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How do we feel? User Perceptions of a Soft Robot Surface for Regulating Human Emotion in Confined Living Spaces

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***Abstract*—Pandemic or not, many of us are spending more time indoors, apart from others and from nature. We report on user perceptions of "pheB," a non-anthropomorphic, bio-inspired, pneumatic-actuated robot surface aiming to help regulate our emotional states when inhabiting confined spaces, such as our homes. A survey (N = 50) tested perceived stress levels before and after performing guided breathing exercises under two conditions: led by the pheB prototype and a 2D vector graphic. We learned that perceived stress levels were significantly lower after performing the pheB led exercises. Comments from respondents who did not prefer pheB suggested a possible "Uncanny Valley" effect. The same survey elicited feedback on possible design features for pheB related to color, scale, orientation, and edge complexity. Beyond reporting on a soft robotic artifact of our own design, the research reported here offers an exemplar for conducting user studies online of novel robot designs, highlights user perceptions of bio-inspired robots in HRI research and considers biophilia and the uncanny valley for non-anthropomorphic robots supporting human-centered design applications.**

I. Introduction

Humans are increasingly living in small homes in rapidly urbanizing settings spending time indoors with little access to nature [1]. Due to Covid-19, people are confined to their homes for extended periods of time. Pandemic or not, living in small, confined living spaces, separated from nature and other people outside the household, can increase stress levels and negatively impact emotional wellbeing and mental health [2].

Previous research that explores the relationship between humans, nature, and emotional wellbeing [3],[4] has posited that humans have an intrinsic attraction to nature called *Biophilia*. Biophilic design proposes a set of principles inspired by the patterns of nature to improve human wellbeing in the built environment [5]. Design features that evoke fascination, mystery, and are reminiscent of biological analogues can produce a biophilic effect. *Biofeedback* (a representation of one's physiological states) and breathing exercises have demonstrated beneficial effects for people suffering from anxiety and stress [6].

We are developing a therapeutic device intended to reduce stress, what we refer to as a "plant-human embodied Biofeedback" system, or "pheB" for short. pheB (Fig. 1) is a soft robotic surface we envision covering a segment of a wall or walls in confined spaces such as an interior wall of a living room or bedroom. We aim to support emotion regulation and achieve a relaxed state for inhabitants of confined spaces through biofeedback and soothing behavioral interventions provided by pheB.

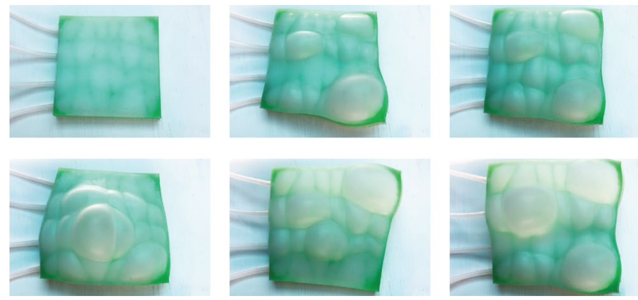

Fig. 1. pheB protype in a series of different inflated states.

Practically, pheB is a soft pneumatic robot which uses plant and human bio-signals to initiate the movement of the surface through inflation patterns (Fig. 1). Design of our early physical prototypes and an early user study of pheB was reported in [7], where we explored user perceptions of pheB in a pilot study with a convenience sample of participants who interacted directly with the physical prototype. To further our investigation, we expanded the survey used in the pilot to create an online survey for deployment during the pandemic, the results of which are reported in this paper. A video (http://bit.ly/pheB_demo) briefly presents a pheB prototype and excerpts from our interactive survey.

As the pandemic prohibited conducting in-person user studies with pheB, we were compelled to explore user perceptions of pheB without using real-time biodata; instead, we focused on the behavioral intervention of guided breathing exercises, which is one key aspect of the total user experience we envision afforded by this robot surface. The material quality of the inflatable silicone prototype produces a movement that mirrors human breathing that we hypothesize may foster a sense of co-embodied breathing as a means of emotion regulation, and therefore, achieving a relaxed state. In theory, the efficacy of the system is dependent on *entrainment*, a process where one's physiology synchronizes with rhythms experienced in the physical environment [8].

To emphasize pheB's biophilic sensibility, and encourage calming breathing patterns, we translate rhythmic patterns of natural phenomena (e.g., patterns of ocean waves) into inflation patterns. To inform our work to develop these soothing, bio-inspired behaviors, we examined user preferences of visual representations of several natural

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phenomenon to serve as a grounded design inspiration [9]. We also investigated how effective pheB was at leading a guided breathing exercise compared to a 2D animation (Fig. 2), as well as preferences for different possible design features for future iterations (Fig. 3). We discuss the feedback collected in the survey and examine how the results inform future design work to refine our soft robotic surface.

II. Related Work

Soft robotics is a relatively nascent field that utilizes flexible materials rather than rigid-body kinematics. While the field of human robot interaction (HRI) has a sizable community of researchers studying human perceptions of different robot typologies, there is little work specifically investigating user perceptions of soft robots [10]. Here, we fill the gap in the literature by conducting user studies to gain insights into how human users respond to the materiality and movement of a pneumatic soft robot. The compliant nature of elastomer materials (e.g., silicone rubbers) in soft robotics provides good reason to explore their use for social and therapeutic applications, as they can reduce many of the safety concerns created by rigid robots interacting with humans in interior spaces [11]. Furthermore, the materiality lends itself to bio-inspired design applications [12], [13], which translate biological behaviors into robotic systems, often simulating locomotion and other practical tasks that benefit from deformability. Our prototype does not employ bio-inspired design to simulate the functional abilities of a biological analogue; rather, in our approach, we translate biological inspiration into aesthetic principles and soothing behavioral properties towards therapeutic goals.

Silicone has also been explored for potential affective purposes. One such study examined how silicone could be used to make an expressive skin to convey emotional expressions [14]. Many humanoid robots utilize silicone to simulate human skin [15] due to its lifelike appearance and elasticity. This material quality may, however, lead to some experiences of discomfort, or *Uncanny Valley*, in humanoid robots and wearables due to its similar but not-quite human appearance. It is, however, unclear if this perception extends to non-anthropomorphic architectural-scale robots such as pheB. The present paper explores these themes to understand perceptions of our non-anthropomorphic soft robot and gain insights into possible user acceptance of therapeutic bio-inspired surfaces in interior spaces.

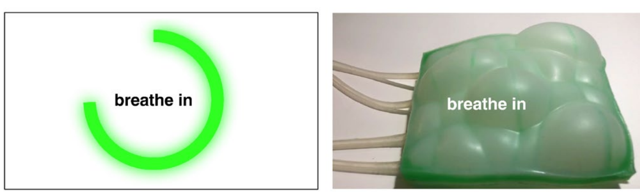

Fig. 2. Still images from the guided breathing exercise conditions.

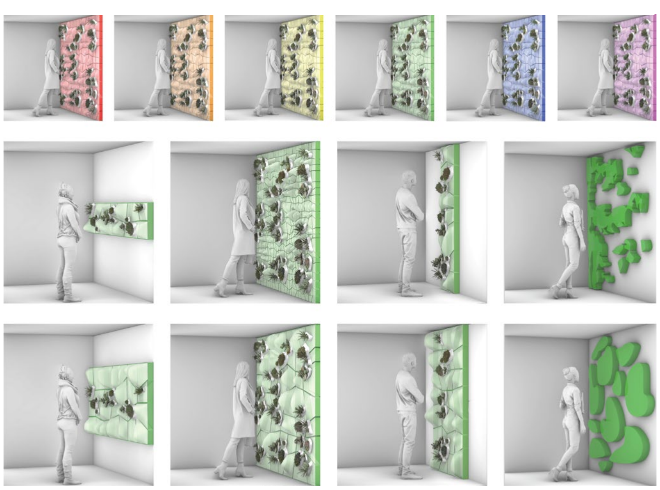

Fig. 3. Rendered images of possible design features for pheB iterations.

III. System Overview

In our design, the behavior and movement of pheB is determined by discrete physiological outputs from plant and human agents. Two types of bio-signals are used to drive the device – human heart rate and electrical impulses expressed by plants – modulated by changes in environmental stimuli and resources (e.g., light). Plant-human bio-signals are translated into distinct inflation patterns by way of air pressure delivered by numerically controlled regulators to the silicone surface with irregularly shaped air chambers [7]. When a human user has an elevated heart rate, the surface can inflate at a rhythm that encourages the user to slow their respiratory rate. Similarly, state shifts in the plant's physiology initiate an inflation pattern that mimics natural phenomena (e.g., calming ocean waves) to make visual the unseen experiences of plants, thereby nurturing a more meaningful interaction between the plant and human users. This connection to the plant operates as a feedback loop for the wellbeing of the human user; when a human tends to the needs of a plant, the health of the plant is an index of the emotional wellbeing of the human performing plant care [16]. pheB therefore captures the physiological state of the plant-human dyad as a coherent biofeedback index.

IV. Methods

We created an online survey with Qualtrics which was administered via Amazon's Mechanical Turk. Our analysis was completed in RStudio (https://rstudio.com/) with data collected from Amazon MTurk master workers (N= 50, *Female* = 15, *Male* = 35, *Non-binary* = 0; M_{age} = 40.7, SD_{age}= 11). We collected 61 responses but excluded eleven for violating the inclusion criteria that follows. We examined the answers to an open-ended question for signs of inattention to confirm the quality of responses. Any response that included text copied directly from the internet was removed. One response was also excluded due to insufficient time completing the survey, which took approximately 15 minutes. Prior to starting the survey, baseline perceived stress ratings were collected on a linear scale from 1-10. This served as the pre-test measurement of stress used to evaluate the effectiveness of the therapeutic behavioral interventions. All significance testing used an α level of 0.05. The survey had two sections: 1) a study on guided breathing exercises, and 2) user preferences for different design features.

A. *Guided Breathing Exercises & Physical Prototype*

The first part of the survey evaluated: (1) if the robot surface was effective at leading guided breathing exercises to reduce self-reported stress; (2) whether there were differences in user perceptions between a 2D animation and a video of the pheB prototype used to lead the pace of the exercises (Fig. 2);

and (3) whether the tangible quality of pheB increased perceptions of co-embodied breathing. The breathing exercises were 1 minute 30 seconds long and used a 4-7-8 breathing pattern, which entailed inhaling for 4 seconds, holding the breath for seven and exhaling slowly for eight seconds. This breathing pattern is used to activate the parasympathetic nervous system and has been shown to produce a calming effect [17]. For the 2D animation, participants followed the pace of a vector graphic, where the path of an animated circle leads the pace of the viewer's breath. When inhaling, the arc of a circle moves towards becoming a complete circle; the complete circle stays motionless during the holding pattern and then starts to disappear to indicate a person should exhale. The pheB visualization (vis) depicted the soft robotic surface inflating, inflated, and deflating at the same pace as the 4-7-8 breathing pattern. It included the sound of the air inflating the prototype, while the 2D vis had no sound. The 2D vis used a green circle to match the hue of the prototype. The circle was also given a feathered edge to provide texture and visual interest.

Both exercises were presented individually on the screen in a randomized order. After each exercise, participants responded to 5-point Likert scale items from 1 (*strongly disagree*) to 5 (*strongly agree*) to assess constructs of interest in our evaluations: (1) *Co-Embodied Breathing* ("The visualization was breathing along with me"); (2) *Pace* ("The visualization helped me to pace my breathing"); (3) *Effective Guide* ("I thought this video was an effective tool for the breathing exercise"); (4) *Relaxing* ("This breathing exercise was relaxing"). Three 10-point semantic differential scales were also included, from low to high: (1) *Mysterious-Familiar*; (2) *Uninteresting-Fascinating*; and (3) *Artificial - Biological*. These scales were included to evaluate perceptions of biophilia. After each exercise, participants again rated their stress level using the 10-point linear scale. After completing both exercises, respondents chose the vis they preferred and were asked to explain their reasoning in an open-ended question. The order of the exercises was randomized to prevent testing effects of the repeated exercises on stress levels.

B. *Design Features & Natural Phenomena*

The second part of the questionnaire asked for user perceptions of different design features through a series of rendered gifs depicting possible design alternatives (Fig. 3). These questions sought to understand user responses to aesthetic qualities, such as scale, orientation, color, and edge complexity. To visualize these different features without investing time and money to make a physical prototype, rendered images were made using 3D modeling software to depict possible realizations of the surface. Gifs were made from the renderings of pheB shown in inflated and uninflated positions to evaluate the prototype in active and resting states. Additionally, the current pheB prototype does not yet have integrated plant life incorporated into the physical system. We included plants in the animations to investigate human perceptions prior to the full realization of the design. For these features we did not form a hypothesis on which would be preferred; we aimed, instead, to explore whether there was strong preferential agreement for certain features.

Participants were first asked to group images of the surface shown in six hues (red, orange, yellow, green, blue, and purple) into three emotional states: exciting, neutral, and relaxing. Given the large body of research related to color-emotion associations [18], we hypothesized that cool colors (blue and green) would be associated with relaxation, warm colors (red and orange) would be frequently associated with excitement, while the colors purple and yellow would be neutral. Collecting color-emotion feedback specific to our prototype will guide the design of lighting features which can be mapped to a user's emotional state, as represented by their heart rate signal, to reinforce the biofeedback facilitated by pheB. The six hues were presented in a random order.

Next, we elicited feedback on perceptions of pheB in a spatial environment. There is little existing literature to inform the design of an architectural-scaled soft robotic surface of this kind; hence, we used the animated images of design alternatives to investigate which were more likely to be accepted by humans in real-world interactions. Participants were asked their preference when presented with three possible design options. Four questions were asked in random order: (1) scale of the air chambers shown at small, medium, and large scale; (2) vertical orientation shown in small, medium, and large widths; (3) horizontal orientation shown in small, medium, and large widths; and (4) the complexity of the edge profile, shown with least, medium, and most complexity. For each alternative presented, all other features of the images were held constant. The three design alternatives (i.e., small, medium, and large scale) were presented in random order. To better understand how to design soothing biophilic behaviors, we asked respondents to rank-order video recordings of natural phenomena. Four gifs were presented in random order: (1) calming ocean surface waves, (2) rainfall hitting the ground, (3) clouds moving across the sky, and (4) leaves in the wind.

V. RESULTS

A. *Guided Breathing Exercises & Physical Prototype*

Of the 50 responses, 54% preferred the breathing exercise led by pheB. Of the respondents who identified as female, 60% preferred pheB. A Pearson chi-square test of independence was performed to look for gender differences among vis preferences, but the relationship was not significant, χ^2 (1, N=50) = 0.06, p = 0.80. However, as the gender ratio of the sample was skewed male, we plan to investigate this further.

To evaluate the effectiveness of the breathing exercises on perceived stress, we performed regression analysis using a linear mixed model that modeled stress rating by vis condition (2D vis *vs* pheB vis), their vis preference, and their interaction. We accounted for order of the breathing exercises and included a random effect to account for the repeated measures of each subject. We conducted this analysis with the lmerTest and emmeans packages [19],[20]. We looked at pairwise comparisons with Tukey adjustment between the three stress ratings: baseline rating, post-pheB vis, and post-2D vis to compare estimated mean differences by vis preference (Table 1). For those that preferred the 2D, estimated mean differences between baseline stress and post-2D, *(p < 0.001)* and baseline stress and post-pheB (p < 0.001) were statistically significant, whereas estimated mean differences between post-2D and post-pheB stress (p = 0.474) were not. For those that preferred pheB, estimated mean differences between baseline stress and post-2D (p = 0.084), and between post-2D and post-pheB (p =

0.529) were not statistically significant, whereas estimated mean differences between baseline stress and post-pheB (p = 0.005) were statistically significant. Descriptive statistics showed mean baseline stress ratings (M = 3.94, SD = 2.41), were higher than post-pheB (M = 3.16, SD = 2.04) and post-2D (M = 3.16, SD = 2.10) ratings.

We performed paired t-tests on the Likert scale questions in each condition to find estimated mean differences; and found differences for *Pace*, $x = 0.18$, $t(49) = 1.12$, $p = 0.269$, 95% CI [-0.14, 0.50]; *Relaxing*, $x = 0.12$, $t(49) = 0.67$, $p = 0.508$, 95% CI [-0.24, 0.48]; and *Effective Guide*, $x = 0.26$, $t(49) = 1.16$, $p = 0.253$, 95% CI [-0.19, 0.71], were not significant. However, the estimated mean difference in perceptions of *Co-embodied Breathing* was significant, $x = 0.84$, t (49) = 4.68, $p < 0.001$, 95% CI [0.48, 1.20]. We also looked at observed mean differences by vis preference group (Table 2). To further investigate group differences, we performed analysis with four linear mixed models for each scale rating by condition, their vis preference, and their interaction, again accounting for order and including a random effect for repeated measures. We found significant interaction effects between condition and vis preference for ratings of *Pace*, $F(1, 48) = 28.58$, $p < 0.001$, *Relaxing*, $F(1, 48) = 19.16$, $p < 0.001$, *Effective Guide*, $F(1, 48) = 25.16$, $p < 0.001$, and *Co-embodied Breathing*, $F(1, 48) = 7.24$, $p = 0.01$ (Fig. 4).

TABLE I. CONTRASTS OF ESTIMATED MEAN DIFFERENCES

(* = α < 0 .05, df =96)	Estimate	SE	t-ratio	p.value
Preferred 2D Vis				
Baseline - Post-2D	1.17	0.22	5.26	<.0.001*
Baseline - Post-pheB	0.91	0.22	4.09	<0.001*
Post-2D - Post-pheB	-0.26	0.22	-1.17	0.474
Preferred pheB Vis				
Baseline - Post-2D	0.44	0.21	0.22	0.084
Baseline - Post-pheB	0.67	0.21	3.24	0.005*
Post-2D - Post-pheB	0.22	0.21	1.08	0.529

TABLE II. MEAN RATINGS OF VIS CONDITION BY VIS PREFERENCE

Preferred 2D Vis	2D Vis Rating Mean (SD)	pheB Vis Rating Mean (SD)
Co-Breathing	3.74 (1.09)	4.09 (0.73)
Pace	4.61 (0.58)	4.04 (0.92)
Effective Guide	4.48 (0.79)	3.74 (1.05)
Relaxing	4.26 (0.61)	3.65 (1.19)
Preferred pheB Vis		
Co-Breathing	2.67 (1.14)	3.92 (0.87)
Pace	3.63 (1.00)	4.44 (0.75)
Effective Guide	3.37 (1.14)	4.48 (0.57)
Relaxing	3.37 (1.11)	4.11 (0.89)
		1= strongly disagree, 5 = strongly agree

The responses to the 10-point semantic differential scales for descriptors, *Mysterious-Familiar*, showed that pheB (M = 5.18, SD = 2.59) was rated more mysterious than 2D (M = 7.70, SD = 1.97). For *Uninteresting-Fascinating*, pheB (M = 6.06, SD = 2.33) was rated more fascinating than 2D (M = 4.40, SD = 2.75). For *Artificial-Biological*, pheB (M = 5.32, SD = 2.87) was rated more biological than 2D (M = 3.34, SD = 3.14). For the semantic scales, we visualized observed mean differences in ratings for both conditions by vis preference (Fig. 5), and paired t-tests were performed to examine estimated mean differences. We found predicted mean ratings for descriptors in each vis condition, *Mysterious-Familiar*, $x = -2.52$, $t(49) = -5.34$, p = 0.0005, 95% CI [-3.47, -1.57]; *Uninteresting-Fascinating*, $x = 1.66$, $t(49) = 3.76$, p < .0001, 95% CI [0.77, 2.54]; and *Artificial-Biological*, $x = 1.98$, $t(49) = 3.93$, p = 0.0002, 95% CI [0.97, 2.99], were all significantly different.

Qualitative feedback collected in open-ended responses also revealed strong bipolar opinions. Respondents who preferred the 2D vis described pheB as *creepy* (x=5), *alien* (x= 3), *gross* (x = 2), *strange* (x = 2), and *disturbing*, *scary*, and *unsettling* (x = 1). Whereas respondents who preferred pheB described the prototype as *natural* (x = 4), *interesting* (x = 3), *organic* (x=2), and *fascinating*, *mesmerizing*, *engaging*, *novel*, and *memorable* (x = 1). Comments that expressed preference for the 2D vis stated that it was "less distracting," "pleasant to look at," and "neat and clear." Those who preferred pheB stated the 2D vis felt like a "generic graphic" and called it "ugly and uninspiring." Responses to the prototype from the pheB vis preference group stated that it gave them, "a connected feeling" and that it was a "visceral analogue to breathing." Another respondent stated pheB "helped me to visualize and concentrate more on expanding my chest and taking a deeper breath." Several respondents commented that the sound included in the pheB vis helped them focus on their breath, though one respondent felt the sound was distracting.

B. *Design Features & Natural Phenomena*

Responses from the emotion-color grouping question generally corresponded with our hypothesis that cool colors would be assigned to the *Relaxing* category, warm colors would be assigned to the *Exciting* category, while the colors purple and yellow would be assigned to the *Neutral* category. Looking at the counts of each hue (Fig. 6), we observed that the cool-warm hue associations reflected the same pattern of emotion-color association as stated in our hypothesis, except for purple which was most frequently assigned to the relaxing category (x = 24).

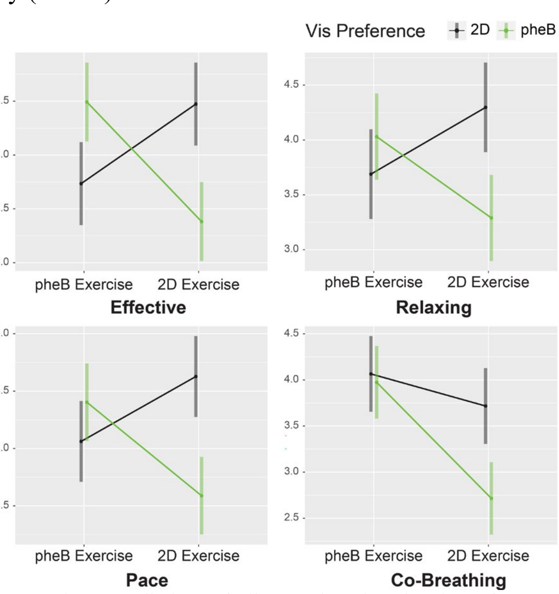

Fig. 4. Linear predictions of Likert scale ratings by vis preference.

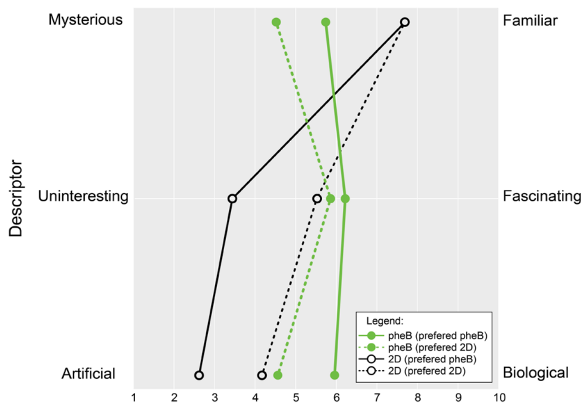

Fig. 5. Semantic differential ratings of vis conditions by vis preference.

User preferences in response to the animated gifs assessing scale of the cellular air chambers and different widths of the prototype in horizontal and vertical orientation demonstrated a clear preferential pattern for larger scale air chambers, and larger widths in both orientations (Fig. 7). Similarly, the most preferred image representing edge complexity was the least complex edge condition. For natural phenomena rankings (Fig. 8), the gif of *Clouds* was ranked 1st most frequently (x = 15), however, it was followed closely by *Waves* (x = 14), and *Leaves* blowing in the wind (x = 13). The gif of *Rain* was preferred the least and was most frequently ranked 4th (x = 21).

VI. Discussion

While there was no strong consensus in favor of the pheB prototype over the 2D animation, the results of the study showed that pheB was perceived as an effective guide when leading breathing exercises, both through rating scales and the observed and predicted reduction in self-reported stress. The model of Likert scale ratings by vis condition (Fig. 6) showed crossover interaction effects on *Pace*, *Relaxing*, and *Effective*, suggesting people had strong feelings in support of the vis modality they preferred and rated the other vis condition significantly lower. pheB's effectiveness is reinforced by the results of the breathing exercises on perceived stress ratings. Interestingly, for the group that preferred pheB, the 2D vis exercise did not have a statistically significant effect on perceived stress, indicating the pheB group did not find the 2D as effective. Conversely, for the 2D vis group, the effects of the exercises were significant in both conditions. These results align with previous research demonstrating the relaxing effect of guided breathing exercises [6],[8],[17]. Although, notably, there was no control condition in our study, therefore, it is possible that lower stress ratings were not an effect of the exercises but rather the participants' engagement in the survey.

One area of strong consensus was in perceptions of *Co-embodied Breathing*; pheB was rated higher than the 2D graphic by both vis preference groups. The 2D vis preference group rated the 2D vis higher for *Co-Embodied Breathing* than the pheB vis preference group rated the 2D. This finding suggests that while the 2D group did not prefer pheB's representation, perhaps perceptions of co-embodiment were still an effective strategy to reduce stress. Yet, the strong aversion to pheB by the 2D vis preference group seen in the qualitative feedback suggests that the morphology and materiality of the prototype is not conducive to relaxation for everyone. The descriptors, "creepy," "disturbing," and

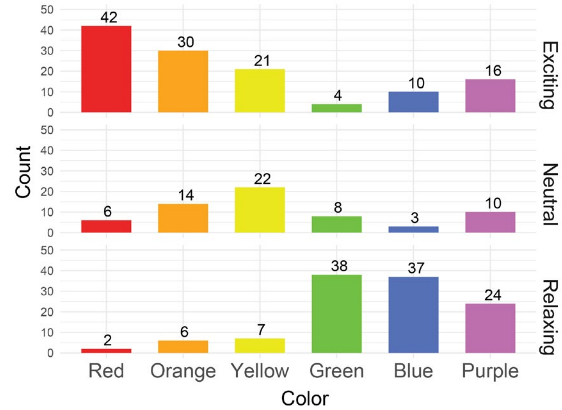

Fig. 6. Bar plots of color-emotion association counts.

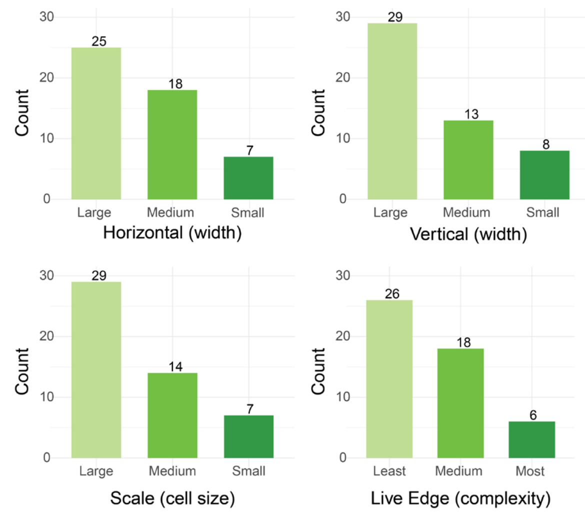

Fig. 7. Design feature counts: orientation, scale, and edge complexity.

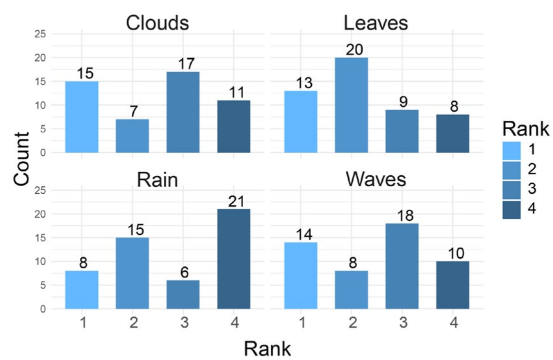

Fig. 8. Ranking preferences of natural phenomena.

"unsettling" indicate that there may be an *Uncanny Valley* effect operating, perhaps due to the lifelike quality of the silicone paired with its organic cellular pattern. While the uncanny valley is most often studied in relation to humanoids and prosthetics [15], the results of our study suggest that future non-anthropomorphic, bio-inspired robots should be mindful of this effect when selecting materials and surface patterns which mimic biological analogues.

Co-embodiment was a desired feature for those who preferred pheB; the lung-like quality helped some people to better focus, and breath more deeply. Furthermore, while almost half the respondents preferred the 2D vis, this does not preclude the possibility that these respondents might have responded differently to the prototype when interacting with it in real life. Furthermore, people from the 2D vis group might still synchronize their breathe with pheB through entrainment if it were an ambient feature in the environment, producing a relaxing effect, regardless of their aesthetic preferences. Still, evoking fear is not a desired goal for a soothing behavioral intervention; efforts will be made to refine our prototype to attenuate negative emotions and perceptions of fear or disgust. For one, the intended experience of pheB does not involve merely focusing directly on it (i.e., as an object) but having it offer an ambient experience as a more integral part of the living environment which, oftentimes, is experienced more peripherally. Moreover, as explored in our earlier in-person user study reported in [7], pheB offers a tactile experience which is important aspect of the user experience intended for pheB but not afforded in the remote study reported here. Our goal is to deliver biofeedback that does not utilize a screen to provide respite from the constant use of electronic screen-based displays. Our hope is that pheB's tangible quality will provide a new modality to receive physiological feedback that is also soothing in its expressive qualities and movement.

Perceptions of pheB did indicate that the prototype has developed a biophilic sensibility, as it was rated higher than the 2D vis for all descriptors associated with biophilic design: *mysterious, fascinating,* and *biological.* Color-emotion associations were mostly grouped with the expected emotion, indicating associations can somewhat reliably be produced through color state changes. For features related to scale, orientation, and complexity, it was noteworthy that the largest option with the least complexity was consistently preferred most, informing us that people would accept larger areas of pheB but perhaps with less complexity in a confined space. While Grounded Theory has been demonstrated to be an effective method for other user-experience design researchers [9], our study which attempted to find coherent preferences in response to representations of natural phenomena was unsuccessful in discovering consensus within the qualitative feedback. Rankings of the natural phenomena gifs showed that no clear pattern of consensus emerged from the data, suggesting that preferences were highly subjective from person to person.

VII. Future Work & Contribution

Current work is being done to integrate feedback from the questionnaire into pheB's design. We have created a larger prototype which removes the previously fixed green color so that colored lighting can be applied to a neutral surface with shifts in emotional states. Larger swaths of pheB might be less uncanny as an ambient spatial experience that is not analogous in size to an anatomical organ. The neutral surface color might also mitigate negative perceptions of pheB, which we will explore in a longitudinal study using real time biodata to control pheB's movement. We have also developed an algorithm to simulate soothing ocean waves through inflation. The research reported in this paper, beyond reporting on a soft robotic artifact of our own design, offers an exemplar for conducting user studies online of novel robot designs, highlights user perceptions of bio-inspired robots in HRI research, and considers biophilia and the uncanny valley for non-anthropomorphic robots for human-entered applications.

VIII. Acknowledgment

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