Sprayful Interaction: Perceptions of a Moss-based SLow-resolution Living Media Display

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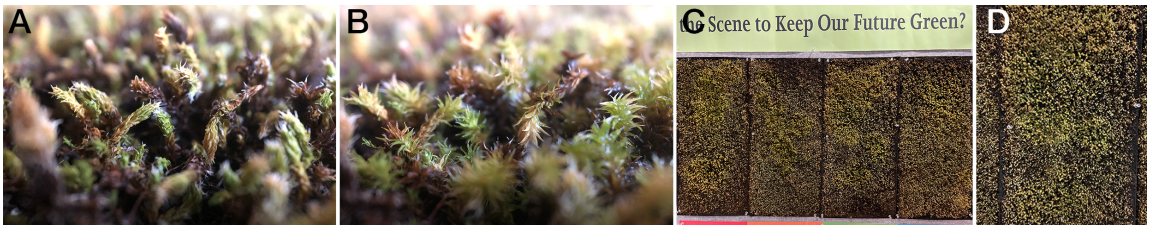

Fig. 1. Interactive moss display: (A) dry moss with closed leaves. (B) the same section of moss with opened leaves after being sprayed with water. (C) The pinboard display of 4 moss panels. (D) A moss panel after user interaction.

Sustainability in HCI is a growing area of research, and a driver of creativity for developing new and interesting interfaces. Low-power technology such as e-ink or flip-dot displays have provided some alternatives, and living media displays present a new opportunity to study displays that consume low amounts of energy. This pilot study explores the design space for a moss-based display installed in a design school, through think-aloud, observation and interview with 10 participants. The study found that users enjoyed the novelty, appearance and interaction with the moss display, showing promise for future applications. We contribute three design considerations and potential applications based on these findings.

CCS Concepts: • **Human-centered computing** → *Displays and imagers*; **Empirical studies in HCI**.

Additional Key Words and Phrases: Biodesign, Living Media Display, Public Displays

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1 INTRODUCTION

Technology is rapidly evolving and changing the landscape of spaces within our cities. Traditional static billboards and signage are being replaced by digital displays which can display dynamically changing content. This is changing how urban dwellers engage with urban environments. For instance, shopping centres are becoming augmented with

interactive public displays enabling visitors to search for shops and be given wayfinding instructions on a map [15]. Other work has demonstrated using public displays as a form of digital community noticeboard, giving local communities control over its content [1]. This evolution has diversified and simplified how we can create meaningful and engaging experiences for people in the public. At the same time, it is important to consider the impact digital technologies like public displays can have on the environment and ensure that beyond the short-term benefits (public engagement), the lifespan and long-term effects are also considered [2].

In certain cases, the use of digital public displays may not be necessary, particularly when the content to be displayed is static in nature or rarely needing to be changed. As an alternative, living media displays have been pitched as a "greener" alternative. These displays are plant-based, using natural materials as an alternative to "pixels", such as fungi, moss, algae, and plants [12, 14]. Their benefits include reducing pollution in our cities and natural environments with e-waste, along with reducing the carbon dioxide production and pollution from petroleum when shipping products across oceans [13]. As a result, some environmentally-conscious designers are collaborating with scientists to explore the use of living media interfaces as a sustainable alternative [4, 12]. There are opportunities to act more sustainably - when appropriate. This pilot study investigates the design space for a living media display made from moss, as a potentially sustainable interactive surface, in order to understand design considerations.

With aims to provide answers for this question, a hybrid field study was conducted using a living media display prototype with a total of 10 participants. Based on the results, this paper adds contribution into a novel research area that will provide new insights into the benefits and great potential of designing living media interfaces as a sustainable option for future public displays.

2 BACKGROUND

2.1 Sustainable and living media

Living media is an emergent material consideration for technological interfaces for its biodegradability, resilience and overall environmental benefits. As the world is becoming increasingly environmentally conscious, recent studies have shown the potential of living media [12], to be applied through Bio-HCI or Biodesign approaches in Human-computer Interaction (HCI) [4, 16, 17].

There is a growing interest in biodesign as an approach to utilising living organisms by applying the affordances of a living organism to a design problem [3]. Many examples collected in [14] include architecture, design, art and technology, such as utilising living trees to build bridges, using luminescence from fireflies to power lamps as well the capability of concrete to self-heal any damages much like skin.

The opportunity for collaboration between design and science is to create *"interfaces that incorporate living organisms and biological materials to take advantage of their qualities to enable different forms of interaction between human and digital systems"* [12, p.3]. Digital products are linked to the energy consumption by creating and processing large amounts of data, the extraction of minerals for manufacturing technical materials, and "e-waste" created through their disposal [18]. As the use of technology becomes a ubiquitous part of daily life, opportunities could be considered to replace digital media with other, sustainable, alternatives such as living media.

Another alternative to graphical user interfaces is an Organic User Interface (OUI). OUIs were termed by Roel Vertegaal and Ivan Poupyrev, to propose a future with flexible display technologies… that are curved, flexible, or any other form, printed on couches, clothing, credit cards or paper," [20, p.28] stretching beyond the limits of current capabilities. This imagined future also sees displays that can take on any shape with the ability to wrap on any type

of surface. Additionally, displays will no longer be static and have the ability to change shape to follow the flow of user interactions [20]. Sustainable, living media displays can be considered a kind of OUIs, as their growth over time changes the form of the display.

2.2 Low or no power displays in HCI

Our motivation to employ a living media system was to investigate how people chose to interact with a living display, which uses no electrical power to function. Low and no power displays have been used in design and HCI research, some of which use electricity only to update the display, and can display information continuously once updated. One example is a flip-dot display, most commonly seen on busses, but have also been utilised in media architecture [6, 7] and in the home [11]. Another low power display technology is electronic ink (e-ink), which is commonly employed in digital book readers. The display technology uses very little power and has higher resolution than the flip-dot display, but in some cases is selected for use because of its aesthetic and visual qualities, rather than for energy performance [8, 9]. One example of e-ink displays used for sustainable HCI up-cycles components from broken electronics for new designs [5].

Our approach uses *Racomitrium canescens*, or hoary fringe moss, which was introduced as a display in work by Kimura and Kakehi [10]. The system presented in their work used microcontrollers to provide water to the moss or dry its roots, creating a low-resolution, slowly changing (SLow Resolution) display. For our project we wished to examine how the user could update the display through their interaction, removing the need for the digital system. The moss was purchased from a homewares shop near our lab, where it is sold on felt sheets, and used as a ground covering for bonsai plants or as a decorative feature.

3 METHODS

We wished to create a prototype interface where participants could respond to a question by spraying water onto the living moss (see Fig. 2 A). The study ran on Level 2 at [our lab and building name] between 10:30am between 2:30pm for one day. This location was chosen as this is where students move and congregate between classes, with the main entrance of the building nearby, as well as the cafeteria and surrounding computer labs and study spaces. The time frame was also selected as a transition for many lecture and tutorial classes, with many people passing through. From passers-by, 10 participants were recruited for an individual audio-recorded interview as well as verbalising their initial thoughts as they interact with the display via the Think Aloud Protocol [19]. An Observational Exercise was also conducted to study user-behaviours and interaction. Results were analysed by Author 1 through a thematic analysis and the themes were then discussed with the other researchers. This study was conducted with ethics approval from our institution [approval 2014/795].

3.1 Interaction with the moss

Moss panels of 4 were lined up and attached to a pinboard. A question was placed above: *YOUR SAY: Is Our Uni Leading the Scene to Keep Our Future Green?* Underneath that moss board were 4 emojis representing each moss panel to represent answers to the question above. Spray bottles of water and circular acrylic laser cut templates were placed on a table next to the pinboard for participants to record their answers (Fig. 2 C).

When the moss was sprayed with water, it would immediately open up and bloom, changing to a lighter green (Fig. 1), and visibly changing in around 2 seconds. Once the water has been sprayed, it takes from 40 to 60 minutes for the open leaves to dry and close back to its initial state, varying with ambient temperature and humidity. We considered controlling the appearance of the moss by using an Arduino to dry the roots but this was not employed for this project

Fig. 2. (A) The moss display with the prompt question and responses on each panel. (B) P4 and P5 observing the display. (C) P9 using the laser-cut template while spraying the moss.

due to the time limitations. As seen in the Moss-Xels project [10], control of information display was achieved by regulating the supply of water to arranged blocks of moss to create perceivable patterns. The laser cut-outs were used to limit participants from spraying the entire moss board, this was considered so other individuals could also participate whilst seeing any changes between the dry and wet moss.

4 RESULTS

In this section we describe results in terms of participants, usability, design, moss functionality and engagement at our university.

4.1 Participants

The age group interviewed were between 20-31 years old, with three declining to provide their age. All interviewees were students or recent graduates studying design programs in our school. From 10 participants, 8 were female and 2 were male. All users had experience in interacting with public displays, such as public art installations or shopping centre way-finding systems. Only P8 had seen a living media display before, though not as an interactive display.

4.2 Usability

When asked to rate the ease of use of this display on a scale of 1-10 the display scored an average of 8.44. All interviewees found the display easy to use. However, 4 participants found it hard to understand how to use it from a first glance. Of the 6 participants who understood its usability immediately, 3 of them relied on observing another person using it to learn how to interact with the display: "*When I saw you setting up I could kinda tell what was going on. I knew it had something to do with voting and some interaction with the moss... I was (also) watching it, so you can see people vote and there are differences in the moss. You can see which parts people voted for*" (P8).

This example shows a *Honeypot Effect* [21] - as a passer-by transitions from a passive observer to an active user and performer - also seen when P5 as P4 was interacting and participating in the study (Fig 2B). P5 approached display curiously and kept glancing back and forth between the spray bottles and the moss. Once handed the bottle, P5 began spraying her answer to the question and agreed to participate in the interview. By observing P4's interaction, P5 clearly had learned about its interaction, but also stated "*it was easy because it was much of a natural instinct to see dry moss and what we usually do is water it to get it back to life. I didn't have to process [the display] to do something*" (P5).

Table 1. Participant Demographics. Some participants declined to answer age (DTA)

ID	Age	Gender	Occupation	Experience with public displays	Experience with LMI
1	DTA	Female	Academic	Yes	No
2	26	Female	Student	Yes	No
3	28	Female	Student	Yes	No
4	31	Female	Student	Yes	No
5	24	Female	Student	Yes	No
6	22	Female	Student	Yes	No
7	25	Male	Student	Yes	No
8	23	Female	Student	Yes	Yes
9	DTA	Male	Student	Yes	No
10	DTA	Female	Student	Yes	No

Out of 10 participants, 3 mentioned that they wouldn't use the laser-cut out. P4 expressed, "in my mind, the cut-out and the spray bottle don't go together, so even if you put those two things together, I'm just going to pick up the spray bottle." Similarly, P1 stated, "if it's (a display to interact with) two hands, I'm usually holding a bottle or something." As the laser cut-out was designed to limit participants from spraying the entire moss panel and allow other participants to notice any changes in the moss.

4.3 Design

All but one of the participants, stated that the display was aesthetically pleasing. P1 stated: *"It's so pretty. It's got a wide array of colours. It's got tons of interesting little sections of greater bloom and less bloom. It's on the wall rather than flat like usual plants which is interesting."* Furthermore, P2 felt that the use of moss was relevant to the question being asked in regards to sustainability, *"I think for your theme and how it concerns sustainability it's pretty suitable."*

4.4 Moss Function

Users expressed surprise and delight when observing immediate changes of the moss, ' *"when I first tried a few times, the effect wasn't super visible. So I tried a few times and it's very cool once you pay more attention and see how it changes,"*(P6). Out of 10 users, 7 users made similar comments that they did not expect the moss to instantly react after being sprayed with water, *"I didn't expect it to do anything. This is a plant, I was thinking it's more of a long term thing. People watering it will keep it alive. I didn't expect it to have an immediate effect"* (P4).

As the participants being first-time living media users didn't have the mental model to understand that the moss can be interacted with, the majority did not expect the moss to respond to water. "I didn't know what to expect because I'm used to interacting with digital devices but not this so I'm not familiar with it. It was my first time using it" (p3).

The moss panels included some bare patches in where there was little to no moss growing. P6 and P3 both sprayed these parts as they assumed it needed more water in the long term and didn't consider any short term transformation from the moss. This consequently also limited them from noticing any immediate changes in the moss. P6 explained, *"I sprayed it on the wrong bit cause I thought, this part needs more water... I didn't expect it to spontaneously turn green but I just thought it needed more water."*

During the Think Aloud session of P1, she verbalised, *"I can see that it's a little bit more moist. And I'm looking at the change. I see it becomes a slightly different texture, I want to touch it. It's just absorbed the water. It's not even wet!"* Users who engaged with the display after a number of people had already sprayed water on the moss found it harder to

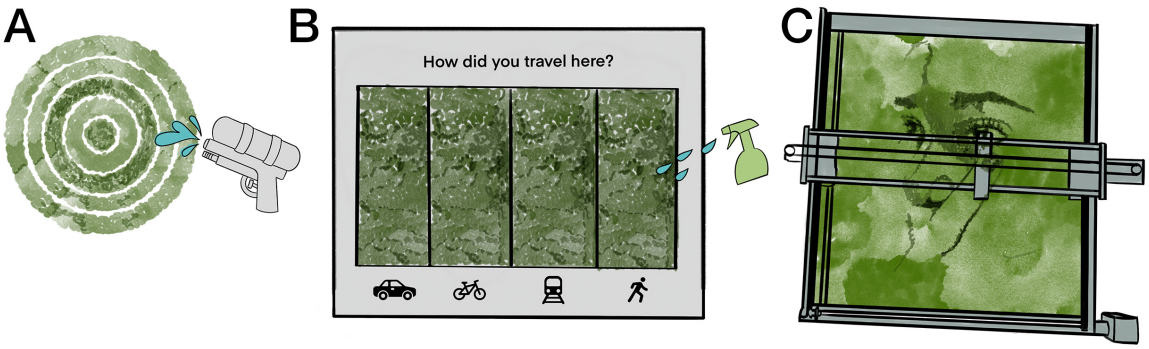

Fig. 3. Concepts for moss displays: (A) A target game for children. (B) A survey system. (C) XY Plotter system.

notice the changes in the moss as well as the contrast between wet or dry moss. When P3 was questioned whether any changes were visible, they responded: *"I think... the difference is that they are different types of grass."* This was due to the previous users who had already sprayed the moss which made it difficult to distinguish any changes. As a result, when P3 sprayed their response on the moss, the blooming of the moss camouflaged with the rest of the board that had been sprayed already.

4.5 Engagement

All users expressed that the moss interaction was the most engaging part of their experience. *"I don't find anything (on campus regarding sustainability) that's kept me so engaged like the moss board"* (P5).

Particularly, upon learning that the moss reacts immediately to water contact, participants found it intriguing and became curious about the moss. P8 mentioned, *"I'd actually like to know more about the moss and why it does that. I think it would be great if there was a description saying this moss does this. So people can see it and think more about the uses it could have. Especially in this faculty, lots of people would be interested in its uses,"* describing potential for future design applications. As well as this potential, P6 mentioned, *"The part that I like is that you can see the frequency of other people's responses,"* noting that the contrasts between the wet and dry moss were an interesting way to display differences in responses to the question above the moss board.

5 DISCUSSION

Overall, this display was a novel and unique experience for both participants and observers as the moss was not only displayed for its aesthetic purposes but for its interactive potential. While it was natural for participants to pick up the spray bottle and water the moss, participants found it difficult to notice the subtle movement of the moss. Participants needed no instructions to use the display - that is, spraying the moss to respond to the question printed above whilst choosing an emoji to represent their answer - but oftentimes needed a hint to infer that the moss does indeed respond. On the other hand, participants usually sprayed a small section of the moss, leaving space on the board out of consideration for other participants to interact.

From this study, we present three considerations for designing with a low-power moss display, and a concept for each which could demonstrate its application.

5.1 Consideration:Novelty *The Moss takes Centre Stage*

The interactivity of the moss was most definitely the centre point to this display and attracted most participants and onlookers. Having been set-up in the busiest part of the building where design students move between classes, there was a keen interest in the utilisation of the moss. As a result, participants thought that the connection to sustainability was an interesting topic for this display, as pointed out by one participant "*it would be great if there was a description saying what the moss does so people can think more about the uses, especially in this faculty, lots of people would be interested*" (P8). Educating individuals on the qualities and potential of moss could motivate students to think about different approaches to sustainability in their design projects, including through Biodesign and BioHCI [4, 16].

Concept: Moss-Shot

The novelty of moss is highlighted in its surprising ability to perceptibly transform, and users can be encouraged to take a closer look and watch the way the moss moves. The interactive nature of moss could be used to create children's games such as moss targets to encourage curiosity, and an interest in sciences through a playful interaction. A water gun could be used to spray the moss target from a distance where children could compete and see who leaves the watermark closest to the middle. Games like this could be a great educational tool and an interactive way to get children involved with the importance of sustainability through playful interaction. Additionally, it could encourage children to "*take a closer look*" as a means to decide who the winner of the game is.

5.2 Consideration: Plants Aren't Pixels

Participants enjoyed interacting with the moss but found it difficult to notice any visible changes. As a result, it is important to consider designing with the slow nature of the moss. In contrast to high-refresh rate in screen-based technology, results from this study urge future iterations to consider placing this display in different environments that pose the question: *how can we encourage our users to slow down?* It can present different opportunities such as placing this display in environments where people are forced to wait, such as in a ticketed service centre or a bus shelter, perhaps to encourage people to be mindful and present.

Concept: Spray It, Don't Say It Survey

A concept that designs with the slow resolution interaction of moss displays could be surveys set up in slow paced environments such as customer service centres or medical centres. Environments where individuals are waiting might be a better place to set up so users have time to pay attention and observe any changes. Displaying such a novel survey could also motivate new and curious users to provide valuable feedback.

5.3 Consideration: The Bio-digital Bridge

Participants were reluctant to scan the QR code to find out more about possible sustainable projects, even when prompted. Participants' motivation to scan the QR code was low due to their frequent use during COVID, and the interaction with the codes was tiresome, as one participant expressed, "*I use them so much that I'm so bored of them and I'm more interested in this moss*" (P9). Not only did participants feel reluctant to scan the QR code, but they also felt unmotivated to read the website content. One of the participants expressed, "*there is so much in the world now that everything gets lost easily. As a design student, it's so hard to make things feel relevant. It feels like it all repeats all the time*" (P10). This leads us to consider how the bioaffordances of the moss [4], its low-resolution and slow changing

moss display, can be amplified through digital technology. A key consideration for future work in this space is how digitally delivering water to the moss might facilitate a broader range of interactions, than just the place-based concept.

Concept: Moss XY Plotter

Rather than marking with ink to produce graphics or text, a Moss XY Plotter could spray water on the moss to create a visible image, using the moss as a canvas. This concept has the additional benefit of immediate feedback to the user through the movement of the plotter, with the moss transforming over time, whether quickly opening over a few seconds, or closing after minutes or hours as the leaves of the moss dry out.

6 LIMITATIONS OF THIS STUDY

We were not able to build a digitally interactive system, such as the XY Plotter concept presented above, which may impact the user experience further. However, as a brief pilot study, this paper only explored the participants' perception of the moss as an interface. The installation was only available for use for one day, due to constraints from the physical space available, and other events that take place.

7 CONCLUSION AND FUTURE WORK

This study has presented a hands-on experience using a living media display prototype for tertiary students interacting within a university campus setting. It has brought together concepts joining user experience design and bio-affordances of the moss to create a novel experience that engages individuals in a unique and interesting way. Participants appreciated the innovative approach to using the surprising and transformative qualities of moss to gauge sustainability concerns at our university. In doing so, also educating individuals that biology has greater use potential than for its aesthetic qualities.

Our study is a novel contribution to the fields of biodesign and Sustainable HCI. By utilising the unique tropisms of living organisms such as moss, it can be used to create an interesting interactive experience for the public, we hope it can inspire future studies on living media interfaces. This study is a start to understanding the relationship between individuals and bio-displays. This study marks the initial investigation into a new direction for future research into "SLow Resolution" bio-digital, interactive, living media displays.

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