SomaFlatables: Supporting Embodied Cognition through Pneumatic Bladders

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Figure 1: The two application scenarios in which SomaFlatables are used: A: "Pardon": This application consists of bladder placed behind the user's ear which when inflated makes the ear bigger and moves it forward; B: "Bye-Bye": This application consists of the bladder attached to the user's palm which when inflated opens up their hand to signal bye.

ABSTRACT

Applying the theory of Embodied Cognition through design allows us to create computational interactions that engage our bodies by modifying our body schema. However, in HCI, most of these interactive experiences have been stationed around creating sensing-based systems that leverage our body's position and movement to offer an experience, such as games using Nintendo Wii and Xbox Kinect. In this work, we created two pneumatic inflatables-based prototypes that actuate our body to support embodied cognition in two scenarios by altering the user's body schema. We call these "SomaFlatables" and demonstrate the design and implementation of these inflatables based prototypes that can move and even extend our bodies, allowing for novel bodily experiences. Furthermore, we discuss the future work and limitations of the current implementation.

CCS CONCEPTS

• **Human-centered computing** → **Interaction devices**; *HCI theory, concepts and models*; **Interaction paradigms**.

KEYWORDS

Pneumatics, Inflatables, Body Actuation, Embodied Cognition, Body Schema

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1 INTRODUCTION

Embodied Cognition as defined by David Kirsh allows our body to serve and function as an extension of our brain even when we do not consciously dedicate an effort to the task at hand [9]. This theory has been backed by an abundance of psychology and sports science research and has offered various explanations of how our body autonomously helps us in navigating through our day-to-day lives without having to pay a conscious effort [3, 4, 21, 25]. Activities such as sports, dancing, navigation, and language production are prominent examples of how our embodiment and cognitive processes are two inextricably linked constructs.

Several researchers in HCI have leveraged the concept of embodied cognition to create research prototypes as well as products that rely on moving our body to facilitate novel experiences [15]. However, these have primarily focused on sensing the body, i.e., reacting to the movement of the user to allow an interaction [16–18, 26]. Meanwhile, the advent of actuating technologies such as EMS and exoskeletons, have allowed researchers to design bodily actuation interactions and experiences [10–12, 19], and while there has been a keen interest from the HCI community to explore body actuation, there is limited commentary on how it can affect user's cognitive load as well as it effects their perception of their own body.

Therefore, in this paper, we present two prototypes which actuate a user's body to help them with day-to-day activities. With these prototypes we support two scenarios: - 1) Actuating the user's hand whenever they meet people online; and 2) Actuating and enlarging a user's ear whenever they ask someone to repeat themselves. SomaFlatables are silicone based bladders worn by the users at location of actuation. The bladders inflate according to the scenarios above to perform the actuation. Pneumatic bladders have been used in HCI research for designing a wide range of applications including controllers for Virtual Reality, rapid prototyping, and tangible shape changing tools for interaction. In this paper, we specifically leverage the bladder's shape changing property to actuate a user's body. Furthermore, silicone based bladders provide a soft and comfortable texture offering an opportunity for soft exoskeletons that can be overridden.

In an informal pilot studies with three participants, we found that the user experience of bodily actuation was much more comfortable than existing techniques such as EMS and motor based exoskeletons.

2 RELATED WORK

In this section we discuss previous relevant research about about embodied cognition as well as techniques of bodily actuation in HCI.

2.1 Embodied Cognition in HCI

Embodied Cognition has been explored by a plethora of researchers in an eclectic set of fields. Kirsh, in his work on embodied cognition, talks about how humans use their body to preempt and perceive their actions and the world around it [9]. Research also suggests how motor movement and perception aid in learning as well as improve articulation in conversation [3, 7]. Further, interaction designers suggested frameworks to understand playful technological augmentations of the human body. In her work Wigglears, Peng created a wearable which wiggles a user's ears based on the phsyiological input from their body to explore playful situations [20]. Svanæs also talks about his learnings from Merleau Ponty's phenomenology of the lived body in creating a mechanical tail and ears[22, 23]. With these prototypes, Svanæs further argues about the challenges of creating technology such that they serve as an part of the user's body such that they can take advantage of the "bodily-kniesthetic intelligence". Owing to these theories of bodily augmentation aiding embodied cognition, in this work, we created two prototypes which are intended to actuate a user's body to help them through certain scenarios without dedicating conscious effort to it thus supporting embodied cognition through bodily augmentation.

2.2 Bodily Actuation in HCI

Several HCI researchers have explored bodily actuation through a variety of techniques to create novel interaction experiences. Technologies such as Electrical Muscle Stimulation (EMS) have recently been employed in order to facilitate proprioceptive interaction [11], playful experiences [19], user authentication [2] as well as providing force feedback for mobile applications [13]. However, EMS is a particularly invasive technology which relies on passing a small amount of electric current through our muscles to create the actuation. Other means of actuation including mechanical exoskeletons tend to suffer from their rigid structures and weight of the motors and pulleys which affects the wearability of the system. In an attempt to create a lightweight, non-invasive actuating prototype, we employed pneumatic inflatables which have been used in a variety of applications by the HCI community. Owing to their shape changing property, pneumatic inflatables have been used to create dynamic controllers for VR [24], an assistive grasping augmentation [28], and provide haptic feedback [5, 27]. Whenever inflated, pneumatic inflatables create space between the surfaces they are situated within and thus present and excellent possibility of being used as a body actuating technology. With SomaFlatables, we employ pneumatic bladders to facilitate bodily actuation at two location: 1) behind the user's ear; and 2) inside of the user's palm.

3 DESIGN AND IMPLEMENTATION

We designed two application scenarios for SomaFlatables: "Bye-Bye" and "Pardon". In this section, we describe the technical setup and then articulate the design.

3.1 Technical Setup

We constructed a partially wearable system that consists of an off-the-shelf pneumatic controller (Programmable-Air)[1] connected to a single-chamber silicone bladder of two different designs: an ear bladder for "pardon" and a palm bladder for "Bye-Bye" (displayed in figure 1). We interfaced a Groove Serial Bluetooth module[2] with the Programmable Air to add voice-control through a smartphone.

We used the lost-PVA technique to create silicone bladders by means of using 3D printed molds, as described by Moradi, et al.

[1] https://www.programmableair.com/
[2] https://wiki.seeedstudio.com/Grove-Serial_Bluetooth_v3.0/

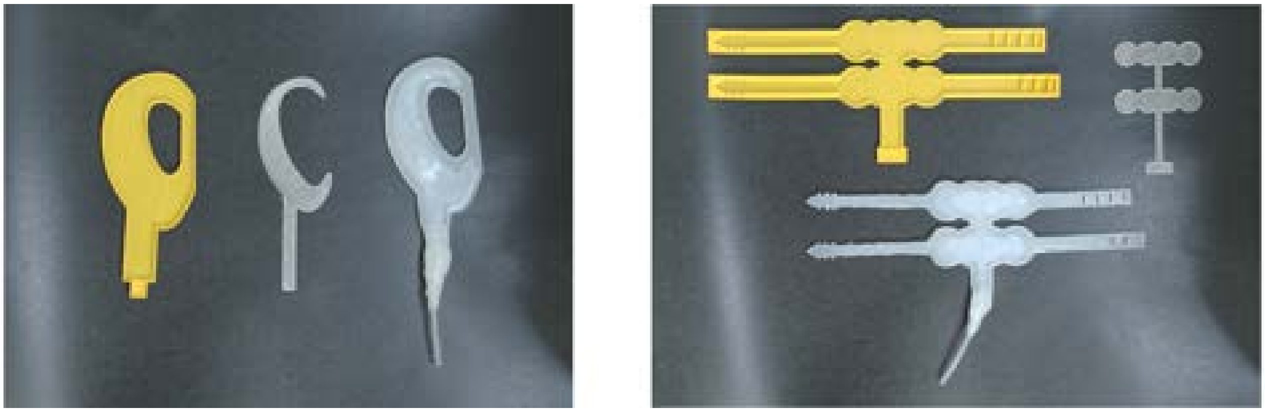

Figure 2: The molds, separators, and the fabricated bladder for the two applications.

[6, 14]. Each bladder is created with a fast-setting silicone mixture (SiliCreate Fast-20 Silicone Rubber) with a firm shore hardness of 20A to discourage leaks whilst still being suitably inflatable. Upon hearing key phrases through the smartphone's microphone, a cloud-based speech API sends a signal for the controller to inflate the intended attached bladder for 5 seconds at max pump speed.

3.2 Pardon

The "Pardon" application consists of an inflatable attached to the back of the user's ear. The inflatable is actuated in the scenario when the user's is unable to clearly hear or understand the person that is speaking to them. The bladder is programmed to be inflated when the smartphone hears the key-words such as, "What did you say?", "Beg your pardon", and "Sorry, could you repeat?". While inflated the bladder serves two purposes: first, it makes the ear visibly larger to the speaker while also altering the user's body schema; second, it actuates the ears towards the speaker which indicates that the user is listening to them intently.

3.3 Bye-Bye

The "Bye-Bye" application consists of an inflatable tied around the palm of the user. Whenever the user or a person they are speaking with says either "bye-bye" or "Goodbye", the bladder actuates the hand in a straight position from a fist thereby by signaling them to use their body to wave goodbye to the other person. The design of the bladder consists of two chambers which when inflated push against each other as well as the user's palm and fingers to facilitate the movement of the hand opening to wave goodbye. Although this prototype is usable for collocated interactions, the current demonstration is motivated by the lack of bodily communication while meeting remotely during the COVID-19 pandemic. This prototype allows the user to leverage conversational cues to support embodied cognition by actuating the movement.

4 FUTURE WORK AND LIMITATIONS

With a round of pilot studies with the current prototypes, we found that our current implementation has some limitations. They key limitation is the Programmable-Air pneumatic controller which is heavy and tethered to a 12V DC supply. We aim to replace it with a wearable pneumatic controller that is lighter while also producing less noise while actuating. We would also design this pneumatic controller to support wireless protocols such as BLE and WiFi for seamless communication with smartphones or external sensors.

Further, the actuation with the bladder for the "bye-bye" prototype was able to perform the intended actuation of opening the user's fist although in our pilot studies the participants reported that "it might be better if opened their whole fist into a straight hand" as it would help them in understanding the systems intent. Because of this, we plan to use artificial pneumatic muscles in our future prototypes to perform gross movements [1, 8].

5 CONCLUSION

In this paper we presented SomaFlatables - two pneumatic bladder based prototypes that alters the user's body schema and image through bodily actuation. Further, we articulated the design and implementation of these prototypes. We also aim to contribute to the theory of embodied cognition through SomaFlatables, since its motor actuation help the user in day-to-day scenarios. In future, we aim to conduct longitudinal in-the-wild studies with the participants in order to gauge the usability and efficacy of our work. Finally, we aim to create design strategies that help future researchers design bodily actuation to facilitate embodied cognition.

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