Lotus: Mediating Mindful Breathing

Sibela Chinareva
University of Bristol
Bristol, BS8 1UB, UK
sc16913@bristol.ac.uk

Dan Kumpik
University of Bristol
Bristol, BS8 1UB, UK
mr19339@bristol.ac.uk

Jack Jones
University of Bristol
Bristol, BS8 1UB, UK
jj16791@bristol.ac.uk

Palvi Shah
University of Bristol
Bristol, BS8 1UB, UK
ps16925@bristol.ac.uk

Nuha Tumia
University of Bristol
Bristol, BS8 1UB, UK
nt16888@bristol.ac.uk

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Abstract
We present *Lotus*; an actuated plant designed to help users perform breathing exercises. The device uses heart rate (HR) monitoring to detect high levels of stress and trigger the start of its guided exercises through the movement of its petals. The prototype demonstration of our system suggests that Lotus successfully helped reduce the amount of stress in 5/10 users. User's experience of Lotus was rated as overwhelmingly positive.

Author Keywords
Breathing Plant, Stress Reduction, Wellbeing, Mindfulness, Breathing Exercises, Metal Health, Heart Rate Monitoring

ACM Classification Keywords
H.5.2 User Interfaces.

Introduction
Modern environments can induce stress which can be detrimental to a person's mental health and productivity. In 2018/19, at least 602,000 workers in the UK suffered from workplace-induced stress, resulting in an estimated 12.8 million work days lost. [2]. Applications such as Headspace have shown success in tackling these issues by introducing mindfulness techniques such as controlled breathing exercises [6]. However, these applications are delivered through mobile phones, devices that can induce stress themselves

Figure 1: The Lotus prototype

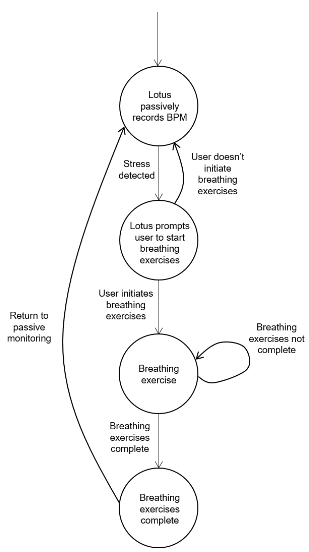

Figure 2: A state diagram illustrating Lotus' intended use

by constantly updating users with, for example, social media notifications.

Lotus aims to promote mindful breathing and reduce stress in a novel and interactive way, where the user's breathing is guided by an actuated flower, prompting the user to take breaks. Lotus will passively track the user's HR until it senses it surpassing a specific HR threshold signifying stress, after which it will initiate its exercises by motor-controlled petal actuation and visual feedback through an LED core. Lotus can be integrated into any user environment, due to its portability and simple design.

Walkthrough

The final version of Lotus aims to be used in the following way, illustrated by Figure 2:

1. The user's HR is measured by a sensor and monitored by the Lotus system as a background process.
2. As soon as stress is detected by the Lotus system, in the form of the user's HR increasing above a personalized "stress threshold", the user is asked to take a break. This is signified by the core LED of the flower glowing green.
3. The user presses down on the exercise initiation button. This causes the core LED to begin glowing magenta.
4. The user is then prompted to breath in and out in time with the rise and fall of the actuated petals, keeping their focus on the inner LED core. This interaction is designed with mindfulness techniques in mind.
5. Once the exercise is complete, the core LEDs glow green and the petals stop moving, signifying to the user that their exercises are complete.

The lower fidelity prototype presented does not automatically infer the occurrence of stress, instead a supervisor initiates actuation in a Wizard-of-Oz manner.

Related Work

The notion of using breathing exercises as a way of tackling stress has been explored heavily. A very early example is the study of yoga which can be traced back to over 5000 years ago [8]. This concept still exists, for instance, Feijs et al. [4] describe the relationship between stress, *heart rate variability (HRV)* and breathing, showing that training of a breathing pattern can increase HRV, indicating lower stress.

Studies like this are responsible for the rapid increase in the number of interactive applications promoting health [1]. However, due to their lack of physicality, they can often feel less engaging to the user and therefore less effective. Partibanda et al. in [7] created the game Life Tree which aims to solve this engagement issue by using *Virtual Reality (VR)*. The players use their breathing as the primary control for the game. Although this does introduce more physical engagement, the user's focus still remains in the virtual world.

To further bridge this physical gap, Macik et al. in [5] propose *Breathing Friend* - a portable device which encourages mindful breathing as a stress coping mechanism. It uses haptic interaction to discreetly stimulate mindful breathing. However, the shape of the device is unfamiliar to most users, exercises feeling unnatural as a consequence. *Lotus* plans to solve this by taking the shape of a plant, becoming an innate and unobtrusive part of any environment.

Design

Preliminary Designs

Many methods were considered for the actuation of the petals. The first was inspired by Albaugh et al. [3], creat-

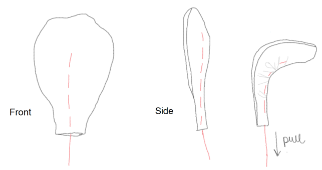

Figure 3: Illustrating petal actuation using *soft actuated objects* technique

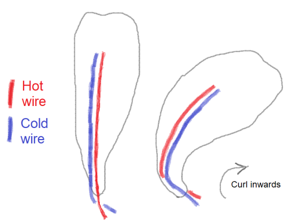

Figure 4: Illustrating petal actuation using nitinol wire. An alternation between the wires takes place, in order for each one to control movements in opposite directions.

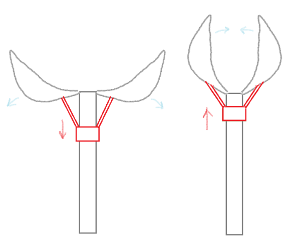

Figure 5: Illustrating mechanical petal actuation, using an origami technique.

ing *soft actuated objects* by pulling thread sewn into the object to create tension in strategic places, causing the object to move in a specific way. This was achieved by sewing plush petal shapes and threading a line down the centre with thread such that when pulled, the petal would curl inwards (Figure 3). The method worked consistently, however the petals created were thick and did not capture the nature of a real flower petal.

The next form of actuation was the use of *nitinol wire*; a shape-memory alloy that changes shape in response to differences in temperature, achieved by passing a current through it. The use of nitinol wire as the stem of the petals allowed for organic movements to be achieved (Figure 4). However, it was difficult to receive enough power from the Arduino alone on demand. The use of external batteries was not desirable, as it would impede with the portability of the device. The need for insulating tape around the wires stiffened their movements, and added bulk to the design. Correctly configuring the wire to take the right shape when heated required it to be fixed into a 3D petal shape and exposed to temperatures of upwards of 500C degrees which also was not feasible to do.

The most successful actuation method used was an *origami* as illustrated by Figure 5 (described in more detail in the Final Design section). The movements that yield the petal actuation were very simple, and gave complete freedom over how the petals could look.

Prototyping

The iterative design process began with paper-based prototypes. The petals were cut out of cardboard and glued together in a triangular form so when pushed together, gave a natural closed form of a flower. The flower head was attached to a wooden dowel used as a stem. The pulling thread was tied to a motor. For simplicity, using only one motor was preferred so either the opening or closing of the flower had to be automated.

Initially, the automation was done with elastic or springs, which would naturally return to their original length once released after a pull by the motor and thread (Figure 6), closing the flower. However, the flower was difficult to move at the correct pace, resulting in hard calibration of the system. Instead, the motor was designed to pull the origami shape up instead of down by putting the thread through the stem (Figure 7) closing the flower when pulled. The weight of the petals would automate the opening of the flower. This resulted in a more synchronised and easier to control movement.

The use of different motors also played an important role during the design process. At the start, a *servo* motor was used. However, it was hard to set the spinning time of this motor, and the motion tended to be uneven in the two directions. Therefore, a *stepper* motor was used instead which solved all of the issues above and allowed for easy calibration of the system.

Final Design: External

As mentioned, the petals are moved through an *origami* technique. The origami-style joints allow for the simultaneous and identical anchored movement of all petals towards or away from a central point. All joints are attached to a tube that can be moved upwards or downwards to push the petals together or pull them apart, respectively. The tube is wrapped around a thick straw that has been re-purposed as the stem, and each petal is anchored to it. The petals consist of scored and folded polypropylene sheets and the supporting strips and tube are also made out of polypropylene. Inline with the Prototyping section, the thread is fed through this straw and down towards a stepper motor.

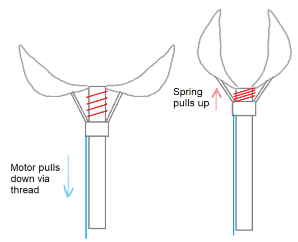

Figure 6: Motorization method one; using an elastic/spring to automate movement upwards.

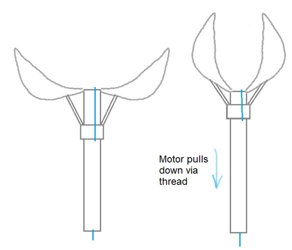

Figure 7: Motorization method two; using the petals' own weight to automate movement downwards.

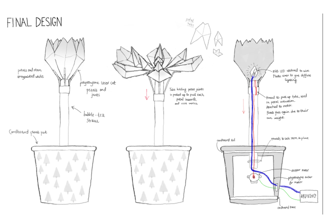

Figure 8: A diagram of the final design of Lotus

A circular piece of cardboard acts as a lid to a plant plot, hiding the actuation hardware from the user and providing structure. A bent sheet of polypropylene sits within the pot to fix the motor and stem in place. This ensures that the entire flower does not get pulled down and only the petals move as the motor pulls the thread. Along with the thread, a set of four wires are fed through the straw to power an RGB LED. The LED is encapsulated by a polypropylene diamond-shape cover to provide diffuse lighting. An illustration of this final design is found within Figure 8.

Final Design: Hardware
Lotus utilises an Arduino board to send two outputs, one to a stepper motor (the petal actuation source) and one to an RGB LED. The motor and LED is connected to the Arduino through a micro-controller and set of electrical wires. A breadboard sits between these connections to implement a set of resistors to mediate the strength of the LED emission and a 9 volt battery to supply power to the motor. The Arduino receives its input from a HR monitor (pulse oximeter). The data received is fed to Arduino and causes state changes that are represented by the emission from the LED and the binary state of the motors actuation, on or off. Due to time restrictions the HR monitor data is merely a prompt to an operator to manually prompt these hardware changes through the use of a button. Excluding the stepper motor and LED, all the hardware is outside of Lotus and fed through a hole in the back of the plant pot, seen in the rightmost diagram in Figure 8.

Final Design: Software
All of Lotus' software is held in the Arduino board. The analogue signal from the HR monitor is subjected to a Fast Fourier Transform to extract the heart beat frequency. The software holds four states. Firstly, a *detection* state where Lotus waits for a strong and consistent HR signal, and secondly a *measurement* state where an average HR is taken over a 40 seconds to extract the users' resting HR. A red emission from the LED that flashes in time with the detected signal represents the first state whilst a solid red emission represents the second. Thirdly, a *monitoring* state is entered to constantly gather a HR signal. When a threshold is reached, the fourth state of *actuation* is transitioned into. After a user conformation (via a button press), the fourth state leads the user through the breathing exercise by running the motor. After actuation, the third state is re-entered. A solid green emission from the LED represents the third state whilst a slow flashing magenta emission represents the fourth.

For our experiments however, the *measurement* state was carried out during a stressful period to establish the user's stressed HR. The third state was excluded and the *actuation* state manually initiated. An extra *measurement* state post-exercise was included to see the effect Lotus had by comparing the two *measurement* state results.

Study
The intention of this study was to assess how easy Lotus was to use. 10 participants were asked to interact with Lotus and then answer questions in a semi-structured interview. The questions were carefully worded to be open-ended and unaffected by the bias of the interviewer. The participants sat down where the flower was clearly visible. We measured their HR as they took a timed inductive reasoning test, designed to induce minor stress and thus physiological arousal. Once they completed the test, the flower began actuating and the participants were asked to try and breathe in as Lotus' petals closed and out as they opened for one minute. At the end of this phase Lotus took a final HR measurement.

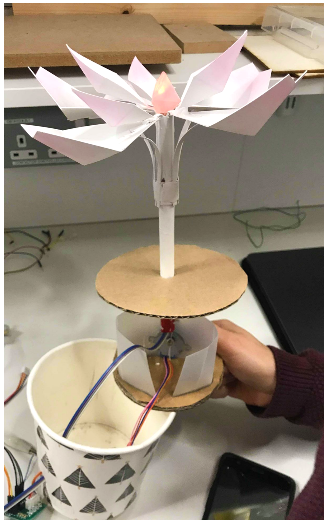

Figure 9: Illustrating what the inside of the plant pot consists of.

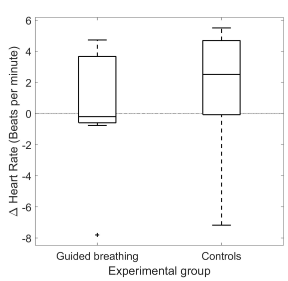

Figure 10: Change in HR after interaction with Lotus.

Usability Study

8/10 participants were stressed within a week before performing the task. Of these, 7 thought Lotus would be “very/quite effective” in helping them relax in a stressed situation. The reasons for this included it being an “attractive prototype that makes you want to interact with it and encourages grounded techniques” and it acting as a “good reminder” to “check [their] breathing”. Half the participants mentioned that they would only benefit from this if they were able to find the few minutes needed for this exercise in their workplace and one student stated that “it would make [them] lose time that could be spent on coursework”. The majority however thought the idea of being reminded to focus on Lotus for a few minutes is appealing. Many comments were made on the “visually appealing”, minimalistic design.

7 participants who were familiar with practicing guided breathing all commented on the benefit of the “tangibility” of Lotus in that they “have a nice visual presentation to look at rather than having to close [their] eyes and think about something”. The participants all saw Lotus as being useful for students with a busy schedule or in a stressful work environment. One interesting suggestion was the use of Lotus in hospitals for patients such as pregnant women who are advised to perform various breathing exercises when giving birth. It was also suggested that Lotus would be beneficial for those suffering from epileptic fits triggered by stress.

Guided breathing with Lotus proved to be “calming”, “enjoyable” or “relaxing” for every participant. 2 participants mentioned the benefit of using an information leaflet to explain the meaning of each LED colour and how to follow Lotus; we had already discussed the use of an information leaflet if Lotus was made into a product and this confirmed its benefit to some users. The general consensus from all remaining users was that Lotus was “very clear” and “really easy to follow”. With regards to viability of Lotus as a product, when asked what participants would change about Lotus if they were to buy it, suggestions ranged from making it ”pocket-sized”, using more “ambient LEDs”, allowing for “personalisation of the petals”, adding a scent to it, to allowing the user to ”vary the times for inhaling/exhaling”.

Participants also rated 7 statements about their experience on a 5-point Likert scale (Figure 11). To assess the strength of these opinions at the group level, the response options were numbered from 1 to 5, and centred them around the most "neutral" option by subtracting 2.5. A Wilcoxon signed-rank test was performed to establish whether the median scores for each question differed significantly from the most neutral option (coded as zero). The median transformed scores for all but the first question, "How frequently did you find yourself losing focus on Lotus?", were positive, and in 5 cases the scores differed significantly from zero. The analysis indicates that Lotus significantly aided in the breathing exercise, that participants often found themselves feeling stressed in their daily lives, felt that they did not have access to a device to help calm them, that participants would benefit from having Lotus in their lives, and that Lotus made them more centred and aware of their breathing (all $p < 0.05$). The two non-significant results indicate that participants only occasionally found themselves losing focus on Lotus ($p = 0.18$), and that the use of the LED in the centre of the flower to act as a focal point was moderately (as opposed to very, or not) important ($p = 0.24$).

Overall, positive feedback was received centred around how easy Lotus was to use, how calm the participant felt after the exercise and the feasibility of the device aiding in stress reduction. We gauged that people would like a more personalised experience in terms of the software parameters and the flower’s design. Some participants were also

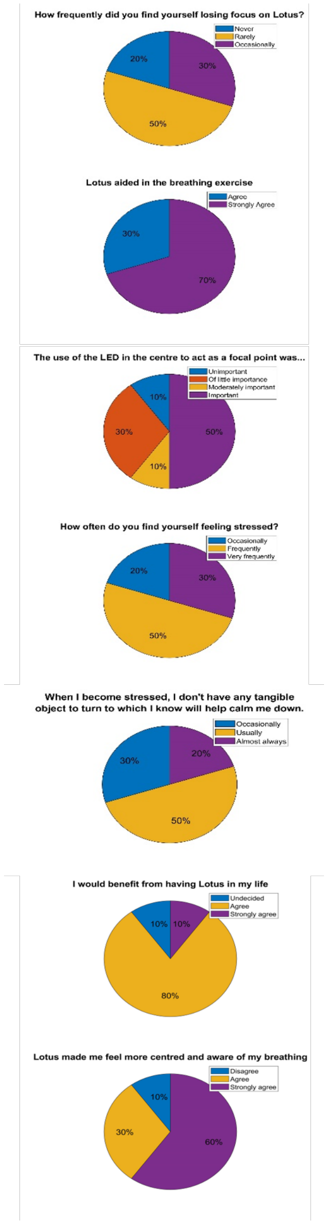

Figure 11: Results from the Likert scale questionnaire.

not confident in being able to find the time to use Lotus in their busy schedules. We believe that the final iteration of Lotus, with its wind chimes as a signal to start the exercise, will encourage dedicating time away from work, reminding users the importance of taking care of their well-being.

Evaluation of Lotus' effect on heart rate
7 control participants interacted with Lotus as described above, but the flower actuation and magenta LED pulses were replaced with a one-minute period where the magenta LED was constantly lit, and participants simply observed the LED before HR was measured a final time. To assess Lotus' effectiveness in reducing HR, we compared experimental and control participants' median HR measurements (Figure 10). 5/10 experimental participants and 2/7 controls exhibited HR reductions, with the rest displaying increases, and although on average both groups experienced an increase in HR this was higher for controls (mean ± SD, experimental group: 0.4 ± 3.59; control group: 1.45 ± 4.35). There was, however, no difference in HR change between the groups (t(15) = -0.54, p = 0.6).

Future work

There are a variety of improvements and additions that can be made as part of higher fidelity prototypes. There are also additional studies to be done in order to further assess Lotus' efficacy, in particular comparing its performance to phone-based applications. These studies will be conducted in a more controlled environment than the experiments reported here, which took place in a demonstration environment (experimental participants) and a busy office (controls). We attribute the HR elevations observed to this lack of environmental control. Lotus can be improved by inserting all of the hardware inside of the plant-pot away from sight. The actuation of the petals was unreliable as the thread could slip around the motor. This can be fixed by using a cog mechanism to anchor it. Error detection and handling mechanisms should also be done, such as when a user's HR cannot be measured. And a *tutorial mode*, to teach users how to use Lotus for the first time.

A smartwatch can be used instead of the current sensor to measure HR. Furthermore an LED screen or accompanying smart-watch application can be used to convey to the user the *system status*, illustrating to them how much progress they have made. Integration with a voice-assistant such as Amazon Alexa could also be done, providing a hands-free interface to the user such as using custom ringtones to tell the user that it is time to take a break. A calming wind-chime sound could be played to notify about start of actuation if the plant is not within eye-shot. User customization may also be facilitated, allowing users to configure the colors of the LED lights as well as the flower petals themselves. In order to give Lotus a more passive presence in its users environment, it could be given secondary purposes, such as doubling as a diffuser or night-light.

Conclusion

In this paper we proposed Lotus; an interactive plant which aims to reduce stress levels and help people lead a healthier life. We believe that after the aforementioned improvements, it would become an efficient and integral part of any day-to-day environment. Alongside its appealing design, it currently provides portability, and would eventually even be integrated with a smartwatch. Our study shows that users were highly satisfied with the look of the device, and claimed they felt calmer after interacting with it.

Team contribution

All team members contributed equally.

REFERENCES

[1] Shuo Feng Haibo Li Walter Osika Bin Zhu, Anders Hedman. 2017. *Designing, Prototyping and Evaluating Digital Mindfulness Applications: A Case Study of Mindful Breathing for Stress Reduction*. https://www.jmir.org/2017/6/e197/

[2] HSE. 2019. *Work-related stress, anxiety or depression statistics in Great Britain*. https://www.hse.gov.uk/statistics/causdis/stress.pdf

[3] Lining Yao Lea Albaugh, Scott Hudson. 2019. *Digital Fabrication of Soft Actuated Objects by Machine Knitting*. https://dl.acm.org/citation.cfm?id=3311767

[4] Mathias Funk Jun Hu Loe Feijs, Bin Yu. 2010. *Designing for heart rate and breathing movements*. https://www.researchgate.net/publication/254883157_Designing_for_heart_rate_and_breathing_movements

[5] Anna Kutikova Zdenek Mikovec Jindrich Adolf Jan Havlik Ivana Jilekova Miroslav Macik, Katerina Prazakova. 2017. *Breathing Friend: Tackling Stress Through Portable Tangible Breathing Artifact*. https://link.springer.com/chapter/10.1007/978-3-319-68059-0_6

[6] Andy Puddicombe. 2010. *"Headspace" Meditation App*. https://www.headspace.com/headspace-meditation-app

[7] Matevz Leskovsek Jonathan Duckworth Rakesh Patibanda, Florian 'Floyd' Mueller. 2017. *Life Tree: Understanding the Design of Breathing Exercise Games*. https://dl.acm.org/citation.cfm?id=3116621

[8] Yoga Basics Website. 2019. *History of Yoga*. https://www.yogabasics.com/learn/history-of-yoga/