Design Ideation and Prototyping for Interactive Footwear: A Report on the Foot-Wearables Design Workshop

Matthew Swarts

Abstract This paper presents the process, output, and outcomes of a workshop on interactive foot-wearables. The first half of the workshop was largely devoted toward creativity through an enactive model of group play. In the second half participants joined together to form production groups with subgroups to maximize the expertise and skillsets of the participants. The result was a rich set of concepts and the deep development of a functional prototype.

Keywords Interactive products · Foot-wearables · Co-creation

1 Introduction

Wearables have become a more popular subject in the interactive design space with the introduction of smart glasses, watches, and clothing. One type of wearable on the feet of legs, which we call 'foot-wearables', seems to have had less development than other forms. While there have been several foot-wearables in both the research and the commercial spheres [1–3], most have been focused solely on either for tracking fitness performance, for rehabilitation, or for training. The primary purpose of this workshop was to explore more deeply the design space of foot-wearables to reveal what potential exists. The secondary purpose was to develop a working prototype and appropriate testing methods. Lastly, we wanted to engage participants consciously in collective imagination using a model of enaction for creativity [4].

In our model of enaction, we used the term 'unclamping' to refer to a process in which each person detaches from their current working model and mindset and the term 'clamping' to refer to the process of everyone collectively engaging in the creation of and latching onto the same world model. As most of the participants were from the same city, the first 'unclamping' activity was to leave that city and fly

M. Swarts (✉)
Georgia Institute of Technology, College of Architecture, Atlanta, GA, USA
e-mail: matthew.swarts@coa.gatech.edu

F. Rebelo and M. Soares (eds.), *Advances in Ergonomics in Design*,
Advances in Intelligent Systems and Computing 485,
DOI 10.1007/978-3-319-41983-1_48

to another. Once arriving in the host city, a series of ‘clamping’ and ‘unclamping’ activities assisted in keeping the focus and intensity of engagement high throughout the workshop.

In the first half of the workshop we spent much time on collective divergent thinking. After generating several concepts, we used a cascading sequence of approaches to collectively converge on a smaller and smaller set of concepts for implementation. In the second half of the workshop we took one concept and implemented both physical and interactive prototypes along with user study and market research method guides.

2 Divergence

The first three days were devoted to collective divergence. The primary design method for this was the card sort [5]. In the first step participants were asked to use the left half of a post-it note to write or draw something you can do with foot-wearables. Participants were given only a few minutes to produce as many notes as possible with an emphasis of quantity over quality. By recording concepts onto physical materials, the mind is less prone to being blocked by lingering thoughts. In the second step, post-it notes were shuffled and re-distributed. Participants were asked to use the right side of the post-it to respond to the left side as a prompt. Again with only a few minutes, participants were urged to produce as fast as possible in order to bypass the decision making restraints of the prefrontal cortex. The following step was to split the notes in half, and then to shuffle them again.

Participants took each of the half sheets and attached them to the wall. They were asked to position the notes near similar notes. This was done without verbal communication so as to delay as long as possible the formation of any categorization or structuring, which could potentially restrict future idea generation. For about an hour we silently attached and reattached notes to the wall, allowing a form to slowly emerge, see Fig. 1. Different colored notes were used to label and

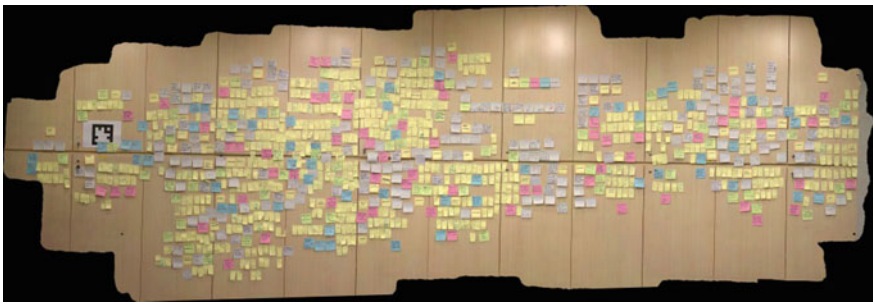

Fig. 1 Output of the card sort activity. Initial ideas are *yellow notes*, cluster labels are *red*, opportunities are in *green*, problems in *pink*, insights in *blue*, and prompts in *grey*. The center contains the prompts for the nine pitches

characterize zones. Guided by one of the workshop organizers, clusters were collectively suggested and named. Once this was done, we added notes for opportunities, problems and insights. Following more discussion we added design prompts.

3 Prompts, Pitches, and Briefs

The result of the card sort was a set of design prompts. Participants were allowed to vote using seven stickers to indicate their preference for a prompt. Based on the voting, the top nine prompts were isolated for further development, see Fig. 2. The following are the nine prompts along with one additional prompt that was highly rated.

1. How do we leave footprints behind that only some people can see?
2. How can we use feet at the input when hands are busy?
3. How do we be become adventurers?
4. What if our shoes could sense other shoes and react?
5. How might we help amputees feel the grass beneath their feet?
6. How can my foot-wearable make me money?
7. How might we support behavioral modification?
8. What if we could run on the spot with a special shoe?
9. What if we create a shoe chassis that can support modular personalization?
10. What if dance patterns could unlock systems?

The eighteen (18) participants were split into nine (9) teams of two (2). Each team was randomly assigned one of the top nine prompts. Each team had an hour to develop a pitch based on the prompt. The contents of this first phase were digitally documented and shared online for all teams to see. Each team presented their findings and pitch. The following day the same teams of two were randomly assigned a different prompt. Incorporating the previous team's efforts, these teams developed a more complete pitch over the course of an hour. These pitches were then presented to all participants. Three (3) were selected for continued development.

Fig. 2 The top nine prompts arranged in order of the number of sticker votes

Table 1 Classification of attributes of the three briefs

Project	Temporality	Scope	Cadence	Emotion
Adventure	Asynchronous	Public	Moderate	Curious
Footprint	Asynchronous	Personal	Low	Intimate
Foot-to-Foot	Synchronous	Personal	High	Playful

At this point in the workshop participants were grouped into three production groups: form, function, and story. The form group was subdivided into the industrial design team and the soft goods team. The function group was subdivided into the software team and the hardware team. The story group was subdivided into the research team and the strategy team. This was done to maximize the skillsets of the selected workshop participants in producing useful output and outcomes.

The six (6) members of the story group developed the three pitches into design briefs. The design briefs contained a description of the design problem, background information, a proposal, requirements, deliverables for the minimum viable product, and initial research questions for evaluation. The first brief was Adventure Footwear—a wearable device that can sense a given waypoint and indicate the direction of travel to it, indicate that the waypoint has been reached, and then find and indicate the next waypoint until the final destination is reached. The second brief was Footprint Tracking—wearable devices that are linked together to support authoring and discovery of spatially positioned activities to enable and enhance connections between specific people or groups of people. The third brief was Foot-to-Foot Communication—a pair of wearable devices that connect parent to child by transmitting haptic representations of the child's patterns of steps. Table 1 shows how the three pitches differ from one another in terms of temporality, scope, cadence (i.e. how frequently the notification/interaction occur), and emotion.

4 Prototype Implementation

While the story group developed the three design briefs, the form group and function group developed materials that were likely to be needed for all of the briefs. All three briefs would likely use some addressable LEDs, force sensitive resistor or Hall Effect sensors, vibration motors, and inertial measurement units. In addition, each brief would require 3D models of feet and footwear along with materials to produce footwear. Once the briefs were developed, all groups decided that there was only enough time to implement one. The Foot-to-Foot Communication brief was selected for implementation as it was the clearest for which to develop a test methodologies due to the high cadence of interaction, and additionally the Adventure Footwear and Footprint Tracking were similar to existing products, reducing the impetus to prototype them.

Fig. 3 Initial foam sheet and canvas material footwear soft goods prototypes based on the lasso shoes

The function group sorted the hardware sensors and actuators available. They also downloaded associated code libraries and produced test code snippets for each component type to prepare for integration of the hardware with the form. The two subgroups of the for form group were not as interlinked as the software and hardware teams of the function group.

The soft goods team faced with the need to produce one pair of footwear for an adult and one for a child, decided to create prototype using the model of the Lasso Shoes by Gaspard Time [6]. Figure 3 shows some of the initial prototypes using foam sheets and then canvas fabric sewn together using a blanket stitch with white cotton thread. While canvas material is durable, the edges fray easily. In a subsequent reversion, the edges were flipped inside out to conceal and control the fraying. Lacking the proper tools and materials to produce robust footwear, the team selected a commercially available shoe, based on the experience gained from the prototyping.

The industrial design team produced 3D models of feet and footwear. They used scanners and photogrammetry to create point clouds as the basis for retopologized 3D models of feet and footwear. Scanning feet was difficult, because the position of the foot when it is under a load is very different form when it has no load. The team applied an artificial load using a clear acrylic sheet so that the team could still scan the foot while under a load, see Fig. 4. Team placed markers on the feet at specific locations that are typical for foot modeling, so that we could see the differences due to loading. Figure 5 shows the output of the photogrammetry of one foot under a load. The team also applied photogrammetry to scan shoes. The 3D models were used to virtually mock up hardware placement on footwear.

The industrial design team also produced casts of two average size feet from among the workshop participants. They used alginate for creating molds from live body parts, as alginate sets quickly and does not heat up as much as other agents. Once set, the team cast the molds with clear silicone. These were useful for the soft goods and hardware teams to physically mockup and discuss sensor placement.

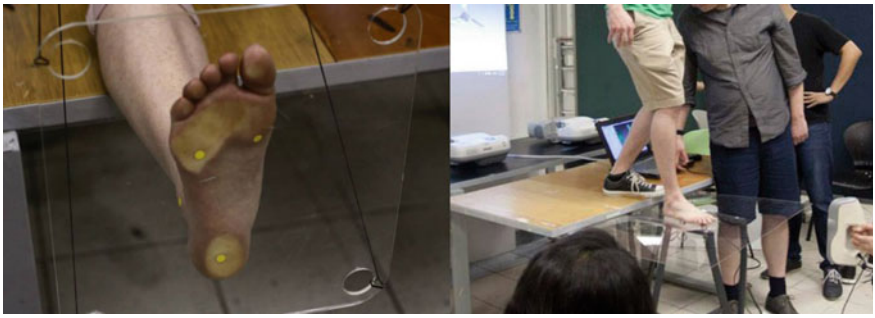

Fig. 4 Scanning and photogrammetry process. To produce scans of the foot under a load, loads were applied using a clear sheet of acrylic

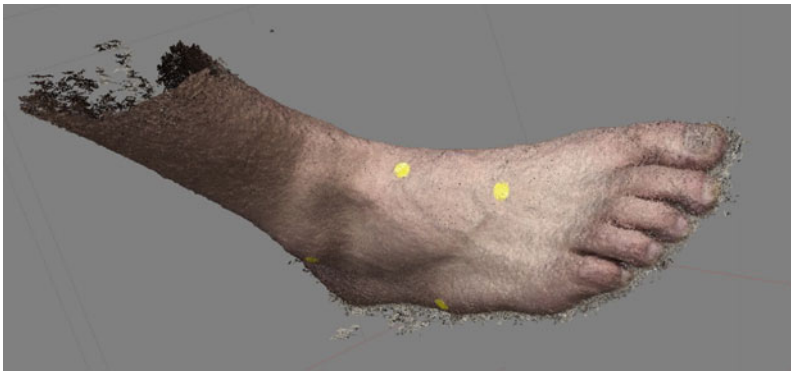

Fig. 5 Scanning and photogrammetry process. To produce scans of the foot under a load, loads were applied using a clear sheet of acrylic

The research team performed a literature review to look for prior works and created a set of testing protocols. The core research questions were about Adoptability, Meaning, Usability, and Intimacy. For Adoptability, the question was 'How do cultural expectations affect perceptions about the adoption and use of foot wearables?' The potential for adoption is the first step in understanding if and when a product might become acceptable enough to enter the market and become viable. There were two about Meaning in how people infer situational meaning from haptic feedback from foot-wearables. One aspect is the peripheral capability of sensing vibrational feedback, while the second is about attentive meaning in the form of a game or communication state. The core question of Usability was about how foot gestures can be successfully used and overall if the foot-wearables can decrease anxiety levels for parents. Intimacy questioned the development of the relationship between the parent and child with the Foot-to-Foot Communication foot-wearable.

The research team developed a compressive plan with three components. The first component was a study to observe the use of the foot-wearable for adoptability and for sensation of the feedback. The second component was a survey on the adoptability of the product. The third component was a set of experiments involving a parent and child to evaluate the physiological responses to the system as well as the gesture learning and retention in an emergency.

5 Observations

The cart sort activities in the first half of the workshop effectively extracted the tacit knowledge of the foot-wearable design space, from which we believe there indeed is a very exciting potential for future design work. The final functional prototype, see Fig. 6, demonstrated the maximal use of the skillsets from all of the participants through the structure of the production groups. The production groups enabled the development of materials for physical prototyping, functional prototyping, and the development of fully formed research methodologies. The use of unclamping and clamping activities, specifically by having the workshop hosted in a different city, allowed participants to engage together. Additionally, with the participants actively aware of the enactive model of creativity, they could observe when teammates were prematurely unclamping from a clamped engagement. This helped to mitigate conflict throughout the process and facilitated an extremely satisfactory experience, output, and outcome for the workshop.

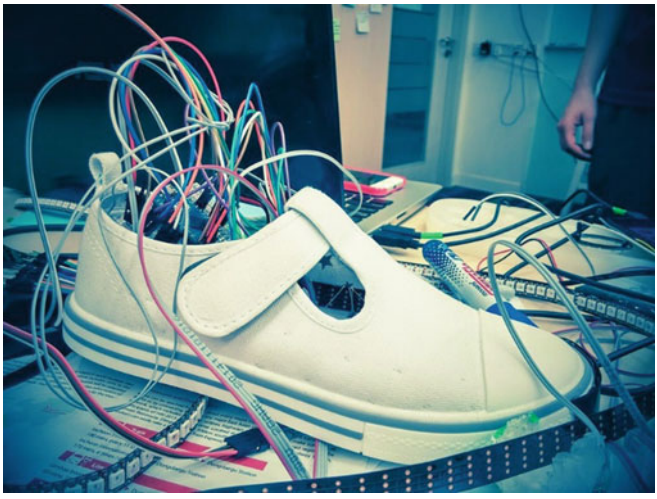

Fig. 6 The first interactive shoe prototype that integrates the visual prototype with the functional prototype using addressable LEDs, microcontrollers, sensors, and bluetooth modules

Acknowledgments This research is supported by the National Research Foundation, Prime Minister's Office, Singapore under its International Research Centre @ Singapore Funding Initiative and administered by the Interactive & Digital Media Programme Office.

We would like to specifically thank Dr. Ellen Yi-Luen Do and the National University of Singapore's Connective Ubiquitous Technology and Embodiments (CUTE) Center for supporting this workshop. We also thank all of the workshop organizers: Clement Zheng, James Hallam, Nick Davis, Emily Keen, and Richard Li.

References

1. Lechal Navigation Shoes and Insoles. http://www.lechal.com
2. GPS Smart Sole. http://www.gpssmartsole.com
3. Hallam, J., Keen, E., Lee, C., McKenna, A., Gupta, M.: Ballet hero: building a garment for memetic embodiment in dance learning. In: Proceedings of the 2014 ACM International Symposium on Wearable Computers: Adjunct Program, pp. 49–54. ACM (2014)
4. Davis, N., Popova, Y., Sysoev, I., Hsiao, C.-P., Zhang, D., Magerko, B.: Building artistic computer colleagues with an enactive model of creativity. In: Proceedings of the International Conference on Computational Creativity, pp. 38–45 AAAI, Ljubljana, Slovenia (2014)
5. Kumar, V.: 101 design methods: a structured approach for driving innovation in your organization. Wiley, New York (2012)
6. Lasso Shoes by Gaspard Tine-Beres at Show RCA. http://www.dezeen.com/2012/06/21/lasso-shoes-by-gaspard-tine-beres-at-show-rca-2012/ (2012)