REFLECTIONS ON AIR: An Interactive Mirror for the Multisensory Perception of Air

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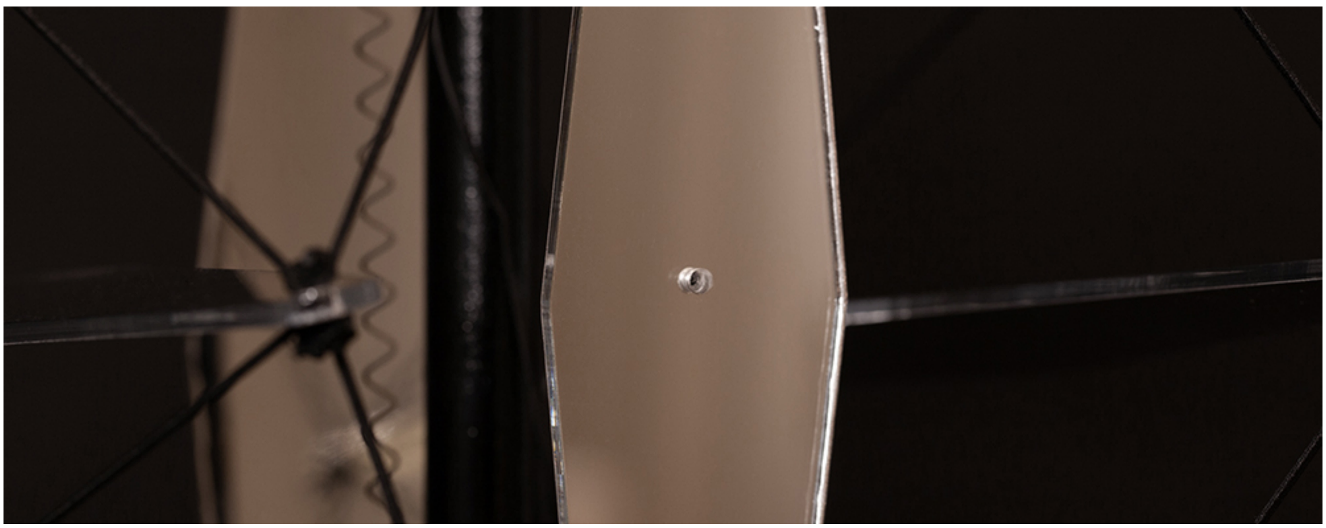

Figure 1: This image presents a detail of the interactive mirror.

ABSTRACT

This paper introduces an interactive mirror that aims to augment human perception and provide people with a visual-auditory experience with the air. To this end, we conceived and implemented a novel interface that responds to carbon dioxide with kinetic behavior and sound. In this study, we outline literature, related works, and the creative process of the practice-based research. We then discuss our findings and conclude with recommendations for the mirror's use as a mediator for raising awareness of the increasing carbon dioxide concentrations caused by human activities.

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CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; *Interaction devices*; Haptic devices;

KEYWORDS

human-atmosphere interaction, atmospheric interface, shape-changing interface, shape-memory alloy, augmented senses, mirror, air, carbon dioxide

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1 INTRODUCTION

While irreversible changes are occurring to the Earth's atmosphere, new responsibilities have emerged for not only scientists and politicians but also for artists [20]. Artist and researcher Janine Randerson stated that "meteorological art acts as an alternative to

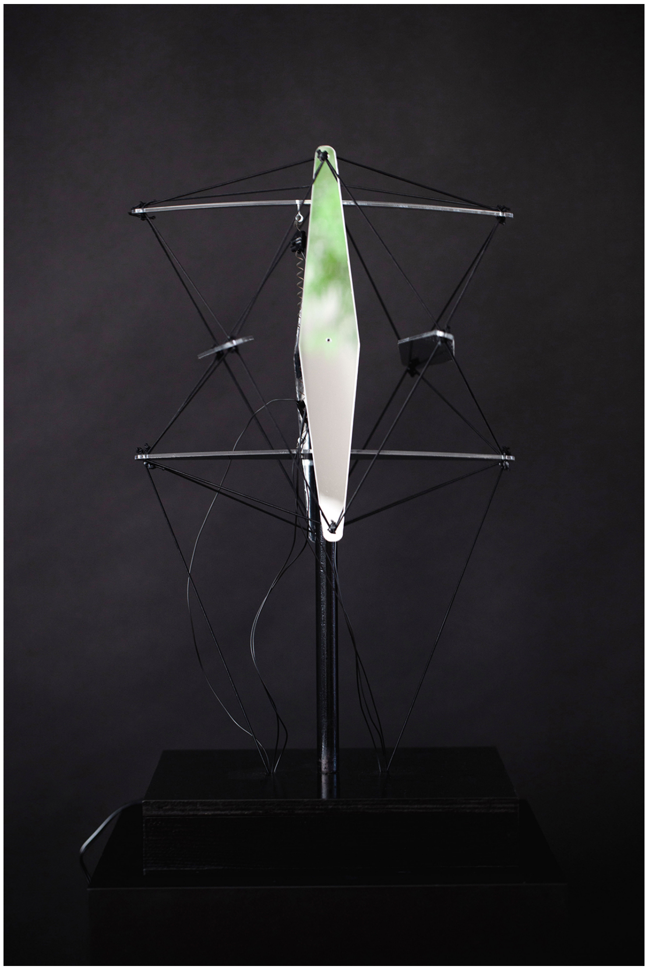

Figure 2: The total view of the interactive mirror.

anxiety-fueling news reports or weighty climate reports as a site of dialogue and agitation" [20, p.xv]. To create meteorological art, artists often utilize the natural environment's dynamics as a direct input to arouse human attention for environmental issues [20]. A notable example of making environmental issues visible is *Human Sensor LDN* by artist Kasia Molga. Molga created wearable costumes that illuminate in response to London's air pollution levels [15]. In contrast to visualizing the air pollution of the surroundings, our motivation is to provide an instrument that reflects on the anthropogenic activities that affect the atmosphere. We, therefore, considered the potential of an interactive mirror to present exhaled carbon dioxide levels and raise people's awareness of the interrelationship between humanity and the environment. Carbon dioxide (CO_2) is a colorless, odorless, and variable component of the Earth's atmosphere that plays a significant role in the greenhouse effect [1]. To perceive the concentrations of this invisible component, we drew on Engelbart's work "Augmenting Human Intellect" [9]. Augmenting human intellect is a conceptual framework that enables humans to increase their capabilities for solving complex problems, such as by using artifacts, language, methodology, or

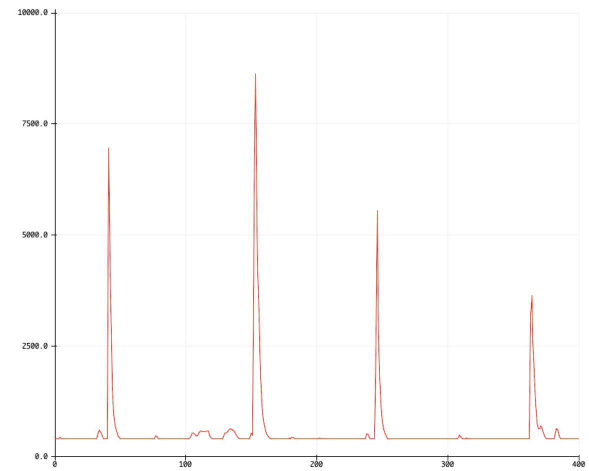

Figure 3: The serial plotter visualizes eCO_2 levels as a waveform that indicates four user's exhalations.

training that can be organized into networks [9]. In 1993, the vision of computer-controlled objects in networks was further developed using "ubiquitous computing," a term that was coined by Mark Weiser and his team at Xerox Palo Alto Research Center [26]. With the integration of computers into people's everyday lives, they envisioned that technological enhancements would be implemented throughout the physical world [26]. In reference to Engelbart's and Weiser's vision's, Schmidt noted that human perception can be amplified through the use of technical sensors that measure information beyond human abilities [25]. In summary, individuals can augment their capabilities to perceive CO_2 concentrations by using sensors that are integrated in computer-based artifacts within an ubiquitous computing environment.

2 REFLECTIONS ON AIR

Motivated to augment human perception, we considered a mirror that could become a mediator for self-reflection on human-atmospheric issues. We, therefore, conceived and implemented a shape-changing, mirrored interface that is enriched by sound to provide a multisensory experience that responds to the CO_2 concentrations of a user's breath. In the following sections, we detail our practice-based research [5] by discussing our design considerations and system implementation.

2.1 Design Consideration

2.1.1 The Mirror as a Mediator. Since prehistoric times, humans beings have been interested in their mirror images and various tools that can reflect images (e.g., shiny stones or pools of water) [16]. Thus, the mirror has become both an everyday object and an artifact of cultural history, that enables an intimate encounter with the self. Mirrors can also reflect the gaze and the activities of their observers to enable self-recognition and incorporate associative properties, such as the reflection of the inner life [2, 16]. In this respect, Melchoir-Bonnet emphasized, that humans look into the mirrors "to observe oneself, to measure oneself, to dream oneself and to transform oneself" [16, p.157]. In addition, the mirror has

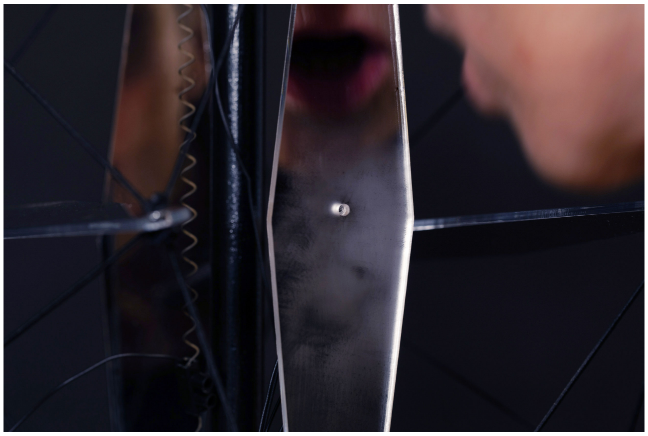

Figure 4: The user's exhalation triggers the interactive mirror.

Figure 5: The breath fogs the mirror's surface.

become a discussed research object in human-computer interaction studies to investigate different sociotechnological issues. For example, *Mirror Mirror* by Saakes et al. introduces a virtual fitting room that projects garments on the user's body [23]. *Mirror Ritual* by Rajcic and McCormack is an affective interface that displays poetry that relates to the user's emotional state [19]. *Biometric Mirror* by Wouters et al. explores facial analysis technology and addresses ethical concerns about automated decision-making [28]. The artist Daniel Rozin created mechanical mirrors that correspond to an observer's movement by changing surfaces that are made out of various materials [22, 27]. In comparison to these examples, REFLECTIONS ON AIR tackles two aspects of the mirror: i) the material that allows for an optical reflection on its surface; and ii) the creation of meaning through the user's interaction with the goal to convey self-knowledge about one‘s own anthropogenic activities.

2.1.2 Visual Perception. Shape-changing interfaces undergo physical changes for user interaction and use various approaches to do so [7, 21]. For example, shape-memory alloy (SMA) is a dynamic material that transforms in response to heat provided by an electrical impulse [6, 7]. Instead of servo motors, this technique enables a silent movement and can be combined with other materials or kinetic structures. For example, Fabrizi's *Fiori in Aria* is a textile flower with SMA wire that opens and closes according to air quality levels [11]. The study *Ivory* by Broscheit et al. presents kinetic behavior with an SMA spring that responds to particulate matter levels [4]. To animate a mirrored surface with SMA, we employed the concept of "tensegrity." The term tensegrity was coined by architect Richard Buckminster Fuller and is a combination of the words "tensional" and "integrity" [17, 18]. Tensegrity is used in architectures (e.g., bridge and rooftop constructions) and appears in different structures (e.g., 3-way prisms, X-modules, and icosahedrons). In addition, tensegrity structures are used for robotics and interactive designs. For example, *SUPERball* by Sabelhaus et al. introduces a tensegrity robot for space exploration missions [24], and *Alloplastic Architecture* by Farahi et al. presents an installation that responds to human movement [12].

2.1.3 Auditory Perception. Rather than simply providing dynamic behavior for the visual perception of CO2 levels, our intent is to create a multisensory perception for the user. To this end, we envisioned the usage of "sonification" to background the interactive mirror with additional information. According to Kramer et al., "sonification is the use of nonspeech audio to convey information" [14, p.1]. This method enables the interpretation of high dimensional datasets or qualitative thresholds through audio signals [14]. One of the well-known achievements in the field of sonifying environmental information is the Geiger counter, a hand-held device that interprets radiation as constant audio information [14].

2.2 System Implementation

2.2.1 Material and Fabrication. Before we began with the implementation of the interactive mirror, we conducted material research that encompassed mirror glass, acrylic mirror glass, mirror foil, metal leaves, and silver paint (see Figure 6). Because mirror glass is heavy and it is not easy to handle, we opted for the acrylic mirror glass and designed six tensegrity struts for laser cutting. Because the acrylic elements had only one mirror surface, we laminated their other sides with mirror foil. We then connected the six struts with elastic cords to arrange a classic tensegrity icosahedron on a wooden display. To enable kinetic movement, we used an SMA spring and placed it in the center of the tensegrity structure. In addition, we used two more elastic cords to speed up the process of bringing the tensegrity structure back into its original position, after it had beed triggered by an electrical impulse.

2.2.2 Electronic Components and Audio Control. For REFLECTIONS ON AIR, we compared the following CO2 sensors according to their measurements and ease of use: i) Adafruit's SGP30, ii) Winsen's MH-Z19B, iii) Sensirion's SCD30, and iv) the MG811. Due to its sample rate, voltage input, small measurements, and I2C interfacing, the SGP30 sensor was chosen. Thus, the electronic components of the prototype include the microcontroller ESP32 Pico Kit, the SGP30 sensor, a LED, a transistor, a resistor, and an SMA spring (see Figure 7). After the component's assembly, we programmed the microcontroller as follows: The SGP30 measures equivalent calculated

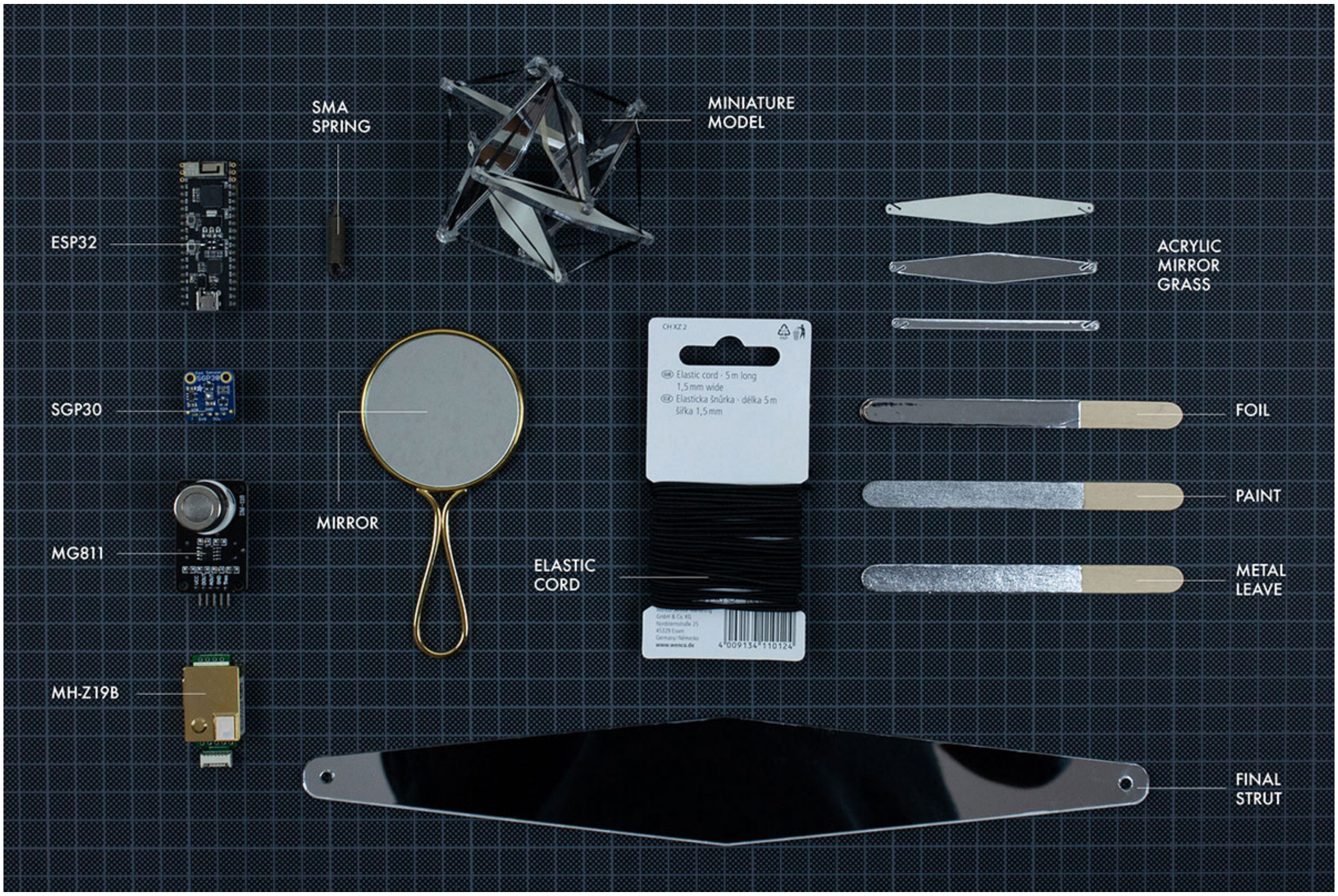

Figure 6: This picture illustrates materials, electronic components, and miniature model.

carbon dioxide (eCO2) levels within a range of 400 to 60.000 parts per million (ppm) and transmits the data to the microcontroller. A program in the microcontroller interprets the data to control both the SMA spring and the ambient sound. When the eCO2 levels are below the defined threshold of 1.700 ppm, the mirror's kinetic movement is inactive. If the eCO2 levels are at or greater than the defined threshold, the SMA spring receives an electrical impulse. As a result, the SMA spring shrinks and changes the shape of the construction. Simultaneously, the microcontroller transmits the eCO2 information to the audio software Max/MSP with open sound control and user datagram protocol within a shared network. Then, the audio software maps the incoming eCO2 data range of 400-2.500 to a range of 200-125 for frequency modulation. Additionally, a sound file is triggered if eCO2 concentrations reach the defined threshold. Finally, external speakers transmit sound on-site. This entire system has been implemented, and the functionality of the prototype (30 cm length x 30 cm width x 55 cm height) has been documented.

3 DISCUSSION

The term "mirroring" in the sense of reflection is ambiguous. Optical reflection is an active process, but a mirror is a passive mediator when a subject engages in inner reflection. In contrast to the silent and passive mediator from the past, REFLECTIONS ON AIR brings both of these meanings together and presents an active and audible mirror to explore CO2 levels that come from the human breath. In addition, the user's interaction leaves a temporary coating of condensation on the mirror's surface that nebulises the optical reflection (see Figure 5). Although a single human breath does not cause climate change, an increasing population and anthropogenic impacts are identified drivers of rising CO2 concentrations. To visualize this abstract concept, we utilized tensegrity structures to present the air through an intersection of visual-auditory dynamics, multiplied reflection, and an open but defined space. In addition to the interface's kinetic behavior, its sonification conveys more nuances of CO2 levels. The interactive mirror's electronic components are also visible to users, which enables the observation of its technological process. According to the SGP30 data sheet, the calculated eCO2 levels of the sensor are not reliable enough for laboratory measurements. However, the serial plotter visualized clear indicators when a user exhaled on the sensor (see Figure 3). Although CO2 levels differ depending on the intensity of the user's exhalation, the threshold of 1.700 ppm seams to be a good value for interaction. An average value is something that needs to be evaluated in a user study depending on the microclimate. To present REFLECTIONS ON AIR in a white cube gallery, improvements must

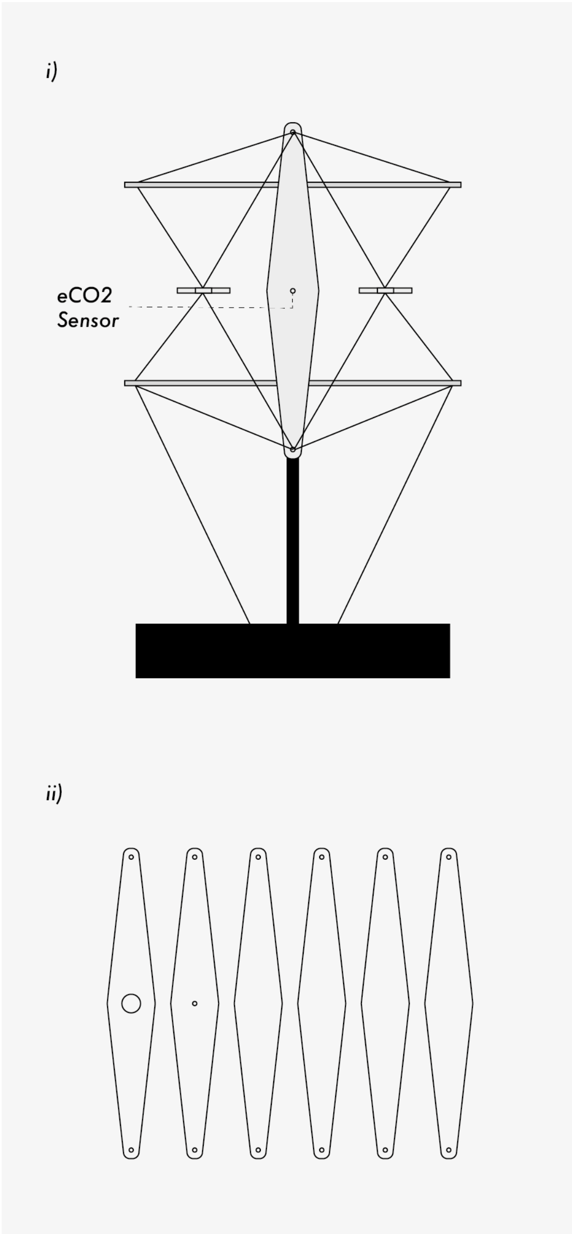

Figure 7: The figure illustrates i) the technical drawing of the kinetic mirror and ii) the six-struts for laser cutting.

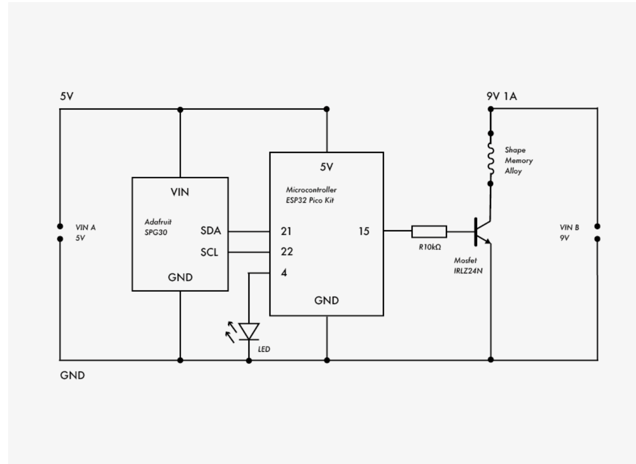

Figure 8: The schematic diagram of the interactive mirror.

Figure 9: The SGP30 sensor is attached on the backside of the tensegrity strut.

first be made. For example, the tension of the tensegrity is slightly too strong for the acrylic glass struts, which causes the element on the top of the construct to bulge (see Figure 2).

4 CONCLUSION AND FUTURE WORK

In this study, we presented an interactive mirror for the visual-auditory perception of CO2 levels. This construct reinforces our assumptions that a mirror could function as a mediator to allow people to reflect on the Earth's rising CO2 concentration. We also provided literature, outlined our practice-based research, and discussed our findings. In summary, REFLECTIONS ON AIR demonstrates great potential for becoming an object that supports critical thinking and reflection [8, 13]. It holds a mirror up to individuals to reflect on human-atmospheric interaction. Future research should be conducted to evaluate the first person perspective with the think-aloud method [3, 10]. This research should then be cross-referenced with numerical data to provide results about how users experience their novel perceptual abilities and whether they are aware of the overall context of this project. We would then discuss our findings with computer science, environmental science, and sociology experts to find novel ecological solutions.

5 VIDEO DOCUMENTATION

Jessica Broscheit. 2021. *Reflections on Air*. Retrieved January 15, 2021 from https://vimeo.com/500575042

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