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Virtual Reality for Environmental Sustainability: Case Cruise Entertainment

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Abstract

This paper outlines a study exploring the potential of implementing a behavior change intervention via virtual reality (VR) to further sustainability communication. A prototype experience was created and tested utilizing the distinctive possibilities of VR, in the context of doubling as entertainment for cruise guests.

Tailoring sustainability information to a specific audience while being entertaining, utilizing the features and understanding the limitations of VR in this context were some of the challenges faced. The methods utilized to overcome these barriers should provide valuable insight on the practical application of VR, and understanding the interplay of sustainability communication and the features of VR has the potential to help create powerful tools for fighting climate change.

Participants (n = 70) played through the interactive VR story experience of building a ship, choosing between sustainable and unsustainable options. The survey filled after the experience employed both traditional and tailored information gathering methods. Analysis of this wide range of survey questions revealed avenues for improvement such as tutorializing and limiting VR sickness, while also proving success in creating an interesting VR sustainability story with a user experience evaluated as good. Indicative success as a behavior change intervention was found, with participants reporting increase in key determinants of green purchase behavior. As sustainability behavior change applications have previously largely utilized long-term, non-VR applications, the results of this novel multidisciplinary study should prove meaningful.

Introduction

In this paper, a research prototype experience is introduced that investigates the use of Virtual Reality (VR) as a medium for *sustainability communication*. Sustainability communication is an emerging field with substantial potential to enhance public understanding and stakeholder engagement by rendering visible the environmental initiatives, technological innovations, and long-term commitments undertaken with contemporary industry. Although notable progress in sustainable practices has been achieved across multiple industrial domains, public perceptions are often shaped by outdated narratives and persistent stereotypes resulting in reputational disadvantages not aligning with present realities. By utilizing the immersive and innovative features of VR, opportunities are created for sustainability communication to be conveyed in a more engaging, transparent, and impactful manner.[1]

VR is characterized by a number of distinctive advantages over other forms of communication. Foremost among these is the concept of presence, understood as the subjective sensation of being situated within the virtual environment [2]. Embodied interaction can be intuitive, memorable, and highly enjoyable [3]. These advantages of VR provide a plethora of possibilities for application across domains including industrial, commercial and governmental actors. While limitations in current and emerging VR technologies remain, the breadth of potential use cases continues to expand with new technologies and applications.

The potential of VR was integrated with principles of behavior change theory to inform the design of a *sustainability behavior change intervention*. This intervention was implemented as a VR experience that was further evaluated for its usability as an entertainment-oriented activity in the context of a family cruise. The experience was tested on a test group closely tied with cruise guests. The primary emphasis was placed on environmental sustainability communication through VR technology to address the following research questions:

- RQ1: How can a virtual reality sustainability application with a focus on scientifically accurate communication be designed to have a good user experience?
- RQ2: Can a virtual reality sustainability experience be used as entertainment for cruise guests?
- RQ3: How can a virtual reality sustainability experience be used to affect sustainable purchase behavior related to cruises?

This paper first provides an overview of the fundamentals of VR and environmental sustainability, establishing a theoretical foundation through a review of existing research in relevant scientific domains. Following this background the design and development of the VR experience are presented, the research methodology is outlined, and the data collection process is described. The subsequent sections offer a detailed presentation and discussion of the results. Finally, conclusions are drawn and directions for future work are identified.

Background

VR allows exploring scenarios unrealistic for the real world thus having an advantage over competing digital solutions and real-world implementations [4, p. 48] [5]. For example: without VR, security reasons and both physical and temporal separation make it impossible for cruise guests to explore the ship they are on when it was under construction.

Derived from sustainable development, introduced in *The Brundtland Report*, sustainability refers to meeting the needs of current generations without compromising the ability of future generations to meet theirs. It is often divided into the same three areas as sustainable development: ecological, economic, and so-

cial. [6, p. 58] This paper explicitly focuses on the ecological area, also known as environmental sustainability.

Sustainability communication research brings options for effective communication to light. Behavior change can be considered a core challenge in science communication for sustainability [7, p. 282]. Specific methods that have been proven effective include utilizing storytelling [7, p. 3, 90], helping recipients reason for themselves, [7, p. 75], upholding accuracy and truthfulness [8] and creating content tailored for the recipients [8], [7, p. 3, 287].

Behavior change interventions aim to change the behavior of a person, group or organization. Their basic structure is forming a logic model of determinants affecting behavior, then affecting these determinants. An attitude-behavior gap has been extensively documented regarding environmentally sustainable behavior [9], making it very valuable to directly study how these behaviors can truly be changed. Motivational game design for sustainability can borrow from a multitude of behavior theories and motivational perspectives [10], but for the purposes of this study, borrowing from the science of green purchase behavior seemed the most apt.

Green purchase behavior (GPB) refers to buying ecologically sustainable products and services, such as tickets to a greener cruise. Important factors for GPB agreed upon by the literature consist of personal/subjective norms, perceived consumer effectiveness, environmental concerns, green advertising skepticism, and perceptions of product quality [11] [12]. Personal norms are more stable when compared to the other behavior factors, making them harder to affect. One study found, however, that the effects of personal norms were fully mediated by purchase satisfaction [12].

Related research has been made on sustainability research and motivation, finding information sharing the key pro-environmental element and game-like elements often being utilized [10], such as flow [13]. These studies mainly focus on long-term gamified experiences, such as mobile applications. Studies on sustainability communication VR applications have revealed potential for its usage. Simulations to demonstrate industrial processes can effectively be used in a business-to-business context [14], and audiences can be receptive to sustainability data through VR, but prefer not to receive it exclusively through text [15]. VR Stories being used to influence action has precedent, one example being a game using procedural rhetoric to evoke emotion and enable introspection [16]. VR experiences to support environmentally sustainable behavior have been studied as well. A systematic review found papers in three categories for such VR experiences: 26 explorations where awareness is raised through emotional involvement, 19 simulations where understanding is provided through testing predictions, and 8 games where interest is raised and knowledge is provided through engagement [17]. The experience created for this study could be categorized as a game in this trichotomy, providing valuable data for an understudied category.

Design and Development

This study was conducted in collaboration with a shipyard and a cruise company. A VR experience was created, focusing on the accurate communication of sustainability facts and concepts related to cruise ships. The user was transported into a virtual world, a story where an assistant robot takes them through building a ship for the cruise company. The building process was heavily simplified, as the entertainment value for the target audience would suffer from long technical explanations. Informing recipients enough to reason for themselves is effective for sustainability communication, but the topic of sustainability can be complex and emotionally taxing. This was reconciled by focus- ing only on fuel use which was deemed the best choice as it contributes greatly to the lifetime greenhouse gas emission of a cruise ship. The experience had the player enter computer-generated 3D environments mixed with stereoscopic 360-degree images and videos of the real world. There, they would receive sustainability information and advance in the story through simple embodied interaction.

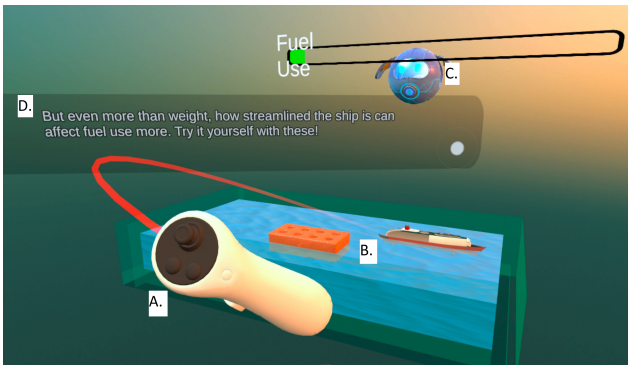

Figure 1. *Example of gameplay*

For example, in the gameplay seen in Figure 1, the user would see an immersive 360-degree image of the shipyard surrounding them, replaced in the figure with a gradient 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. The robot has floated around the user, directing their attention to a set of two shapes in a water tank (B.). The user could then use their controller (A.) to experiment with the shapes, noticing they have different resistances to movement, and different effects on the Fuel Use meter (C.).

The basic structure of the experience was receiving information relevant to an aspect of fuel use, then making either a sustainable or an unsustainable choice. The dialogue in the game heavily encouraged the user to pick the sustainable option, which rewarded the player with positive feedback. Making an unsustainable option would lead to a narrative anticlimax, which was meant to be comedic in tone. When all choices were made, the ship was complete and a summary of the effects of player choices was given. The user then had the option to make new choices and see different summaries.

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, and 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.

As a behavior change intervention, a selection of determinants affecting GPB was chosen to be key targets for the pilot.

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 chosen GBP was the purchasing of tickets to a greener cruise. Trust in the greenness of the service was fostered in the experience through a thorough explanation of factors affecting fuel use, helping recipients reason for themselves. Perception of service quality was fostered through assurance that reductions in fuel use do not have to directly impact cruise enjoyability. Assumed purchase satisfaction did not have a logic model explaining how it would be raised, but was expected to increase with the other two determinants.

As cruise guests of a relevant cruise type were unavailable, the test group consisted of workers with experience working 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. Testing was performed in three different locations, all with a similar setting: Two testing stations consisting of Quest 3 VR headsets and controllers on two chairs were available, allowing two simultaneous users. The experience was advertised to passersby by test personnel and a screen displaying gameplay. A tester would play through the game for as long as they wanted, approximately taking anything from a few minutes to half an hour.

The experience was created with the development platform Unity. Development resources allowed the construction of a visually pleasing and functional experience somewhat below the level of a commercial grade product. The experience ran locally on the Meta Quest 3 headset necessitating meticulous balancing on visual quality and performance costs. For example, a design model of a cruise ship provided by the shipyard was manually modified and optimized for the purpose.

Methodology

The study employed an evaluative research design centered on the development and assessment of a VR experience. Data were collected using a mixed-methods strategy combining questionnaire-based self-report measures and direct observation by test personnel. Quantitative data comparable to prior user experience evaluations were obtained using the shortened version of the established *User Experience Questionnaire* (UEQ-S) twice, first from their own perspective and then again evaluating the perspective of a cruise guest.

Tailored survey items were employed to gather data related to cruise context suitability and determinants of GBP. The collected data were subsequently analyzed to assess user experience, contextual suitability, and the potential of the intervention to influence behavior-related outcomes.

Data Collection

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) [18] 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).

VR sickness is a well-documented issue. Questions for capturing its wide range of forms were derived from the symptoms used in the *VR Sickness Questionnaire* [19], which are sorted into oculomotor, and disorientation categories, with the addition of nausea from the *Simulator Sickness Questionnaire* it 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 utilized due to a need for brevity.

A tailored method for gathering expert-by-experience opinions on suitability for cruise guests was utilized. As well as filling the UEQ-S regarding their own experiences, respondents were asked to estimate how a guest would rate the experience on the UEQ-S, and to explain why the guests would give such ratings via an open-ended question. This is referred to as the *estimation UEQ-S*.

As tracking actual changes to GPB 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 tailored method of self-reporting was used instead where respondents reported on changes to key determinants.

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

Results and Discussion

This section of the paper provides an overview of the most significant results found. 79 % of the 70 respondents reported some degree of familiarity with cruise guests, with 37 % reported being very, or extremely familiar with them. This top 37 % of respondents will be referred to as experts in this paper. Most respondents were male (77 %) and in the 31-50 age bracket (60 %). Around three fifths of the respondents had some prior experience with VR. 23 respondents ended the experience early, referred to as early enders in this paper, with the inverse referred to as finishers. A typical playtime of a user was estimated to be 20 minutes.

User experience was evaluated as good, as indicated by Figure 2. The overall average was 5.4 out of 7 being considerably above the scale midpoint. The averages for pragmatic (questions 1-4) and hedonic qualities (questions 5-8) showed no significant difference.

Two demographic factors were identified that significantly affected user experience, as Figure 3 illustrates.

Nausea during the experience was relatively common, illustrated by Figure 4. 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).

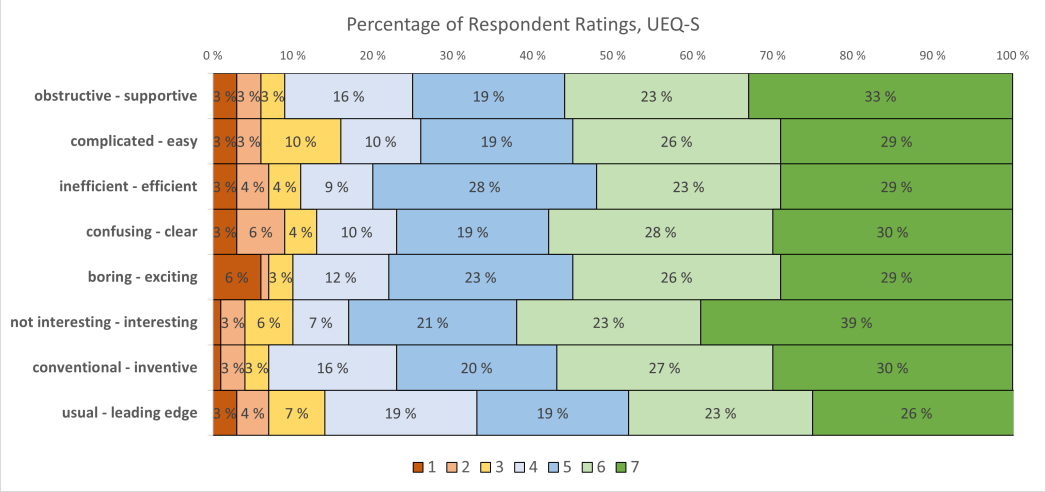

Figure 2. *UEQ-S results, on a scale between the item pairs on the left.*

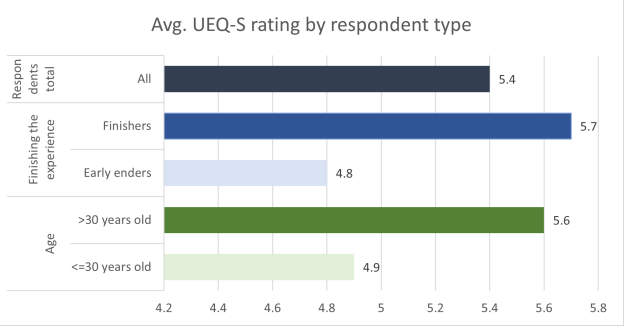

Figure 3. *Significant factors affecting the average of all UEQ-S items.*

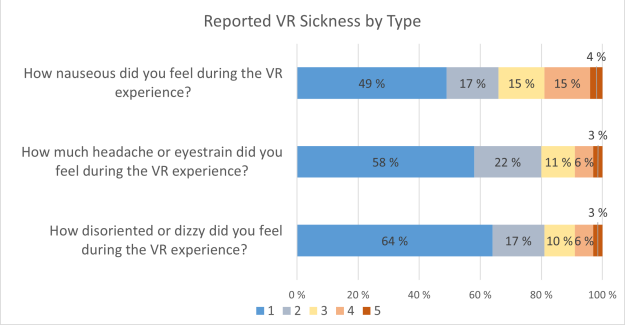

Figure 4. *VR Sickness results, 1 corresponding to "Not at all", and 5 to "I felt this to an extreme degree"*

The average score for the UEQ-S used to estimate suitability for cruise guests was 5.6, which is slightly higher than the average of the earlier, typical UEQ-S. A clear difference in pragmatic and hedonic ratings was found, with an average of 5.4 for the pragmatic quality, and 5.8 for the hedonic quality. The 34 open-ended responses for the rationale behind these estimations had seven responses alluding to something being ill-fitting for cruise guests, complexity being the most common reason (four responses). 20 responses contained positive feedback.

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" to cruise guests or that they would be "curious". It would stand to reason that the simplified communication in the experience was effective at keeping interest. The way the experience employed 360 images of the inside of a ship under construction and of the shipyard was alluded by two respondents as specifically interesting.

Four main compounding reasons are thought to be the main contributors to the large number of early enders (23 out of 70 participants): VR sickness, usability issues, the length of the experience, and the limited time of the test group. 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 [20]. Optimization issues and hardware limitations caused the frames per second to go below 30 at certain points of the experience.

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 that nausea caused some users to become early enders, but as prolonged exposure to VR can increase the probability and severity of VR sickness, the extent of this effect might have been confuscated.

Contrary to the findings of Kim et al. in their influential article on the Virtual reality sickness questionnaire [19], 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 levels 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 was observed contributing to the number of early enders.

The user experience was rated as *very good* overall. Even early enders rated the experience above the scale midpoint of four and finishers rated it significantly above.

It is unclear what caused the lower ratings of respondents under 30-years old seen in Figure 3. The difference was seen in both pragmatic and hedonic qualities. Neither gender nor not having any previous VR experience were found to statistically explain these results. Generational demographic differences, such as amount of exposure to similar non-VR technologies (e.g., video games), amount of exposure to specific kinds of media (e.g., social media) are potential explanations for these findings.

As using the UEQ-S as a tool to estimate how another user group would rate the experience was a tailored information gathering method, its results should be taken as indicative. Combined together with the open-ended answers, the results seem quite promising. 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 estimation UEQ Avg. = 5.7). The greatest contributor to the gap between pragmatic and hedonic qualities is presumably the usability issues addressed previously. Four experts commented that the experience would be interesting for guests specifically. Most experts agreed guests would appreciate the experience for being new or innovative.

Early enders had a 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 a lower pragmatic quality on the traditional UEQ-S.

Changes to GPB, displayed in Figure 5, followed expectations. The statements corresponding with changes to key target determinants were agreed with the most. In addition, this higher increase of key determinants was only found in finishers. This indicates that the intervention achieves its goals when experienced as it was deliberately designed.

The experience included an interactive segment where the player could steer the ship they had created through the embodied interaction of turning a steering wheel. During this, they received dialogue ensuring them of a potential green cruise where the quality of the service has not been compromised (equal enjoyment to a regular cruise). As the corresponding statement received the highest level of agreement, the experience seems highly effective at increasing perceptions of service quality.

The statement corresponding to increased trust in greenness claims received a high rating. A major contributor to this is presumed to be allowing users to reason for themselves by giving them a thorough explanation of contributing factors to cruise fuel use. The statement corresponding to purchase satisfaction received a high rating. It was presumably raised by other GPB determinants, though the mechanics of its increase remain unknown. Statements corresponding to determinants that were not key targets, increased environmental concern and increased knowledge about sustainability, received a lower rating. This rating was elevated from the scale midpoint regardless.

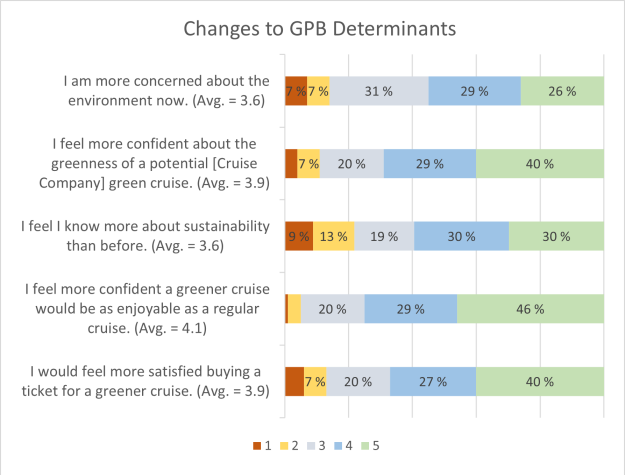

Figure 5. *Level of agreement with statements on changes to GPB determinants. 1 corresponding to "Disagree", 5 corresponding to "Agree".*

Conclusions and Future Work

This study was on the effectiveness of VR as a medium for a sustainability behavior change intervention that doubled as cruise guest entertainment. The results can be assessed through the research questions:

Creating an experience that takes advantage of the affordances of VR, embodied interaction and displaying things not possible in the real world, seems to be effective for scientifically accurate communication with a good user experience (RQ1). Simplifying the information, helping targets reason for themselves, and utilizing storytelling were all proven effective. However, the resulting length of the experience (typically approximately 20 minutes) seems like a contributor to the VR sickness and early ending issues discovered.

Expert opinions and high ratings on the UEQ-S and the evaluation UEQ-S reveal great potential for VR sustainability experiences to work as entertainment for cruise guests (RQ2). The usability issues and relatively high VR sickness ratings could likely be alleviated through a greater focus on them during development.

This study indicates sustainability experiences can affect the determinants for GPB, making them a potential medium for GBP change interventions related to cruises (RQ3).

As the study relied on self-reporting, the validity of 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. Such a study would also reveal more on the practical suitability of a VR sustainability experience as entertainment for cruise guests.

Overall, the experience achieved promising results on the metrics used in the study, while also revealing venues for improvement. Taking part in the maturation of the fields of sustainability communication, behavior change interventions and virtual reality research, this paper provides new insights in these fields and provides valuable data on the use of specific methods.

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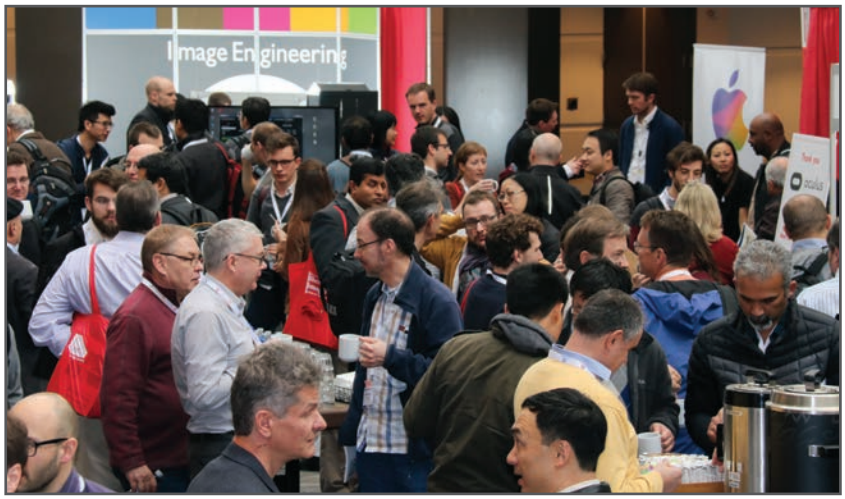

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