VR the change

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With Advisors Coye Cheshire and John Chuang

MIMS Capstone, Spring 2017

Team member contributions:

Sameer Bajaj served as a core member on the development team, sound engineer, and movie editor. He was in charge of 3 of the 9 designed interactions in the main experience, assisted in layout of the architecture of the room, as well as adding ambient audio that would not be distracting. Dina Bseiso served as an interaction designer and developer, screenwriter and storyboard artist, and lead researcher on this product. She storyboarded the initial concept, which was then scoped down to meet implementational deadlines; she wrote and recorded all voice over material; she also designed and implemented the research plan and conducted analysis of the results. Safei Gu served as an interaction designer for the project and visual designer for overall visual elements, as well as supporting researcher. Safei also designed all the 18 pop-up visualizations, cooperated with pop-up interaction implementation, and was also in charge of leading the research for environmental and economic impacts of the 9 designed interactions. Keshav Potluri served as a core member on the development team, supporting interaction designer, technical lead and architect. Keshav designed and developed the virtual landscapes for the butterfly migration narrative, developed some of the core software components and consulted on any technical challenges during the development. Richa Prajapati served as a core member on the development team, lead of marketing materials, as well as supporting researcher. She was in-charge of implementing 6 out of 9 designed interactions in the main experience, incorporating support for mixed reality videos, co-creating the onboarding scene, and helped in implementing the pop-up framework and researching which pop-up designs worked best. All members contributed to their respective fields of focus in the paper.

Acknowledgements:

- Thank you to Max Curran and Anne Jonas for their keen expertise, insight, and creative contributions on the research team, as well as to all our research participants that allowed us to gather insights about our product with respect to the larger problem space.
- Thank you to Michaela Byrne for her exceptional voice acting expertise, without whom *VR the Change* would be a fundamentally different, and less friendly, experience.
- Thank you to Leon Lee for his scripting support for integrating Safei's 2D visualizations.
- Thank you to Daniel Brenners for his insights in interaction design for virtual reality, performance-saving when developing in Unity, and terrain-building.
- And, of course, a big thank you to professors and advisors Coye Cheshire and John Chuang for asking critical questions, giving constructive feedback, and lending VR hardware resources. Without their support, this product would not exist.

I. Product Description

VR the Change is a MIMS Capstone Project and a virtual reality experience. As a proof of concept, it is intended to serve as an intervention for attitudes and behaviors that contribute to climate change. It is a gamified, educational application in which a person's home practices and the environmental consequences of their behavior are bridged with the narrative of a monarch butterfly migration from Canada to Mexico.

II. The Problem Space: Climate Change

Regardless of belief surrounding climate change for any one particular person, climate change remains a real problem impacting the planet at an accelerated rate ((S.), N. S. (2009). Solving the puzzle: researching the impacts of climate change around the world. Arlington, Va.?: National Science Foundation.). Even amongst people who believe in climate change, there exist barriers to behaving in ways that would mitigate its accelerated effects. Furthermore, in people who do not believe in climate change, there are ulterior motivations for why someone may behave in ways consistent with believing in climate change (such as monetary, convenience, etc). It is this end behavior, regardless of belief, that our product intended to impact, along with attitudes that can contribute to a shift in belief and eventually behavior.

The lack of sustainable practices by individuals in their homes is not a new phenomenon, nor is the attempt to address this deficiency with various forms of media and research intended to encourage positive behavioral change.

In order to gain a better understanding of people's sources of influence that may impact attitudes related to decision-making, and (more specifically) climate change, as well as to investigate barriers to behaving sustainably, we conducted a focus group. In order to gain a better understanding of the successes and shortcomings of some surrogate products, we conducted a competitive review of their features and relevance to *VR the Change*. Lastly, in order to assess the merit of our product with respect to these attitudes and behaviors of interest, we conducted an evaluation study with follow-up interviews a week after engaging with *VR the Change*. These methods and their findings are detailed below, under Research.

III. Virtual Reality (VR) as a Medium

VR was selected as an appropriate medium for this intervention due to its unique storytelling capabilities. VR has also been shown to have an encouraging effect on perspective-taking and empathy (Ahn et al., 2016; Bailey et al., 2015; Gehlbach et al., 2015; Oh et al. 2016). And while climate change is controversial, the motivating factors for improving sustainable practices can be monetary, social, or otherwise. The development team wanted to explore an array of potential influences to encourage people, regardless of opinions on climate change, to take on sustainable practices within the home, as it is our end-behavior that bears consequence on the planet. We believe that virtual reality as a platform allows for the inclusion of multiple incentives within a narrative, as to be holistic and not overwhelming.

IV. The Narrative: Helping Monarch Butterflies from Your Room

The incorporation of a narrative was not a trivial one. We wanted to utilize virtual reality's unique storytelling capabilities to engage as many sensory modalities as possible. By incorporating a story, people are able to revisit in their mind themes of the story while going through the interactive environment. It was important to the team that the narrative pertain to an issue resultant of climate change. It was furthermore important that there be some seamless connection between a person's actions and this narrative; otherwise, we felt the platform would be underutilized.

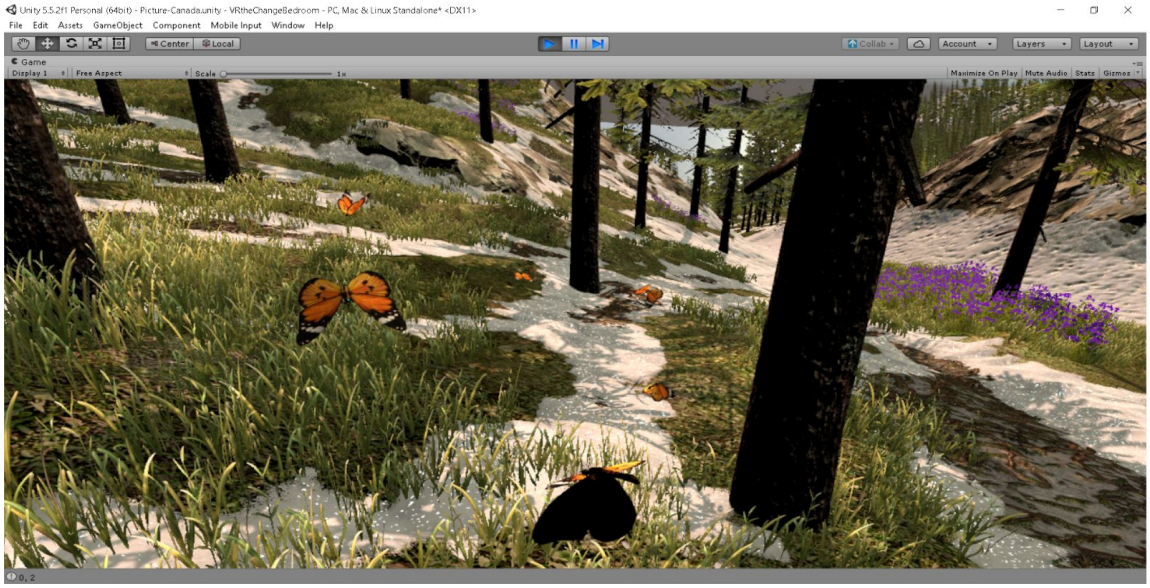


Figure 1: A frame from the first scene of the Monarch migration, from a participant's POV.

Initially, the product's proof of concept was overly ambitious, hoping to integrate various narratives within a larger home; however, given time constraints, scoping to polishing one narrative was deemed appropriate. For this reason, we settled on the story of a Monarch butterfly migration. It is the longest migration of any species, taking place from Canada through the United States and eventually to Mexico (World Wildlife Fund). Butterflies in general are delicate creatures, sensitive to a change in climate; they are also viewed as a creature of beauty and being generally harmless. The team wanted to invoke a sense of responsibility and empathy for these butterflies, thereby programming a successful migration as being dependent on the completion of ordinary tasks within a person's home.

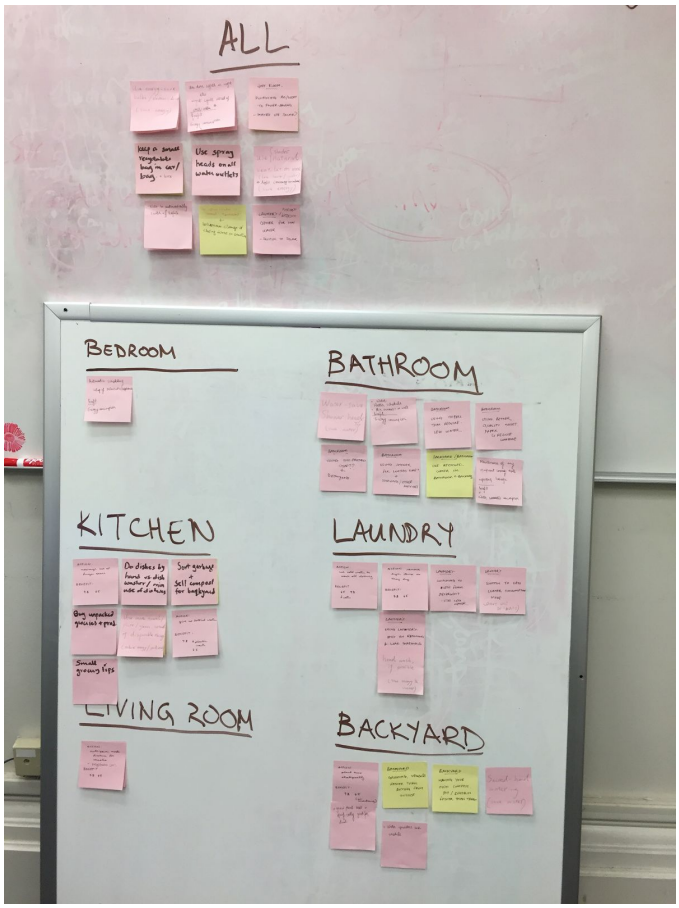


Figure 2: Affinity diagram for ordinary tasks that occur in some or all of the rooms listed, as a way of functionally building the virtual environment.

The setting of a person's home was also not arbitrary. An impactful experience is one that is relatable, and also one that celebrates everyday activities. When a person comes out of the virtual reality experience, we wanted to maintain a sense of connectedness to the story. As butterflies exist in real life, and the story is pulled from events that occur naturally, we hope that the behaviors and responsibility towards the butterflies are carried from the experience and into their own homes.

V. Technical Specifications

This project was particularly challenging from a technical point of view - we faced three critical challenges on every step of the development. First, for most of the development process, we required hardware to be able to code and debug our code. We were limited by the hardware we had - 2 HTC Vive sets placed at 2 locations where different team members could access them at specific times. Next, we all were new to Unity and had to scale an extensive learning curve on not only how to implement certain interactions but also whether certain interactions were even possible in the first place. Given the huge size of our project and its assets, every boot of Unity took around 15-30 mins which required a significant time commitment from our end. Finally, we were particularly limited by the beta version control of Unity - "Unity Collaborate" on cloud. While it helped us to save, share and sync our Unity project from the 2 different locations, only one of the 2 locations could "save, share and sync" the code at a time. This was because while we were working on different parts of the same project file, we were still working on the same file - which was the lowest granularity of saving, sharing and syncing as supported by Unity's collaborate feature. We tried using Git but doing so took us out of the "Unity environment" and transferring the code in and out of Unity could take upto 4 hours every time - a time we could not afford to have for every code building and iteration exercise.

We used the following as the base for our project:

Hardware:

- HTC Vive (Virtual Reality System) Set - It includes a head mounted device, 2 controllers and 2 base stations (along with chargers and connectors)

- Windows PC - To develop on Unity, following are the minimum requirements of a Windows PC (note that we could not use Mac OS for development since our Macs didn't meet the graphical card requirements)
    - OS: Windows 7 SP1+, 8, 10
    - GPU: Graphics card with DX9 (shader model 3.0) or DX11 with feature level 9.3 capabilities.

Software:

- Unity (v5.5.2f1) - Unity is a cross-platform game engine developed by Unity Technologies and used to develop video games for PC, consoles, mobile devices and websites.
- SteamVR - SteamVR leverages OpenVR to support HTC Vive set hardware (head-mounted device, controller and base stations) and other VR sets and is the environment for VR for Steam (including APIs). SteamVR also provides a plugin for an external camera to record mixed reality video
- Windows 8.1(64-bit): Visual Studio 2013 or later and Windows 8.1 SDK;
- UWP: Visual Studio 2015 or later and Windows 10 SDK;
- IL2CPP scripting backend also requires C++ compiler feature to be installed with Visual Studio.
- OBS Studio for stitching real videos (taken from an external camera) and VR videos (from Unity) in real-time to generate mixed-reality videos.

VI. Design and Development

A. Onboarding

One of the core observations from the evaluation study pertaining to usability was that people needed some sort of a "tutorial" to get oriented to the "ways of VR" such as moving and interacting with objects in the virtual space. While we did have an "onboarding audio" at the beginning of our main experience, the research team found that people still had difficulty in paying attention to and/or recalling the instructions in the audio. They were also distracted by the virtual environment around them for various reasons such as novelty to VR, movie playing on the TV, a butterfly in the room, etc.

Thus, we made an explicit onboarding scene where people will have the option of learning the "ways of VR" in a step-by-step and non-distracting way. Alternatively, they will always have the option of skipping the onboarding instructions and moving on to the main experience if they are not visiting the experience for the first time.

The onboarding scene starts off with a bare white room — there are no objects or colors in the room to ensure that people do not get distracted and focus on the instructions played in the audio. They are given only one task at a time and they are given audio instructions on how to accomplish the said task. Only on successfully completing the given task, say teleportation, will the instructions and objects pertaining to the next task appear.

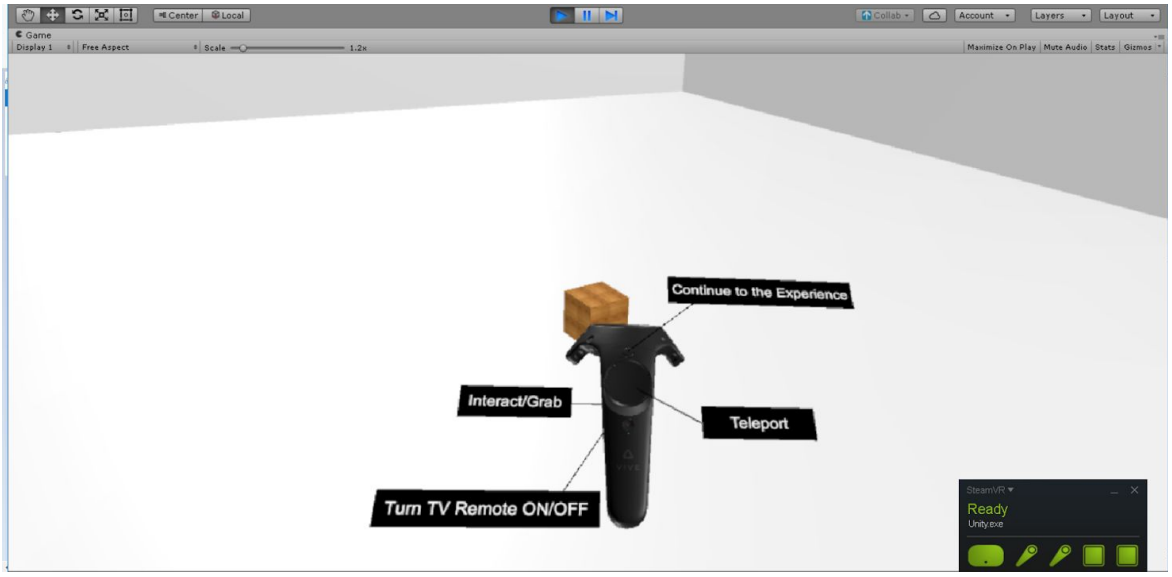


Figure 3: An image of the onboarding scene showing an object to be interacted with against a bare backdrop

This process ensures that the user is focused on only one task at a time and is "prepared" to focus on the experience, the story, and the messages we aim to deliver in the main experience rather than grapple with how to interact in VR and feeling frustrated at their inability to complete the "simple" tasks they do in real life.

B. Teleportation

One of the challenges in a Virtual Environment is movement. Although the user is immersed in a potentially unbounded and limitless environment, the user themselves are bound to a confined space in the physical world. Add to this the limited reach of the VR equipment like the sensor range, length of the headgear connectors etc., demands a solution that allows the users to freely move around in the Virtual Environments. There has been already extensive research on possible solutions for this problem. Room-scale locomotion, vehicles, teleportation, fade & appear, flight, shuffle, etc. are just to name a few. Out of these, studies in the industry as well as

our own User Research allowed us to decide that teleportation is the most comfortable form of locomotion within our environment. As compared to some of the other methods, where there have been documented cases of user discomfort and nausea, teleportation provides a more comfortable means of locomotion in VR environments.

For our implementation of teleportation, we first created a “laser pointer” which appears whenever the user presses the trackpad on the left controller. The pointer extends from the left controller to the surface in the environment which supports teleportation (the teleportation surfaces are only limited to the floor in our product).

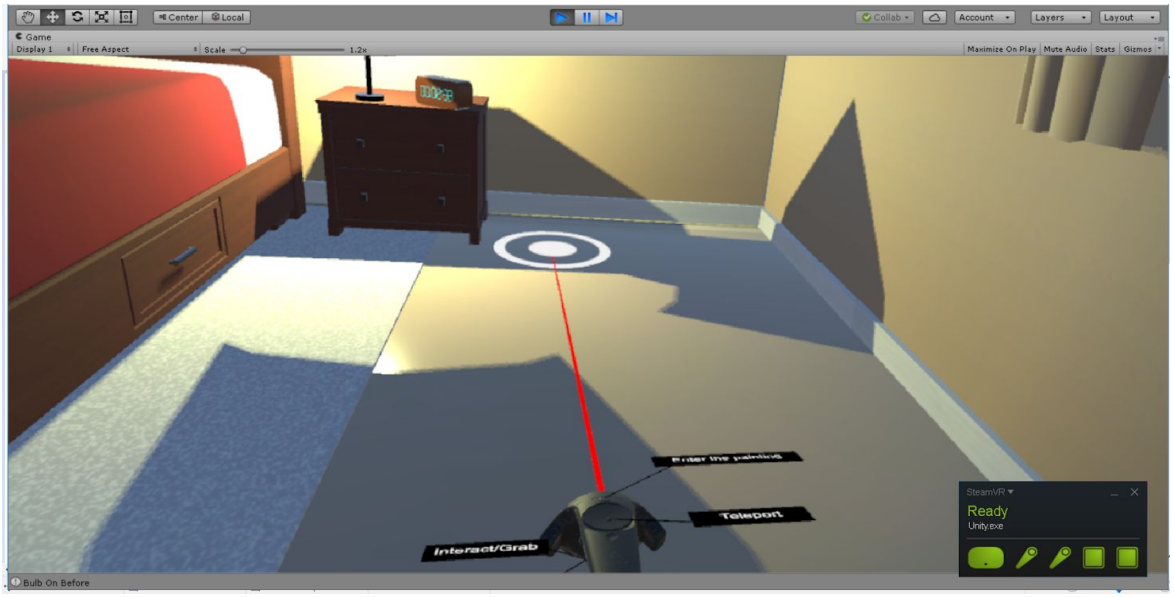


Figure 4: An image of the laser pointer for teleportation

This laser pointer allows the user to visually see where they would teleport within the environment, and adjust the end location if required. Once the user releases the trackpad, the user is “teleported” to the end location by updating the user’s 3-D coordinates to where the laser pointer ended.

C. Tangible Interactions

If we were to make our experience as immersive as possible, we had to make sure that they could interact with objects in the system. Moreover, creating a functional (and believable) virtual reality is about consistency. We wanted our users to put on the headset and immediately be able to unconsciously understand the laws that govern that world. The physics don't necessarily need to be 100% accurate, but if we want the player to think critically about these virtual laws, to use and subvert them to solve problems, then we have to make sure we apply these laws consistently across our experience.

Tangible interactions such as removing the lightbulb, turning on/off the switch, opening drawers, doors etc required an understanding of packages that would enable us to seamlessly integrate/modify these kind of tangible interactions.

By using the Virtual Reality Toolkit (VRTK), we were able to integrate the interactions such that when the user tried the pick up or interact with an object with the Vive controller, that object would be parented to the controller and made kinematic. Through parenting, the position and rotation of the object were matched to the position and rotation of the player's controller. Moreover, we designed the interactions in such a manner that didn't allow objects to go through other physical objects. We maintained this consistency of our world throughout our experience. It was also important for us to integrate a haptic feedback when the user touches an object that he/she could potentially interact with.

Figure 5: Labels on the controller showing possible interactions. The bulb in the drawer is intractable.

While interacting with objects in the VR, the object's location (and rotation) is dynamically updated in the x-y-z plane. The bulb interactions had to designed such that when the user removes the bulb from the lamp, the light source of the bulb would immediately turn off. When the old bulb (or the new bulb from the drawer) is placed in the defined x-y-z location coordinate area, then the lamp automatically turns on.

Apart from changing the location and rotation of an object, some tasks had additional requirements.

One example was keeping track of the number of objects that were in a designated area. For example, two food items were required to be inside the freezer to consider the “fill the freezer” task completed. This was done by tagging objects and using box colliders as trigger because triggers have the functionality of keeping track of what entered/exited them (such as

tagged objects). This in turn helps in keeping a count of objects, with say specific tags, in the space enclosed by the box trigger.

Another example was providing feedback that an object has been placed in the wrong area. This had two sub-components: (1) bringing the object back to its original location - for example, while is a person sorting trash into compost, recyclable and trash, if he/she puts a recyclable object into say, the trash can, the recyclable object would fly out of the trash can and go back to its original place; however, if the user put the recyclable object into the recyclable bin, the recyclable object will stay there. This was done by tagging objects as “compost”, “recycle” and “trash” and using box colliders as triggers that will accept only objects tagged one of “compost”, “recycle” or “trash”. The “flying of objects” was done by using lerp and slerp functionality of Unity. And (2) providing an audio feedback explaining what is happening - using the same example above, when the user puts a recyclable object in trash and the object is flying back to its original position, an audio will explain that the object is flying back because it was sorted in the wrong bin. Alternatively, users were also given feedback when they sorted the right trash object in the right bin to let them know of the progress. This was done by using an “if-then-else” functionality and playing an audio whenever the situation arise.

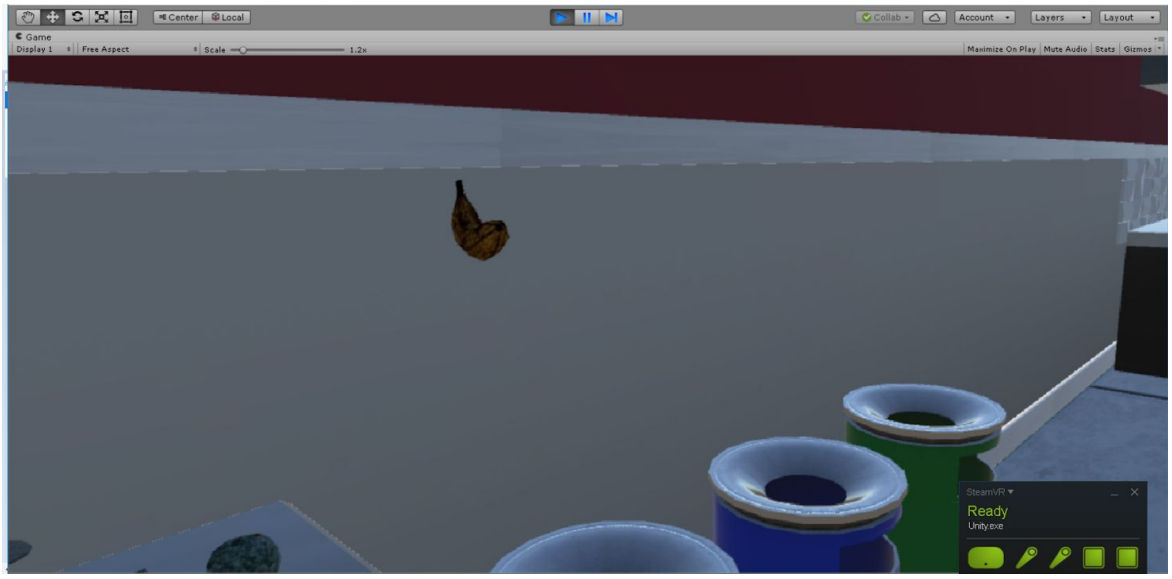


Figure 6: An image of a compostable object (overly ripened banana) flying back to its original position upon being put in the wrong bin

The above feedback (on doing a task right/wrong) was incorporated as a result of research finding which showed that without feedback, users are "expected" to know which trash is supposed to go in which bin (compost/recyclable/trash) and have no way of knowing whether they are making progress or where they made a mistake. However, providing an audio and visual feedback bridges this gap and also makes the mundane (and often disgusting) task of sorting trash fun.

D. Remote Interactions

In order to mimic life-like interactions in Unity, we decided to build interactions such as turning a television on and off, and putting the home entertainment system on sleep mode using a remote. These remote interactions were substantially different than the tangible interactions like picking up the light bulb, sorting the trash items, or turning a faucet on and off. We decided to

use the Vive controllers as the remote to reduce the amount of task complexity (say, finding a remote) for user.

The remote interaction functionality was incorporated using the UI Pointer and UI Canvas components of Unity. The UI Pointer was a (transparent) ray that emanated from the left controller and had the ability to interact and communicate with UI Canvas components. The UI Canvas and its components rendered a menu (listing TV turn on/off and Sleep mode on/off options) on the TV screen when the UI Pointer interacted with the TV screen. By moving the UI pointer around, user could move between the different options on the menu and by pulling the trigger, the user could select the menu option he/she was hovering on.

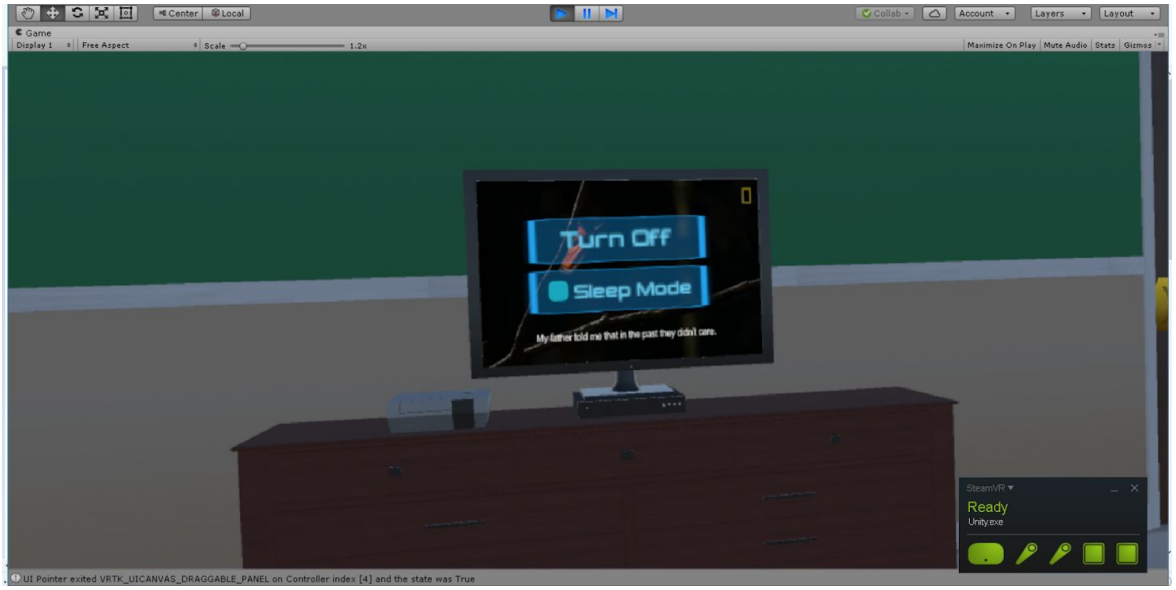


Figure 7: An image of the TV menu activated by the TV remote.

During development we realized that, like with the teleportation, it would be helpful to provide users feedback on the direction they are pointing their controllers to so that they can

move between the different TV menu options. Thus, we added in a laser renderer (similar to the "colored" rays of presentation pointers) which gets "activated" every time the user decides to use the controller as a remote.

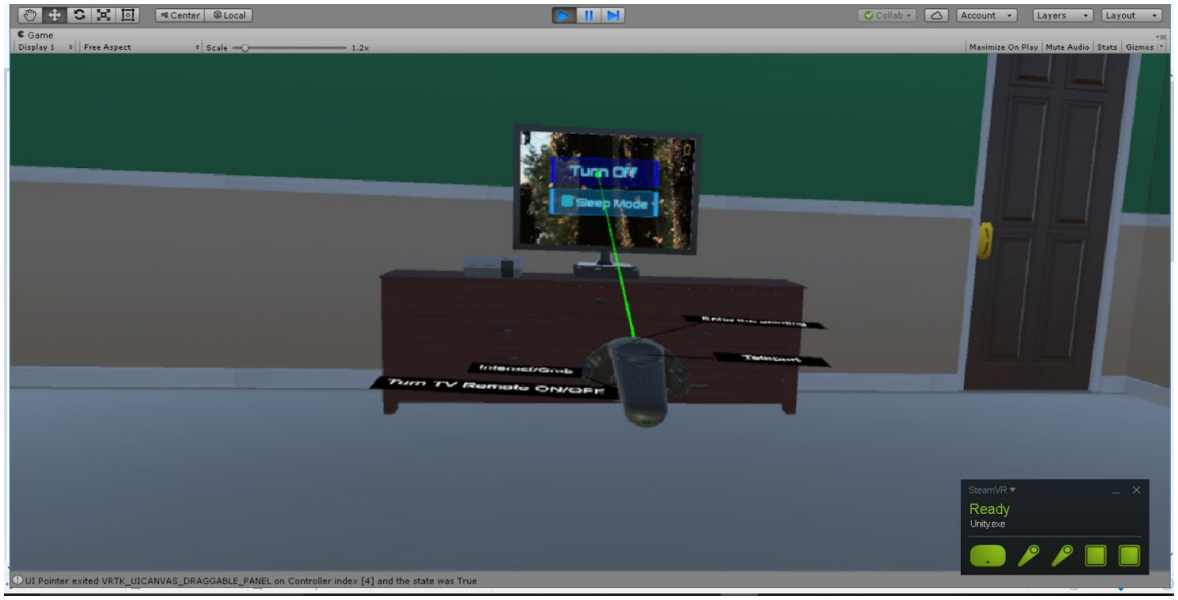


Figure 8: An image of the colored TV pointer aiming at one of the TV menu components.

E. Central Grid Menu Framework

Virtual reality posed an interesting problem when designing a hub of information that people may refer to that did not interfere with their interactions within the larger virtual environment. To completely transfer conventions of menu design from website and mobile applications would be erroneous, as the bounds of virtual reality are within a person's frame of view, and not the frame of a device; however, the concept of embedded information is an abstract one, and does not readily have physical metaphors that are intuitive.

We designed a menu that would be persistent — in view and in focus only when a person seeks the information it holds; otherwise, it is dropped out of their frame of view. We attached a menu in the form of a 3x3 grid to house the objectives needed to be completed within the bedroom. Atop this grid is a progress bar, indicating where the butterflies are in their migration.

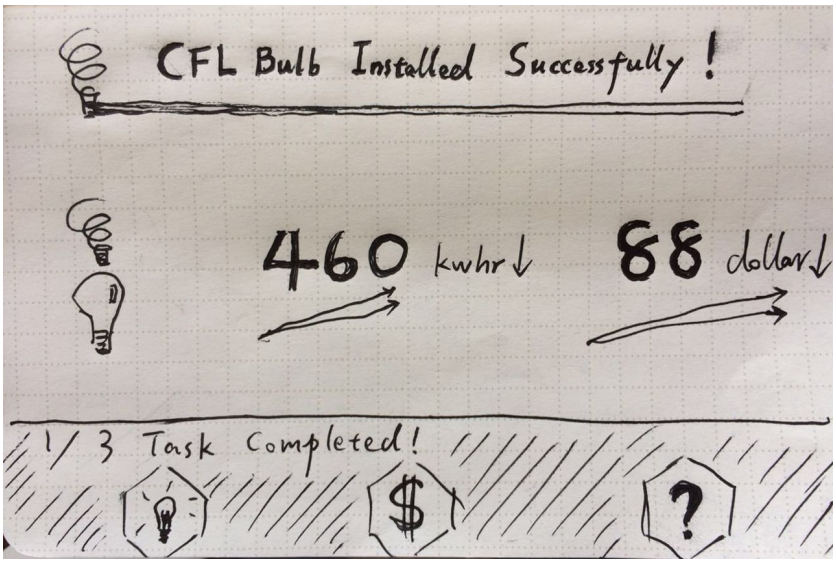
The ways in which to interact with the grid menu were designed after a series of crude prototypes were developed using paper. In our design, a person uses the a trackpad on the same controller the menu floats above to navigate it. Were we to use both controllers to navigate the menu, for example, level of accuracy and efficiency would have been impacted negatively. We considered alternative options for the grid menu design, such as having it not be persistent in the environment but hidden and accessible via a button-press, similar to a video game Pause Menu; however, the affordances of such a menu are few given the all-encompassing nature of virtual reality environments. The likelihood of a person accessing a hidden menu in an experience paralleling their own is low.

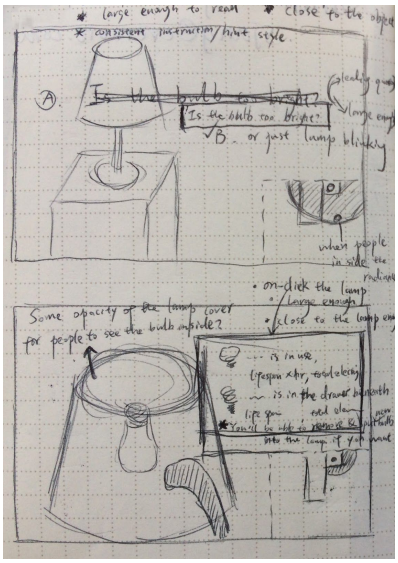
Information intended to be held within the tiles of the grid menu are reflective of the objective status. If the objective has yet to be completed, a certain information visualization can be accessed by selecting the tile and pulling the trigger on the respective controller. Once the task has been completed, the color of the tile changes from black to white, and the information within the tile indicates benefits of having done such a task. It is in these graphics (detailed in the next section below) that introduce motivations other than the butterfly migration.

F. Information Visualizations

We used information visualization charts to work as pop-up notifications in the VR environment to notify users about which task they need to complete and what the aggregate statistical environmental impacts from those behavioral changes are within the virtual household. When we refer to them as "pop-ups," we refer to their animation into the scene upon intentional user-behavior, as opposed to autonomous behavior of a window within a frame (as they were made notorious in the 90s).

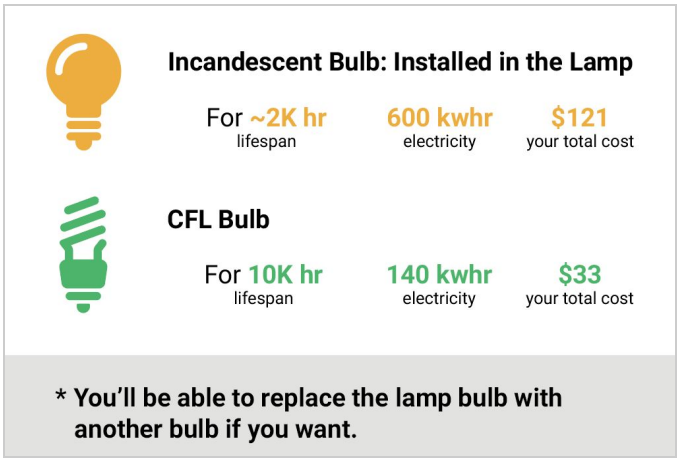
For the visualization pop-up for each task, we did substantial research to estimate the aggregational environmental impact in terms of how much electricity or water can be saved and what's the corresponding CO2 emission reduction and monetary saving amount for the user as additional levels of incentives. For example, for the filling-freezer task, behind the simplified visualization of what's the electrical cost, we actually went through complicated calculations of how much air exchange would be every time user opens a freezer, and how much electricity it would take to cool down the exchanged room-temperature air to freezer temperature. However, the reason why we tried our best to simplify the presentation of such complicated information visualization is because during our initial user research based on paper prototype of the pop-up contents, the more complicated the information we presented to the user, the more confused the users will be when using the VR system. So we made this design decision to simplify the presentation of the visualized information in the pop-up notifications.

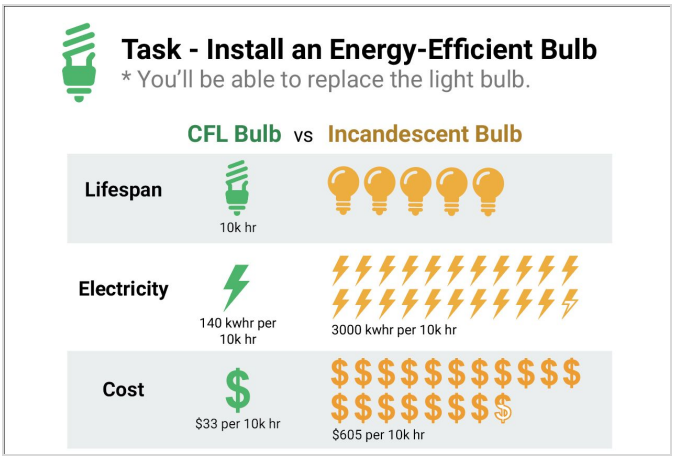




Images: paper prototypes (left) , and the initial research plan layout in a household (right)

We also iterated from number-driven visualizations to icon-driven visualizations for the pop-up notifications, based on the user insights from our usability testings. Because the initial version of number-emphasized visualizations are still text-heavy, users are not really interested in reading those pop-up notifications, even though we had kept the text as simplified as possible. As a result, we changed all of the pop-up notifications to the more graphic-driven visualizations.





Images: one of the previous number-driven visualizations (left), one of the icon-driven visualizations (right)

G. Maintaining State across Virtual Environments

Our narrative follows the journey of Monarch butterflies in their migration from Canada to Mexico. As users complete more and more tasks in their own house, they enable the butterflies to travel further by reaching milestones in their journey. Our experience allows the users to follow this journey by visiting these different milestones, from Canada to Mexico, visually experiencing this wonderful two month long journey. The users can travel between these environments and the bedroom as they wish; however, while the users move across these environments, it is important to maintain the user's progress throughout the experience to ensure a cognitive continuity and prevent frustration with the system.

In Unity, our VR development environment, each of these environments is developed as a separate "Scene" which has its own set of dependencies, libraries, code, scripts, and all the other components that make up the environment. As the user travels from one scene to another, the previous scene along with all its components gets destroyed and the next scene along with all its own components gets loaded. As such to ensure we keep a track of user's progress, we developed an ingenious way of maintaining state across the virtual environments. We created a static global object and added this object to each of the scene. We load this object in the first scene and specify that the object may not be destroyed on scene exit. Next, in all the other scenes where we added this object, on load, instead of creating a new object of the same name, we assign the object that was previously created in the first scene and not destroyed, to the object in this scene. This object contains different variables like current scene name, next scene name, which tasks have been completed, how many tasks have been completed, which audio should be

played, which audio has already been played etc. Once we have this global state managed, it becomes extremely easy for us to save the state of a scene, go to another scene, return, and load the previous state of the scene we just entered. Although logically, the process of maintaining states seems straightforward, with the limitations of how certain things work in Unity as well as limitations on the libraries currently available, this was a comparatively time consuming effort. However we managed to implement it correctly and simplified a lot of our other tasks.

It is to note that while the state in the grid menu is saved, the state within the home's environment is not. For example, if you turn off the lamp and go into the painting, upon return the lamp will be on again. There were instances in which the person would return from the painting, discovering that while they got credit for completing a task previously, would out of guilt or new-found annoyance turn off the faucet, lamp, etc.

VII. Research

A. Methods

We chose three methods aimed at addressing the research questions above from different perspectives in order to triangulate our data: a focus group, evaluative interviews, and a competitive review.

1. Focus Group

<u>Method rationale</u>

We conducted a focus group to gain an understanding of people's general experiences and perceptions of behavioral change in their own lives. Drawing on Baxter et al.'s assertion, "Focus groups are particularly well suited to answering questions that explore attitudes, feelings,

and beliefs about a topic, elicit concerns" (Baxter et al., 2015, p.342), we chose the focus group to investigate people's beliefs about how changes to attitudes and practices occur, what sources influence those changes, and what barriers exist that stand in the way of change. We utilized the focus group method for "idea generation" (p.101) about concepts which we could then use to evaluate *VR the Change's* potential influence on attitudes towards environmentally sustainable practices. By having a group discussion, rather than individual interviews, we were able to prompt a deeper array of reflections as people built off of one another's ideas through "synergy" (Baxter et al., p.362) and differentiated the kinds of "problems, challenges, frustrations, likes, and dislikes" (p.101) they had regarding attempts to incite changes in people's lives. We also incorporated individual activities, such as having each person write down their thoughts before sharing, in order to avoid group-think.

Recruitment strategy

Participants for the focus group were recruited from the research team members' contacts, either socially or through shared work/school experiences. The team screened participants by phone or in person by asking a few questions, including about a recent experience resulting in some form of behavioral change - the full screener is included in appendix A. Criteria for inclusion centered around ability to engage in thoughtfully answering the question, not too shy or sparse of an answer, but also not too overbearing, as well as availability for the one hour scheduled period for the focus group. We also recruited several participants who had experience with advocacy and communications work, who would be likely to have thought about how to shift people's attitudes and behaviors from a professional as well as personal perspective.

Description of research activities

The focus group included a self-introduction period, drawing of mental models of their personal information-influence networks, a modified card sorting exercise on barriers to practicing sustainable behaviors, and group discussion throughout. Prior to the introductory phase, all participants were given their reward (a cookie) in order to build trust, and offered the chance to participate in a VR experience at the time of their choosing. Participants took time to draw out their sources of influence, shared with the group and reflected on themes, then each discussed a critical event where they had shifted their attitudes or behaviors. The facilitator followed up on participant discussion with probes asking for greater elaboration and alternative opinions, and with prompts that reframed what the participant had said in the form of a question to the group, paused to offer participants the chance to speak, and checked for understanding, per Baxter et al. She also directly elicited comments from participants who had been quieter, and tried to highlight potential shared concepts and points of divergence in order to incorporate participant feedback.

Figure 9: An image of the card sorting activity, complete with tallies participants had placed on their personal greatest barriers to executing environmentally sustainable behavior.

The group organizers had put together cards with potential barriers to sustainable behavior, which the facilitator read to the group and then asked for their additions, eliciting their own language and framing, which were added to new cards. Participants were then each given three markers with which they could indicate the three barriers they felt represented the greatest challenges to sustainable behavior, and were asked to group concepts they felt overlapped together. They were given the option to put a marker across multiple items if they were grouped together, and to put multiple markers on one item to indicate its importance, though no participants performed this later action, with each placing all three markers on different cards. Participants then discussed their rationale for their choices. This concluded the group meeting and participants were thanked for their participation.

2. Evaluative Interviews

Figure 10: During our evaluation study, participants exhibited different approaches and perspectives to experience *VR the Change,* as they would outside the virtual environment.

Method rationale

The VR product experience was paired with semi-structured interviews to gain high-fidelity understanding of participant's interactions with and responses to *VR the Change*. Interviews are desirable to "get information about attitudes, beliefs, feelings, and emotional reactions," "get answers to open ended questions," and "gather detailed and in-depth responses" (Baxter et al., p112). The research team believed that this methodology had the potential of addressing, in part, all of our research questions.

Recruitment strategy

The participants for the evaluative interviews were recruited primarily through the research team members' contacts and other connections in an attempt to achieve some diversity

in age, profession, and set of values/beliefs. The team screened participants via an online initial questionnaire, asking participants to share the frequency of engaging in certain behaviors. An excess of some behaviors are viewed as unsustainable in practice, and these inquiries were purposefully buried among other behaviors not related to sustainability (see Appendix C). Participants were also asked about the frequency with which they played video games, because VR as a platform has been strongly marketed toward gamers, and as a platform can be received differently by such a demographic. Additionally, participants were asked to share their top three values when consuming or purchasing certain products, as a means to gauge how environmentally conscious they may already be. Our intent was to screen for particularly environmentally conscious people; however, this proved to be an insurmountable challenge given our recruitment pool was limited by time, lack of participant compensation, and the necessity of physical colocation to experience VR.

Description of research activities

Participants tended to have limited VR experience. To diminish a novelty effect and potential overwhelming nature of playing with emerging technology, we placed participants in a functionally similar VR experience developed by Valve, *The Lab*. This way, they would be able to acquaint themselves with movement and interaction controls before entering *VR the Change,* as well as adjust to being in a virtual world. Participants were then placed into *VR the Change*, and were instructed to think aloud their thoughts primarily pertaining to the content rather than usability issues with the experience. Participants were notified that the experience was not created by professionals, and was currently in the stages of development. The research team

remained mostly quiet, only speaking when the participant could be in danger in physical space, and to assist in overcoming usability issues or bugs (e.g. teleporting through a wall).

After completing *VR the Change*, participants were interviewed briefly in a semi-structured format by the research team. Questions ranged from talking about the experience, how they felt, how relatable the experience was to their lives, and who they might speak to about this experience, if anyone (see Appendix D); follow-up questions and probes were employed by interviewers. A week after this interview, the research team followed up with each participant, asking them to reflect on whether the experience affected their week in some way and whether they spoke with others about the experience (see Appendix E). Participants were compensated with a cookie and an opportunity to explore other professionally developed VR applications after the interview.

3. Competitive Review

Method rationale

The lack of sustainable practices by individuals in their homes is not a new phenomenon, nor is the attempt to address this deficiency with various forms of media and research intended to encourage positive behavioral change. In order to gain a better understanding of the successes and shortcomings of these surrogate products, we conducted a competitive review of their features and relevance to *VR the Change*. We also believed that a competitive analysis was appropriate, as "no product is so revolutionary that there is not someone out there from which to learn," especially considering that the issue of environmental sustainability is a longstanding one (Baxter et al, 2015).

Competitor selection strategy

We chose four products that had an educational and/or advocacy goal, two of which were specifically about climate change and environmental sustainability, but were different media forms (a novel — *Flight Behavior* — and documentary film — "An Inconvenient Truth"), and two of which were applications in Virtual Reality (The Body VR and Ahn et al.'s perspective taking VR research project from 2016).

Description of research activities

We looked at each individual surrogate product for its unique features, design strengths and weaknesses, and any hardware requirements as they compared to those of *VR the Change*. These ranged from more subjective evaluations to more objective aspects (e.g. whether content is interactive). We also assessed the presence of selected core features, focusing especially on level of accessibility [See Appendix F]. We added an intermediate "maybe" category, designated with a ~ , to indicate the ways in which these features may be only partially present. We initially had other qualities, such as visual imagery, text, and haptics, but deleted them when we decided these were not core features of the experiences.

B. Key Research Findings

Inextricable usability

Theme: We found that usability remains tightly interwoven with presentation of content, and how effective that presentation could be in engendering contemplation and potential behavior change. This also came up in a prior usability study of surrogate product *The Body VR*,

where participants often struggled to take in and recall information due to being distracted by understanding how the environment worked, and that it often did not work in expected ways.

Recommendation: Incorporate iterative/agile process of testing and development for both usability and narrative simultaneously, as they are closely linked.

Power of awe & nature

Theme: This aspect was a strength of *Flight Behavior*, which imagines the personal impact on one woman and her town when monarch butterflies reroute their migration due to climate change and unexpectedly descend on a small Southern town. Similarly, "An Inconvenient Truth" uses sweeping images of large scale environmental change which, at least according to film critic Roger Ebert, incited behavioral changes of the type desired. Multiple interview participants spoke about the sweeping landscapes in the monarch portion of the VR the Change experience, expressed the desire to spend more time in that element, and spoke about it to friends. Additionally, research in psychology has suggested inducing feelings of awe can contribute to prosocial behavior (Piff et al. 2015), and this is particularly apt for *VR the Change*'s goal of behavioral change toward sustainable practices.

Recommendation: Take advantage of the awe-inspiring qualities of immersive nature scenery, perhaps by allowing for more time and exploration in these scenes and improving their fidelity.

Recognition and reflection

Theme: During the focus group, participants spoke about the impact of learning about an alternative way of approaching a concept or set of practices and seeing directly how that could fit into their lives - the importance of contextualizing abstract ideas in their daily environments, for example, when one participant's supervisor scolded her for not separating garbage into different bins. Learning about something from an external source, such as a podcast, book, or a loved one's comments, caused participants to begin to examine their behaviors and attitudes differently going forward. While in the experience and in the following interviews, several participants said variations on "I do this at home," and reflected on the extent to which tasks in the experience matched their daily chores. Several participants specifically mentioned the running water in the sink - that it was a "pet peeve" of theirs, or that they felt guilty to leave it running. This element of recognition and reflection is clearly central to VR the Change, and one participant specifically noted in his follow up interview that after going through the experience he reflected on how full his refrigerator was at home (one of the tasks in the experience) and tried to keep it more full to save energy.

Recommendation: *VR the Change* should continue to match and incorporate things people recognize from their daily lives. In future variations, the team should perhaps research additional areas where people struggle with environmental sustainability in their daily lives (e.g. transportation) and add those in. We found that some tasks were relatively rote and deeply familiar to people (such as the sink), while others were somewhat surprising or provided more context (such as the refrigerator and sorting the garbage). The development team could further work to identify the tasks that both resonate most deeply *and* provide opportunity for new reflection and behavior change.

Change is social and gradual

Theme: In our focus group, participants repeatedly mentioned those around them as having a profound influence on their attitudes and behaviors. Similarly, in our interviews, participants highlighted the way friends' behaviors could directly impact them. Peer pressure as a social good is a common technique of technological health interventions, such as Fitbit, that encourage sharing for mutual support and friendly competition. Participants also highlighted the way change often took place for them over time, as they saw something repeatedly reinforced by different aspects of their lives, suggesting that a long term vision is necessary to connect to a wider ecosystem of efforts to support a shift in attitudes and practices. "An Inconvenient Truth" and *Flight Behavior* both focus on the power of social and community norms in shifting someone's practices over time.

Recommendation: VR the Change could integrate some level of social sharing into the experience itself - anything from encouraging participants to share badges of accomplishment or VR selfies among the monarchs on social media to shifting the information presented about energy savings to reflect how you as an individual contribute to larger changes in your neighborhood, city, state, country, etc.

Rational understanding + care = change

Theme: Several interviewees expressed confusion about the relationship between the home tasks and the butterfly migration. While the same participants claimed to already practice sustainable behaviors and be knowledgeable about environmental concerns, they still felt the link

between the behaviors and the butterfly's experience was tenuous. At the same time, they expressed a feeling of joy and awe in regards to the butterfly portion of the experience. During the focus group, many people spoke about change coming not from rational understanding alone, but often from a combination of facts and expertise and emotional attachment. This combination is nascent in *VR the Change* as it stands, with both facts and emotional connection built in in the form of informative slides about sustainable behaviors and the butterfly migration experience.

Recommendation: The development team should further play up the connections between the tasks and the butterfly experience, fleshing out the links without overwhelming participants with further reading - perhaps through an animation or other experiential aspect.

Universal Accessibility Areas for Improvement

Theme: We did not yet conduct research with individuals with various disabilities, but a set of core features in our competitive review revolved around the accessibility of the experiences provided by the products. *VR the Change*, like other VR experiences, is currently heavily dependent on the audio and visual ability of the user, as well as the ability to interact with hand controllers.

Recommendation: As much as possible, we encourage the development team to provide alternatives to visual and audio experience such as descriptive audio and subtitles. The ability to teleport in the environment is helpful to those unable to move around the room, but perhaps an alternative interaction method to the hand controllers could be explored. We also recommend conducting future user research with individuals with disabilities to confirm the usability and positive experience by these individuals.

C. Research Limitations and Future Work

Our primary limitations revolved around limitations in time, location, and resources, which overlapped with usability issues that arose due to the ongoing nature of development, where participants encountered bugs and other usability concerns. It was difficult to recruit people who fit our profile without funding for participation incentives and in a limited time span in the Bay Area; additionally, the fixed location of the VR equipment meant we were unable to engage remote participants. Due to resource constraints, we avoided doing a diary study, which could have offered more fine grained information about participants' behaviors. However, such a study might also have the confounding effect of creating its own prompt, and thus might have required a control group of even more participants.

A further complication in the research we conducted was trying to match the participant population with a suitable target audience of *VR the Change*. The participants recruited through connections of the research team generally did not have much room for improvement with their at-home sustainability practices - though as we describe in our reflection and relatability finding above this did not mean no value could be gleaned by users in this group. With additional resources and time, there would be much to gain from repeating the focus group and evaluative interview methods with participants who do not already have an understanding of sustainable practices.

In addition to future work that might target a broader cross-section of the population and more participants who are not currently engaged in environmentally sustainable behavior, future research might also investigate opportunities to expand VR the Change or embed it within a

wider system of experiences. In order to determine what experiences might be most resonate and effective in terms of promoting long term behavioral change before development has taken place, future researchers might use paper prototyping or scenario based surveys, as well as field research and interviews, to generate further ideas for iteration and expansion.

VIII. Additional Media

The team developed an archival website to post related information to the product and its development at http://vrthechange.wordpress.com. In addition to this website, the team worked on mixed reality recordings of the experience to display, in a different format as to make accessible the concept, the experience.

IX. References

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X. Appendices

A. Focus group screener

B. Focus group guide

C. Interview preliminary questionnaire

D. VR experience & interview guide

E. Follow-up call guide

F. Competitive Analysis grid

Appendix A: Focus group screener

Briefly describe focus group activity and purpose, that it is not an experiment or an attempt to change anyone's mind, but that we are looking to understand people's experiences and attitudes, as well as available times and compensation (cookie and VR).

- What is your job?
- What are your hobbies?
- Do you have experience with marketing / communication / advocacy (in a professional or volunteer capacity)?
- Tell me about the last time that you changed your opinion on towards an issue?
- Can you think of a time you substantially changed your behavior based on something you heard, saw, or experienced? What was that?

Appendix B: Focus group guide

Welcome everyone, thanks for coming. For this group, we'll discuss how attitudes and behaviors form and change. All ideas are useful and please speak one at a time. Your individual experiences may be different - please respect each other's experiences and thoughts - it's OK to disagree but please don't critique each other. We will be audio recording this activity and taking pictures for our project. This will last until 6pm.

Introduction (Name, Job, Pronouns) – 5 min

(Have nametags)

Map of sources of influences around issues of public interest: e.g. daily news

Have sharpies and paper

-- 5 min to draw your map

-- 10 min to share with new color to revise

Discussion

Can you tell us about a recent time that their opinion or behavior changed based on something they heard, saw, or experienced (doesn't need to be the one from before) - 15 min discussion (2 min write notes, then share out)

Exercise

What are the biggest barriers you face to improving the environmental sustainability of your behaviors? (you write down yours first - 2 min, here are the ones we came up with, what others are there? - 3 min, we'll give you 3 post it notes and feel free to distribute them on the things you think are the greatest barriers, please discuss your thought process as you do it) - 20 min

- Cost
- Inconvenience
- Sentiment / tradition
- Not knowing about alternatives
- Don't think our actions will make a difference
- Not wanting to face the harsh truth

Final Thoughts

Do you have any final thoughts? 5 min

Appendix C: Interview preliminary questionnaire

1. List three problems in the world you are most concerned with.
2. Estimate how many hours per week you spend doing the following activities: Watch TV (on a television), Read printed material (books, magazines), Spend time on a computer, Use a mobile device (phone, tablet, etc), Play video games.
3. Estimate how frequently you do the following activities: Look at your utility bill(s), Go shopping for new clothes, Use a washing machine/dryer, Purchase fuel for a vehicle.
4. Of the list below, rank your top three (1 most important) factors when purchasing food. (Appearance, Cost (to you), Environmental Sustainability, Expert Reviews, Labor Practices of Producer, Nutritional Value, Peer Recommendations).
5. Of the list below, rank your top three (1 most important) factors when purchasing technology. (Appearance, Cost (to you), Environmental Sustainability, Expert Reviews, Labor Practices of Producer, Technical Specifications, Peer Recommendations).
6. Choose the mode of transportation you most commonly use for your daily commute. (Walking, bicycle, personal car, bus, train, carpool, other).
7. Briefly describe how you use water.
8. In the next two weeks, which days and times would you most likely be available to come to South Hall at UC Berkeley South Hall for a 1 hour study visit?

Appendix D: VR tutorial, experience & interview guide

VR Tutorial and Experience

Greet participant, explain they will spend about 20-30 minutes in VR and 30 minutes interviewing immediately afterward. Both will be recorded via video and written notes. Confirm they're okay continuing. If at any time during the VR experience they feel nauseous, or feel uncomfortable in the interview, they can stop & that is OK.

[Ask any questions about their responses to the pre-visit questionnaire here]

Unity scene should be pre-loaded. Should it not be, open Unity from the desktop, and open file "VR the Change Bedroom." It should be the most recent file that has been opened, and so the first one listed. The file itself takes ~10 minutes to load without an indication of progress, sometimes causing Unity to hang, and requires Unity to be force quit. Patience is your best friend, but in the event that it is taking particularly long, do not hesitate to force quit and restart the application. In order to initiate the program, click the Play button toward the top-center of the program.

Moderator: [*Holding a controller*] "This is one of the hand controllers for the VR experience. You will have one in each hand. There are a few buttons you will be able to use - the touchpad to use with your thumb, and the trigger button underneath to use with your index finger. There are other buttons but you won't need to use them. At the start of the experience, a narrator will go into further detail about the controllers. Listen for her throughout your experience."

Place the VR headset on the participant's head, explain they can adjust straps on sides for a snug but comfortable fit. Have them make a fist with each hand to put their hand through the loop and have them grasp the controller.

Confirm they're okay to continue.

Moderator: "You will begin in a bedroom in a virtual home. You can move around in two ways. First, you can physically walk, turn your head, or any other typical motion - there is a limited place space so if you see a transparent blue wall you know you are out of bounds and should take some steps backward to return to the center of the room. The second way to move is to press and hold on your right touchpad and point to a location, upon releasing the touch pad you will teleport to that location. We recommend this method of locomotion to avoid bumping into walls in the physical space. Try this out now, teleporting to a location in the room.

You can also interact with some objects in this room. You can try pointing at something and pressing the trigger button on your right hand. You can also go up to some objects and press and hold the trigger button to push or pull them.

On your left hand you will see a grid-like display. Each image of the display represents something in the room. Can you tell me what you think the first icon represents?"

Wait for response - correct them if they're wrong.

Insert instructions for accomplishing first task. Include whether they notice anything different.

Moderator: "For the remaining 20 minutes I'd like you to explore and interact with the room on your own. I will stop you if you are about to run into something or otherwise hurt yourself, as well as if the program encounters an unexpected error. Otherwise I will remain silent until the end."

Once 20 minutes have passed.

Moderator: "Okay you've finished this portion. I'm going to help you take off the VR equipment now."

Take controllers and headset.

<u>Post-VR Interview Guide</u>

Moderator: "Now we'll move into the interview portion. I'd like to remind you there are no incorrect answers and we are hoping for your honesty. We did not build this experience, we are simply helping to evaluate it. All of your responses will be reported anonymously, but you don't have to answer any question if you don't feel comfortable doing so."

Interview questions:

- How are you feeling?
- Can you tell me about what you just experienced?
- What were your favorite parts? Your least favorite parts?
- Was this a memorable experience? Why/why not?
- How relatable was this experience?
    - Some parts more than others?
- How do you think this experience will influence you?
- Given the option, would you return to this experience again?
    - Would you recommend this experience to anyone you know? Anyone in particular? Why?
- Is there anything you thought I would ask that I didn't?
- Anything else you'd like to share?

Thank participant for coming - give them a cookie, and let them know we will contact them by phone for a short follow up in one week. Ask for their phone number.

Appendix E: Follow-up call guide

1. Under what circumstances did you think back to the experience? Describe those times.
2. Did you tell anyone about the experience? Who? What did you say?
3. Has anything come up about the experience since the interview that you'd like to share?

Appendix F: Competitive Review Grid

	VR the Change	*Flight Behavior*	An Inconvenient Truth	The Body VR	Ahn et al.
Design strengths	Immersive, requires full attention, gamifies best practices in sustainability to make the link to everyday life, awe-inducing nature scenery	Single mode (reading) may allow for less distraction and more focus - since people imagine visuals rather than are provided with them they are inherently required to connect the material to their existing mental models, strengthening impact	Music, facts, description, images combine to make a point	Multiple modes (short interactive films, 3D anatomy viewer), self-guided	Involves both VR and in person physical engagement to promote embodied reactions and experience
Design weaknesses	Some instructions required given bugs exist (e.g. teleporting through wall), not yet distributed beyond development team	Requires a longer amount of time and higher level of literacy / willingness to stick with it, May not resonate with people in very different situations from the characters [< - too plot oriented? i think it's relevant...] Set path through the material, No interactive component	No interactive component Emotional resonance of music / dramatic effect may overwhelm details of potential alternatives	Virtual reality/interactive component distracts users from fully exhibiting the narrative/educational content	Requires outside intervention to perform physical engagement, no narrative component, only ocean acidification experience currently distributed beyond lab
Requirements	Only accessible with HTC Vive hardware	Accessible to anyone who can purchase a book or borrow one from a library	Available to stream on a variety of digital services, originally accessible in theaters	Requires HTC Vive, Occulus, or Samsung Gear VR hardware	Requires customized VR hardware in Stanford VHI lab
Core features (educational)					
Interactive content	✓	✗	✗	✓	✓
Physical interaction	✓	✗	✗	✓	✓
Self-paced	✓	✓	~	~	~
Direct connection to daily practices	✓	✓	~	✗	✗
"Game-like" qualities	✓	✗	✗	✓	✓
Accessible to people without hearing ability	✗	✓	✓	✗	✗
Accessible to people without visual ability	✗	✓	✓	✗	✗
Accessible to people without leg movement abilit	✓	✓	✓	✓	✓
Accessible to people without hand movement ab	✗	✓	✓	✗	✓
Accessible to people without reading ability	~	✓	✓	✗	✓
✓ Total	6	7	5	4	6