelines VR2 and SC1.

Table A.4: VR × SC summary synergy table

	VR1	**VR2**	**VR3**	**VR4**	**VR5**	**VR6**
SC1	1.1	2.1	3.1	4.1		6.1
SC2		2.2	3.2	4.2	5.2	6.2
SC3	1.3	2.3	3.3		5.3	6.3
SC4		2.4	3.4		5.4	6.4
SC5	1.5		3.5		5.5	6.5
SC6			3.6			6.6
SC7	1.7	2.7	3.7		5.7	6.7
SC8	1.8	2.8	3.8			6.8

Due to overlaps found, the following design questions are combined with VR × BCI synergies and missing from the tables below:

- VR × SC 1.7
- VR × SC 4.2
- VR × SC 5.4
- VR × SC 6.2
- VR × SC 6.7

The original design questions can be found in Appendix B.

Table A.5: VR1 × SC synergy table

Guideline	Explore Environments and Scenarios Unrealistic for the Real World (VR1)
Use Innovative Alternatives to Mainstream Communication Methods (SC1)	What novel and innovative environments and scenarios can capture the interest of the recipients?
Uphold Accuracy and Truthfulness (SC3)	Are there views of the real world the recipients cannot access, but help to fully understand the situation? Can the transparency of the sustainability information used be increased by demonstrating how it was formed?
Prioritize Hope Over Fear (SC5)	Are there positive success stories from the target sustainable behavior that can be showcased? Are there visions of a hopeful future that can be created?
Utilize Storytelling (SC8)	Can the message be given through a story with environments and scenarios unfeasible for a real-world experience?

Table A.6: VR2 × SC synergy table

Guideline	Utilize Embodied Interaction/Learning by Doing (VR2)
Use Innovative Alternatives to Mainstream Communication Methods (SC1)	How can novel embodied interaction be used to increase interest in the message?
Understand the Recipients and Tailor the Content to Them (SC2)	Are there sustainable behaviors that specifically the recipients can train in in VR?
Uphold Accuracy and Truthfulness (SC3)	Could the recipients experiment with a simulation of the situation for a more accurate understanding?
Utilize Scientific Theory (SC4)	Do the utilized theories have concepts related to learning by doing?
Help Recipients Reason by Themselves (SC7)	Can a task or tasks be constructed that enable recipients to test how systems related to sustainability function?
Utilize Storytelling (SC8)	Can an interactive story be utilized?

Table A.7: VR3 × SC synergy table

Guideline	Utilize Empathy and Emotion (VR3)
Use Innovative Alternatives to Mainstream Communication Methods (SC1)	Can the emotional aspects of the experience be used to increase interest in it?
Understand the Recipients and Tailor the Content to Them (SC2)	What topics surrounding the target behavior do recipients have strong emotions about? Are there emotions that act as determinants for the behavior that can be targeted?
Uphold Accuracy and Truthfulness (SC3)	Danger: are the utilized appeals to emotion conducive to an accurate image of the situation?
Utilize Scientific Theory (SC4)	Do the utilized theories have concepts related to empathy and emotions? Can emotional responses to specific contexts be measured with the VR experience?
Prioritize Hope Over Fear (SC5)	A sense of presence can enhance emotional responses, can this be used for showcasing a positive future?
Use Two-way Communication (SC6)	Can two-way communications through VR meetings between recipients and people involved in the situation be used to improve empathy?
Help Recipients Reason by Themselves (SC7)	Can the reasoning process enabled by the experience include emotional arguments? Danger: do emotions hinder reasoning?
Utilize Storytelling (SC8)	Can an emotion evoking VR story be utilized?

Table A.8: VR4 × SC synergy table

Guideline	Minimize Cybersickness (VR4)
Use Innovative Alternatives to Mainstream Communication Methods (SC1)	Danger: does a VR experience simplified for the sake of minimizing cybersickness retain its novelty value?

Table A.9: VR5 × SC synergy table

Guideline	Take Advantage of the Total Control of the Environment (VR5)
Understand the Recipients and Tailor the Content to Them (SC2)	In cases where a real world scenario is created in VR, what features are required for it to be valid for the recipients specifically?
Uphold Accuracy and Truthfulness (SC3)	Danger: can the situation be stripped of tertiary factors for a concise experience, without compromising accuracy?
Prioritize Hope Over Fear (SC5)	Can framing be used to prioritize hope over fear?
Help Recipients Reason by Themselves (SC7)	Can framing be used to guide user focus to the information necessary for reasoning about the situation?

Table A.10: VR6 × SC synergy table

Guideline	Utilize the Social Possibilities of Digital Environments (VR6)
Use Innovative Alternatives to Mainstream Communication Methods (SC1)	Can the novelty of VR communications be used to increase interest in the experience?
Uphold Accuracy and Truthfulness (SC3)	Can live communications in VR with an expert on the situation be used to answer questions the recipients have?
Utilize Scientific Theory (SC4)	Can communication theory inform the design of communications in VR?
Prioritize Hope Over Fear (SC5)	Can multi-user VR be used to share success stories of sustainability?
Use Two-way Communication (SC6)	Can the experience enable direct or indirect communication between recipients and different stakeholders?
Utilize Storytelling (SC8)	Can the experience benefit from person-to-person storytelling?

A.3 Synergies Between Behavior Change Interventions and Virtual Reality

The synergy tables in this section triangulate the guidelines of behavior change interventions and virtual reality research.

The behavior change guidelines can be found in Table A.2. Table A.11 summarizes synergies found, displayed explicitly from Table A.12 to Table A.17 for each VR guideline.

Table A.11: VR × BCI summary synergy table

	VR1	**VR2**	**VR3**	**VR4**	**VR5**	**VR6**
BCI1				4.1		6.1
BCI2	1.2	2.2	3.2		5.2	6.2
BCI3	1.3	2.3	3.3	4.3	5.3	6.3
BCI4		2.4	3.4		5.4	6.4
BCI5	1.5					6.5

Table A.12: VR1 × BCI synergy table

Guideline	**Explore Environments and Scenarios Unrealistic for the Real World (VR1)**
Utilize Multiple Behavior Change Techniques, Consider Actions Beyond the Intervention (BCI2)	Can the experience include multiple scenarios to employ more techniques of the chosen model of behavior change?
Improve Comprehension (BCI3)	Can specific scenarios be showcased for a comprehensive understanding of the situation, allowing the recipients to reason by themselves? Are there non-immediate goals or consequences for the experience that can be demonstrated in VR?
Apply Social Pressure (BCI5)	Can the experience benefit from collective social behavior change techniques? For example, a social norm intervention showcasing a common or uncommon sustainable action performed by peers (social norm or social-tipping interventions), or using collaborative reasoning and decision making.

Table A.13: VR2 × BCI synergy table

Guideline	**Utilize Embodied Interaction/Learning by Doing (VR2)**
Utilize Multiple Behavior Change Techniques, Consider Actions Beyond the Intervention (BCI2)	Could the behavior change techniques used in the experience be complemented by the increased engagement and memorability of embodied interaction?
Improve Comprehension (BCI3)	Can learning by doing be utilized in the experience, improving comprehension?
Affect Perceived Capability (BCI4)	Can the perceived capability of recipients be increased by providing them with embodied VR tasks where they achieve success performing the target behavior?

Table A.14: VR3 × BCI synergy table

Guideline	**Utilize Empathy and Emotion (VR3)**
Utilize Multiple Behavior Change Techniques, Consider Actions Beyond the Intervention (BCI2)	Does the utilized theory of behavior include mechanisms involving emotions?
Improve Comprehension (BCI3)	Can seeing the point of view of another be used to empathetically understand the situation?
Affect Perceived Capability (BCI4)	Can positive encouragement from others be used to increase perceived capability?

Table A.15: VR4 × BCI synergy table

Guideline	**Minimize Cybersickness (VR4)**
Follow a BCI Framework: Utilize a Logic Model and an Iterative Process (BCI1)	Can early testing with recipients be used to reveal cybersickness issues?
Improve Comprehension (BCI3)	Danger: does simplification to minimize cybersickness compromise giving a comprehensive look at the situation?

Table A.16: VR5 × BCI synergy table

Guideline	**Take Advantage of the Total Control of the Environment (VR5)**
Utilize Multiple Behavior Change Techniques, Consider Actions Beyond the Intervention (BCI2)	Can VR be used to study stimuli and concepts in isolation, such as comparing different determinants or behavior change techniques?
Improve Comprehension (BCI3)	Can framing be used to guide the focus of recipients to what is conducive for comprehending the situation?
Affect Perceived Capability (BCI4)	Can feedback of success be implemented in the experience, increasing perceived capability?

Table A.17: VR6 × BCI synergy table

Guideline	**Utilize the Social Possibilities of Digital Environments (VR6)**
Follow a BCI Framework: Utilize a Logic Model and an Iterative Process (BCI1)	Can VR meetings enable natural communications between recipients and different stakeholders?
Utilize Multiple Behavior Change Techniques, Consider Actions Beyond the Intervention (BCI2)	Does the utilized theory of behavior include social techniques that could be utilized in a multi-user experience?
Affect Perceived Capability (BCI4)	Can encouragement or learning by example be utilized to improve perceived capability?
Apply Social Pressure (BCI5)	Can social interactions in VR be utilized in a social norm or social-tipping intervention?

Appendix B Framework Analysis for Overlaps and Synergies

In this appendix each design question found is evaluated for synergies with the remaining area of research, and examined for overlap with other design questions. For example, design questions in the VR1 × SC synergy table (Table A.5) will be triangulated with every guideline from behavior change interventions. A cursory triangulation is also performed between design questions for possible overlap and more specific cross synergies. These are examined at a surface level, as the triangulation of 30 VR × SC synergies and 23 VR × BCI synergies amounts to 460 considerations. Overlaps allow streamlining the framework by combining design questions. The combined questions fit both categories and so will be arbitrarily categorized as VR × BCI synergies, replacing the original design questions. Dangers will not be included in this search for synergies.

As in Appendix A, design questions are referred to by the notation found in the summary synergy tables. For example, "VR × BCI 1.3" refers to the design question combining VR1 and BCI3. The number of synergies found is stated for each design question, along with an explanation of each one.

SC1 was found to synergize in a predictable way with VR × BCI synergy tables. Incidental increased interest in the experience could be found in synergies already covered by VR × SC synergy tables, as all of VR usage benefits from its novelty. These synergies are omitted from the findings below.

Similarly, SC4 was found to synergize with VR × BCI synergy tables in a predictable matter through its commonalities with BCI features. As all BCI guidelines are based on

scientific theory, synergies regarding this fact are omitted as well. Synergies related to enabling the scientific method were not omitted.

B.1 Overlaps found

For the sake of comprehensiveness and transparency, this section will list overlapping synergies in their original form.

VR × BCI 1.3 and VR × SC 1.7 Overlap: increasing comprehension through the use of environments and scenarios.

- **VR × BCI 1.3**: What environments and scenarios increase recipient understanding of the situation? Are there non-immediate goals or consequences for the experience that can be demonstrated in VR?
- **VR × SC 1.7**: Does a comprehensive overview of environments and scenarios related to the situation allow for sufficient reasoning?

VR × BCI 1.5, VR × SC 6.7 Overlap: collective social behavior change techniques.

- **VR × BCI 1.5** Can the experience showcase scenarios that apply social pressure for the behavior, such as showcasing sustainable actions performed by peers?
- **VR × SC 6.7** Can collaborative reasoning or decision making be utilized in the experience?

VR × BCI 4.1, VR × SC 4.2 Overlap: Early testing to reduce cybersickness.

- **VR × BCI 4.1** Can early testing with recipients be used to reveal cybersickness issues?
- **VR × SC 4.2** Can the susceptibility for VR sickness of the recipients be measured or estimated in advance?

VR × BCI 5.2, VR × SC 5.4 Overlap: Isolating stimuli.

- **VR × BCI 5.2** Can different behavior change techniques be evaluated in relative isolation in VR?
- **VR × SC 5.4** Can the highly controllable digital environment that closes off the outside world be used to gather data of extremely isolated phenomena? For example, affective responses to isolated stimuli.

VR × BCI 6.1, VR × SC 6.2 Overlap: Benefits of VR meetings. As a disclaimer, this is not a clerical error. The synergy was found and written the same way twice with full intention to combine them.

- **VR × BCI 6.1** Can VR meetings enable natural communications between recipients and different stakeholders?
- **VR × SC 6.2** Can VR meetings enable natural communications between recipients and different stakeholders?

VR × BCI 6.3, VR × SC 6.7 Overlap: Collaborative reasoning and decision making in VR. Prior overlap with VR × SC 6.7 exists, see Paragraph **VR × BCI 1.5, VR × SC 6.7** above. VR × BCI 6.3 was removed from the framework as redundant.

- **VR × BCI 6.3** Can collaborative reasoning be utilized in the experience?

B.2 Synergies of VR × BCI Design Questions

VR × BCI 1.2 *Can the experience include multiple scenarios to employ more techniques of the chosen model of behavior change?* Three synergies with SC4, SC7, and SC8 were found.

Multiple explicit behavior change techniques allow for their separate evaluation, as well as ensuring a chosen theory is followed robustly (SC4). Many techniques being used might allow for a more complete understanding to aid in reasoning (SC7), and scenarios can be bound by a story (SC8).

VR × BCI 1.3 *Can specific scenarios be showcased for a comprehensive understanding of the situation, allowing the recipients to reason by themselves? Are there non-immediate goals or consequences for the experience that can be demonstrated in VR?* Four synergies with SC2, SC3, SC5, and SC8 were found. Additionally, this design question is the result of an overlap with VR × SC 1.7, indicating a three-way overlap.

To enable a comprehensive understanding of the situation in recipients, understanding them is a must (SC2). A comprehensive understanding upholds accuracy and truthfulness (SC3). Positive consequences and goals of the experience can be non-immediate (SC5). A story is natural way to include multiple scenarios (SC8).

VR × BCI 1.5 *Can the experience benefit from collective social behavior change techniques? For example, a social norm intervention showcasing a common or uncommon sustainable action performed by peers (social norm or social-tipping interventions), or using collaborative reasoning and decision making.* Four synergies with SC2, SC3, SC5, and SC7 were found. Additionally, this design question is the result of an overlap with VR × SC 6.7, indicating a three-way overlap.

Understanding who recipients hold as respectable peers is vital for social-tipping interventions (SC2). Social norm interventions are based on showing truthfully how common the desired behavior is (SC3). A focus on the desired behavior rather than an undesireable one is also prioritizing hope over fear (SC5). Collaborative reasoning and decision

making are a strong use of two-way communications (SC6) and helping recipients reason by themselves (SC7).

VR × BCI 2.2 *Could the behavior change techniques used in the experience be complemented by the increased engagement and memorability of embodied interaction?* Five synergies with SC2, SC3, SC4, SC7 and SC8 were found.

The VR2 × SC synergy table provides behavior change techniques that might benefit from the increased engagement of embodied interaction: training recipients in sustainable behaviors (SC2), experimenting with a simulation of the situation (SC3) or specific systems (SC7), and delivering the message through an engaging interactive story (SC8). If a specific theory of behavior is utilized and provides additional behavior change techniques, these techniques may benefit from increased engagement and memorability as well (SC4).

VR × BCI 2.3 *Can learning by doing be utilized in the experience, improving comprehension?* Five synergies with SC2, SC3, SC4, SC7 and SC8 were found.

Training in VR can increase comprehension regarding the situation and target behavior (SC2). A simulation of the situation (SC3) or tasks constructed to demonstrate related systems (SC7) can increase comprehension greatly. Involvement through an interactive story can increase comprehension as well (SC8). Additionally, specific theories of behavior with concepts related to improved comprehension should benefit from learning by doing in VR as well (SC4).

VR × BCI 2.4 *Can the perceived capability of recipients be increased by providing them with embodied VR tasks where they achieve success performing the target behavior?* Four synergies with SC2, SC3, SC5, and SC8 were found.

The most direct way of increasing perceived capability is VR training in the target behavior (VR × SC 2.2). Besides training, simply performing the target behavior in an accurate scenario in VR helps give an accurate image of the situation as well (SC3), as part of a VR story experience for example (SC8). Increasing perceived capability is well within the guideline to prioritize hope over fear (SC5).

VR × BCI 3.2 *Does the utilized theory of behavior include mechanisms involving emotions?* Four synergies with SC2, SC4, SC5, and SC8 were found.

Affecting emotions reliably likely requires content tailored to the recipients (SC2), such as a story that resonates with them (SC8). Testing the way emotions and the chosen theory interact can be more reliably done in VR (SC4), which is especially valuable if the experience either uses guilt and fear or wants to avoid doing so (SC5).

VR × BCI 3.4 *Can positive encouragement from others be used to increase perceived capability?* Four synergies with SC5, SC6, SC7 and SC8 were found.

Encouraging can focus on hope rather than fear if, for example, stories of success are shared (VR × SC 6.5). Encouragement like this could be given in multiplayer two-way communications (SC6) or in the format of a story (SC8). In multiplayer VR, collaborative reasoning and decision making could act as a natural venue for encouragement (VR × SC 6.7).

VR × BCI 4.1 *Can early testing with recipients be used to reveal cybersickness issues?* No synergies were found. However, this design question is the result of an overlap with VR × SC 4.2, indicating a three-way overlap.

VR × BCI 5.2 *Can VR be used to study stimuli and concepts in isolation, such as comparing different determinants or behavior change techniques?* Two synergies with SC2 and SC4 were found. Additionally, this design question is the result of an overlap with VR × SC 5.4, indicating a three-way overlap.

Isolating phenomena benefits the scientific method greatly (SC4), enabling a systematic way of analyzing the recipients at even early parts of the design process (SC2).

VR × BCI 5.3 *Can framing be used to guide the focus of recipients to what is conducive for comprehending the situation?* 3 synergies with SC2, SC3, and SC7 were found.

To find what information the recipients specifically need to comprehend the situation, understanding them is needed (SC2). With this understanding, it becomes less likely

that the experience will mislead them in some way (SC3), even if they are trusted to reason by themselves (SC7).

VR × BCI 5.4 *Can feedback of success be implemented in the experience, increasing perceived capability?* Four synergies with SC2, SC5, SC6, and SC8 were found.

Feedback can bolster the increased perceived capability when training in VR (VR × SC 2.2). An interactive story could also provide feedback of success (VR × SC 2.8). Focusing on successes is key when prioritizing a hopeful message (SC5), and this feedback could be delivered from those related to the situation, whether they are experts of affected by it (SC6).

VR × BCI 6.1 *Can VR meetings enable natural communications between recipients and different stakeholders?* Three synergies with SC2, SC3 and SC8 were found. Additionally, this design question is the result of an overlap with VR × SC 6.2, indicating a three-way overlap.

Meetings with stakeholders can be used to increase transparency for the recipients (SC3) and understanding of the recipients for developers (SC2). More natural or digitally enhanced person-to-person storytelling becomes possible through multiplayer VR (VR × SC 6.8).

VR × BCI 6.2 *Does the utilized theory of behavior include social techniques that could be utilized in a multi-user experience?* Two synergies were found with SC2, and SC6.

An accurate analysis or categorization of the recipients could enable a more accurate utilization of social techniques (SC2). These techniques may be utilized for communication between recipients and stakeholders (SC6).

VR × BCI 6.4 *Can encouragement or learning by example be utilized to improve perceived capability?* Five synergies with SC3, SC5, SC6, SC7 and SC8 were found.

Synergies for encouragement were already analyzed for VR × BCI 3.4, applicable to this design question as well. An additional synergy regarding learning by example was

found: truthfulness can be upheld if recipients can learn from the examples of real people (SC3).

VR × BCI 6.5 *Can social interactions in VR be utilized in a social norm or social-tipping intervention?* Four synergies with SC2, SC5, SC6, and SC7 were found.

Social norm and tipping interventions require understanding the social context of the recipients very well (SC2). Showing how some people behave sustainably rather than raising fear and apathy by displaying unsustainable actions is certainly in line with SC5. This can be shown through multiplayer VR (SC6). These interventions may allow recipients to come to conclusions about the situation by themselves (SC7).

B.3 Synergies of VR × SC Design Questions

VR × SC 1.1 *What novel and innovative environments and scenarios can capture the interest of the recipients?* Three synergies with BCI1, BCI2, and BCI5 were found.

Iterative creation processes with end users help find what captures recipient interest (BCI1). Using multiple scenarios and environments lends itself well to utilizing multiple, scenario fitting behavior change techniques (BCI2). Observing social norms is likely of interest to the recipients, allowing the simultaneous application of social pressure (BCI5).

VR × SC 1.3 *Are there views of the real world the recipients cannot access, but help to fully understand the situation? Can the transparency of the sustainability information used be increased by demonstrating how it was formed?* Four synergies with BCI1, BCI2, BCI3 and BCI5 were found.

The iterative development process of BCI frameworks involving end users helps understand what information recipients lack but cannot access (BCI1), allowing the experience to improve their comprehension of the situation (BCI3), potentially of a campaign beyond the experience (BCI2). This is also the case if the way the sustainability information was formed is demonstrated. Helping recipients understand the situation is the behavior change technique for social norm interventions (BCI5).

VR × SC 1.5 *Are there positive success stories from the target sustainable behavior that can be showcased? Are there visions of a hopeful future that can be created?* Four synergies with BCI2, BCI3, BCI4 and BCI5 were found.

As society-wide behavior change requires multi-level action beyond the intervention, truthful visions of a hopeful future fit such campaigns the best (BCI2). Displaying the positive end results of the target behavior can improve comprehension of the situation (BCI3), but especially increase perceived capability (BCI4). Such displays of others successfully performing the target behavior are likely to apply social pressure as well (BCI5).

VR × SC 1.8 *Can the message be given through a story with environments and scenarios unfeasible for a real-world experience?* Two synergies with BCI2, and BCI3 were found.

Multiple scenarios in an advancing story can be effectively used for different behavior change techniques (BCI2). Stories are ways to structure information in a comprehensive manner (BCI3).

VR × SC 2.1 *How can novel embodied interaction be used to increase interest in the message?* Three synergies with BCI1, BCI2, and BCI3 were found.

Ways to increase interest in the message may be found by forming a logic model, especially if informing is a goal, which is typical for sustainability experiences (BCI1). Increasing interest in the message also improves motivation to comprehend it (BCI3). Embodied interaction can be applied in many different ways, allowing for multiple behavior change techniques (BCI2).

VR × SC 2.2 *Are there sustainable behaviors that specifically the recipients can train in in VR?* Five synergies with BCI1, BCI2, BCI3, BCI4, and BCI5 were found.

An iterative creation process involving early testing with the recipients can ensure potential behaviors are explored (BCI1). Training alone is not enough if their environment is unconducive for it, so actions beyond the intervention should be considered (BCI2).

The training, if successful, will certainly increase perceived capability (BCI4), helps understand the behavior better (BCI3). It might be an avenue for social pressure as well if the training was collaborative with other recipients they have social interaction with when the behavior is expected of them (BCI5).

VR × SC 2.3 *Could the recipients experiment with a simulation of the situation for a more accurate understanding?* Two synergies with BCI3, and BCI4 were found.

A more accurate understanding means improved comprehension (BCI3). Understanding how the behavior of the recipients can affect the situation also increases perceived capability (BCI4).

VR × SC 2.4 *Do the utilized theories have concepts related to learning by doing?* Three synergies with BCI1, BCI3, and BCI4 were found.

After such concepts are found, they can be utilized by including them in the logic model (BCI1). Utilizing learning by doing increases comprehension (BCI3), and perceived capability if the tasks are related to the desired behavior (BCI4).

VR × SC 2.7 *Can a task or tasks be constructed that enable recipients to test how systems related to sustainability function?* Two synergies with BCI3, and BCI4 were found.

As with experimenting with a simulation of the situation, experimenting with singular systems related to the situation increases comprehension (BCI3), and with the right choice of systems can affect perceived capability as well (BCI4).

VR × SC 2.8 *Can an interactive story be utilized?* Four synergies with BCI2, BCI3, BCI4, and BCI5 were found.

Stories lend themselves well to changing scenarios, where different behavior change techniques can be utilized (BCI2), including affecting perceived capability (BCI4) and applying social pressure (BCI5). Both stories and embodied interaction are techniques to improve comprehension (BCI3).

VR × SC 3.1 *Can the emotional aspects of the experience be used to increase interest in it?* Two synergies with BCI1, and BCI2 were found.

The adaptability of an iterative creation process can aid in the creation of highly subjective experiences, such as those involving emotions (BCI1). Understanding the intervention in its larger context can help map out interest in it (BCI2).

VR × SC 3.2 *What topics surrounding the target behavior do recipients have strong emotions about? Are there emotions that act as determinants for the behavior that can be targeted?* Two synergies with BCI1, and BCI5 were found.

The adaptability of an iterative creation process can aid in the creation of highly subjective experiences, such as those involving emotions (BCI1). Additionally, the found determinants can be used in the formation of a logic model. The social context of the target behavior is a potential source for strong emotions and emotional determinants (BCI5).

VR × SC 3.4 *Do the utilized theories have concepts related to empathy and emotions? Can emotional responses to specific contexts be measured with the VR experience?* Three synergies with BCI1, BCI2 and BCI5 were found.

The measuring of emotional responses can be used to prove a logic model, if it includes such determinants (BCI1). Likewise, VR enables relatively separated comparison of the relationships between emotions and concepts (BCI2). Applying social pressure can evoke negative emotions in the recipients, tracking this phenomenon can be used to mitigate it (BCI5).

VR × SC 3.5 *A sense of presence can enhance emotional responses, can this be used for showcasing a positive future?* Three synergies with BCI1, BCI2, and BCI3 were found.

The adaptability of an iterative creation process can aid in the creation of highly subjective experiences, such as those involving emotions (BCI1). Showcasing a positive future fits well with sustainability projects with a large scope, beyond a single intervention (BCI2). For such projects, helping others comprehend what their end goal is could be an

important are of application for VR experiences (BCI3).

VR × SC 3.6 *Can two-way communications through VR meetings between recipients and people involved in the situation be used to improve empathy?* Three synergies with BCI1, BCI3 and BCI5 were found.

VR meetings between stakeholders can be used as part of an iterative process (BCI1), increasing comprehension of the situation for everyone involved (BCI3). This is a potential method to apply very direct social pressure (BCI5), but the dangers of apathy through evoking guilt/fear should be taken into consideration.

VR × SC 3.7 *Can the reasoning process enabled by the experience include emotional arguments? Danger: do emotions hinder reasoning?* Two synergies with BCI1, and BCI3 were found.

The adaptability of an iterative creation process can aid in the creation of highly subjective experiences, such as those involving emotions (BCI1). Methods to enable the reasoning process improve comprehension of the situation (BCI3).

VR × SC 3.8 *Can an emotion evoking VR story be utilized?* Five synergies with BCI1, BCI2, BCI3, BCI4, and BCI5 were found.

The adaptability of an iterative creation process can aid in the creation of highly subjective experiences, such as those involving emotions (BCI1). Stories lend themselves well to changing scenarios, where different behavior change techniques can be utilized (BCI2), and can improve comprehension by structuring information (BCI3). Example evoked emotions include pride in performing the target behavior, increasing perceived capability through belief in one's skills (BCI4), or pride in belonging to a social group that performs the behavior (BCI5).

VR × SC 5.2 *In cases where a real world scenario is created in VR, what features are required for it to be valid for the recipients specifically?* Three synergies with BCI1, BCI3, and BCI4 were found.

Reliably creating valid scenarios for the recipients requires understanding the recipients, possibly through an iterative process involving them directly (BCI1). Such valid, unabstracted scenarios are easily comprehensible for recipients (BCI3). A natural use case for such scenarios would be direct training in the target behavior, improving perceived capability (BCI4).

VR × SC 5.5 *Can framing be used to prioritize hope over fear?* Two synergies with BCI3, and BCI4 were found.

Framing is representing chosen parts of a whole for a specific understanding, both improving comprehension while avoiding evoking apathy through fear if chosen well (BCI3). Instead, the recipients' belief that their actions can make a difference could be fostered for increased perceived capability (BCI4).

VR × SC 5.7 *Can framing be used to guide user focus to the information necessary for reasoning about the situation?* Two synergies with BCI3, and BCI4 were found.

This is a technique for improved comprehension of the situation (BCI3). If the target behavior can actually affect the situation, comprehending it can improve perceived capability (BCI4).

VR × SC 6.1 *Can the novelty of VR communications be used to increase interest in the experience?* No synergies were found.

VR × SC 6.3 *Can live communications in VR with an expert on the situation be used to answer questions the recipients have?* Four synergies with BCI2, BCI3, BCI4, and BCI5 were found.

Communications with an expert can certainly improve comprehension (BCI3), and can potentially utilize multiple behavior change techniques adaptively, as recipients can freely choose topics of discussion (BCI2). For example, convincing recipients that a significant amount of significant people perform the action could be used (BCI5). The expert can also give practical advice and encouragement, affecting perceived capability (BCI4).

VR × SC 6.4 *Can communication theory inform the design of communications in VR?* Four synergies with BCI1, BCI2, BCI3, and BCI5 were found.

Forming a logic model is a potential way to ensure theory is applied robustly (BCI1). Communication theories can potentially cover entire communication strategies, helping define the intervention as a part of a greater whole (BCI2). Efficient communications are conducive to an improved comprehension (BCI3), and are a way to reliably apply social pressure (BCI5).

VR × SC 6.5 *Can multi-user VR be used to share success stories of sustainability?* Four synergies with BCI2, BCI3, BCI4 and BCI5 were found.

The success of actions beyond the intervention can be demonstrated in the experience (BCI2). This can concretize what the sustainability project is about (BCI3), and affect perceived capability if these successes are the result of performing the target behavior (BCI4). Being a multi-user experience with two-way communications, direct advice to recipients also becomes possible, acting to increase comprehension, raise the expertise required for perceived capability, and applying social pressure through showcasing others who engage in the behavior (VR × BCI 6.5).

VR × SC 6.6 *Can the experience enable direct or indirect communication between recipients and different stakeholders?* Five synergies with BCI1, BCI2, BCI3, BCI4, and BCI5 were found.

Two-way communications between stakeholders is key for iterative development processes (BCI1). Two-way communications could be used to supplement the experience: as an example of an indirect method, recipients could leave questions to be answered if they want to comprehend the situation better (BCI3) or engage in the behavior more confidently (BCI4). Messaging from parts of the sustainability project beyond the intervention could be included to raise awareness of them (BCI2). Direct communications are a natural avenue for applying social pressure (BCI5).

VR × SC 6.8 *Can the experience benefit from person-to-person storytelling?* Five synergies with BCI1, BCI2, BCI3, BCI4, and BCI5 were found.

An experience utilizing person-to-person storytelling can benefit from the benefits of social interaction and storytelling. User stories are a way in software development to better understand the needs of end users, and could be used in an iterative creation process (BCI1). Both the multiple scenarios of stories and adaptability of person-to-person communications enable the use of multiple behavior change techniques (BCI2). Stories are a way to structure information in an easily comprehensible way, which can be further enhanced by the ability of the recipients to ask questions (BCI3). The methods of prior design questions are applicable here, such as sharing success stories of sustainability (VR × SC 6.5), potentially improving perceived capability (BCI4) and applying social pressure (BCI5).