Towards the Crafting of Personal Health Technologies

Swamy Ananthanarayan[1], Nathan Lapinski[1], Katie Siek[2], Michael Eisenberg[1]

[1]Department of Computer Science
University of Colorado Boulder
Boulder, CO, USA
{ananthas, lapinski, michael.eisenberg}@colorado.edu

[2]School of Informatics and Computing
Indiana University
Bloomington, IN, USA
ksiek@indiana.edu

ABSTRACT
We introduce a novel approach that merges craft and health technologies to empower people to design and build their own personal health visualizations. In this mutually beneficial union, health technologies can be more meaningful to an individual and encourage higher appropriation, while craft technologies can explore interesting problems in a challenging domain. In this paper, we offer a framework for designing health-craft systems and showcase a system that provides users with the ability to craft their own personalized wearable device. The device tracks their outdoor exposure and visualizes their weekly progress on an ambient tree painting. Finally, we report on a pilot study using this personalized feedback system. Our main contribution is the new lens through which designers can approach health and craft technologies that enhances health management with personal expressiveness and customization.

Author Keywords
Personal health; craft technology; wearable computing

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION
Chronic conditions such as obesity, diabetes, and coronary heart disease are responsible for over 70% of healthcare costs in the United States [29]. Some of the most critical risk factors are lifestyle choices such as physical inactivity, excessive food intake, poor nutrition, and smoking. Successful change towards healthy behaviors is key to both prevention and effective management of chronic conditions. Moreover, adoption of active lifestyles and improved dietary habits contributes towards overall health and well-being.

Due to the high penetration, low cost, and progressively small form factor of technologies such as mobile phones and wearable sensors, researchers in both industry and academia have created a variety of systems for encouraging physical activity and healthy diets. In many ways, work in this area has become a staple of HCI literature [7, 17, 5] with some papers even focusing on how best to evaluate the army of health technologies [14] being produced. Already within the span of a few years, the average consumer has available numerous activity trackers (e.g., Fitbit) and mobile phone health applications (e.g., MyFitnessPal) to help adopt and sustain health-promoting behaviors.

This increasing prevalence of on-the-body sensing technologies has even given rise to movements such as the *quantified self* movement, where individuals regularly track aspects of their lives from mood to blood oxygen levels. While existing devices have enjoyed some success in monitoring, inferring, and presenting activity, both research and industry have focused on pre-built devices and visualizations of health data. The user is often the owner of an off-the-shelf wearable tracker or a participant in a study for a pre-built health device. The user has had little, if any, input into building the device or the accompanying visualizations. With the rise of the maker and DIY movements, we are at the point where we can present users with options for creating their own health technologies and associated health data visualizations. Research has shown that people who are empowered to make their own objects value these objects as much as expert made objects - the "Ikea effect" [24]. Democratizing health technologies has the potential to empower users to implement their own unique, creative, and expressive ideas of health with potentially better adoption and appropriation rates.

In this paper, we offer a new approach to health technologies that lays the foundation for the union of craft and health. We propose a system for ambient and wearable computing where users can craft their own personal meaningful visualizations of health. In this marriage of the maker movement and pervasive health technology, we empower the user to take control of their own health by providing a framework for designing health input and presentation technologies. In that light, the specific contributions of this work are:

- To re-imagine the design of health technology, not in terms of "products to purchase and use," but rather in a way that that integrates craftwork (and possibly artistic expression) with healthful activities and choices.
- To re-imagine the realm of craft technologies so that they extend beyond the typical examples of craftwork (e.g., per-

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author(s) must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.
DIS 2014, June 21–25, 2014, Vancouver, BC, Canada.
Copyright is held by the owner/author(s). Publication rights licensed to ACM.
ACM 978-1-4503-2902-6/14/06 ...$15.00.
http://dx.doi.org/10.1145/2598510.2598581

Figure 1. Cherry blossom visualization with two-toned blossoms. The lighter blossoms indicate the type of tree and the darker blossoms illuminate according to wearable sensor data. In this case, the tree is showcased with all the blossoms illuminated. The birds also respond to data with the seated bird chirping a tune and the humming bird (far left) vibrating.

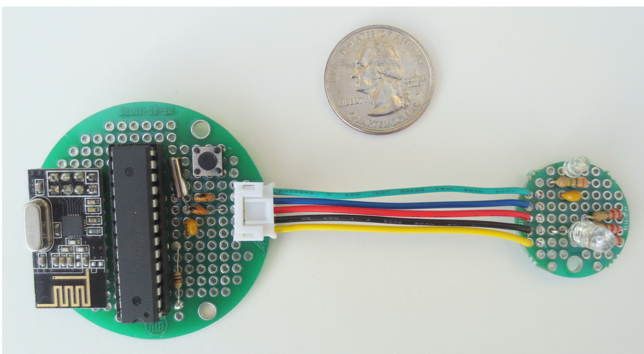

Figure 2. UV Wearable Device with microcontroller/wireless base on left and UV sensor/RGB LED display on right

sonal adornment or utility items) and make use of a broader landscape of techniques related to health and wellness.

Another way of phrasing these two contributions is to say that the two usually separate domains of "health technology" and "craft technology" each have a great deal to gain through this mutual detente. Health technologies can become more expressive, individually meaningful, and even aesthetically appealing. Conversely, craft technology can explore novel problems, information spaces, and applications by being applied to the realm of health and fitness.

SYSTEM DESCRIPTION

We showcase the idea of health crafting with an electronic cherry blossom painting (Figure 1) that reacts to data from a wearable UV exposure tracking device (Figure 2). That is, the user puts on the wearable device and spends a certain amount of time outside; then, once the user returns home, the cumulative time spent outside (measured by UV exposure) is communicated to the painting as a customized display. In this illustrative visualization, the blossoms in the tree increasingly illuminate as more time is spent outside; thus giving the illusion of the tree growing as time progresses. In our example, we chose to visualize time spent outside, but the wearable device and the visualization can be easily modified to support any linear health metric such as step count or minutes in a target heart rate zone. This is in part due to the framework we created for visualizing health data in the tangible interaction space. The cherry blossom is just one of many visualizations than can be made using this framework.

Cherry Blossom Visualization

The visualization consists of a cherry blossom painting on craft paper (Figure 1) that is overlaid on a 91cm x 122cm display board. The cherry blossoms in the painting have a two-toned color scheme with both lighter and darker blossoms. The lighter blossoms highlight the type of tree, and thus do not illuminate, whereas the darker blossoms illuminate according to the wearable sensor data. Since the craft paper by itself is not enough to diffuse the light from the LEDs, we used vellum paper, a type of translucent paper, as a light diffuser on the darker cherry blossoms.

The display board, underneath the vellum painting, houses the circuitry for the visualization (Figure 5). Each cherry blossom and bird is an intelligent paper-based circuit block (Figure 3) that is secured to the board in alignment to the painting. These circuit blocks act as nodes in a master-slave communication network. The nodes in the network are all chained together with copper tape for communication and

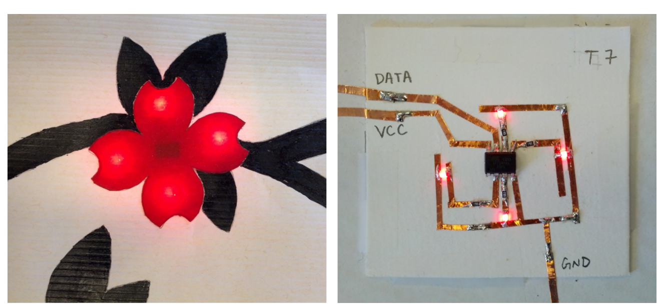

Figure 3. Individual paper circuit block for a cherry blossom. Only three lines (Ground, Data, Power) are required per circuit block.

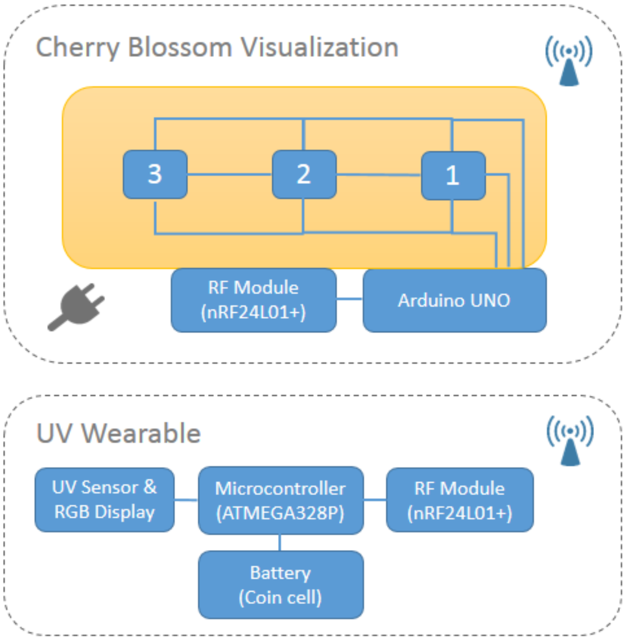

Figure 4. System diagram for cherry blossom visualization and UV wearable.

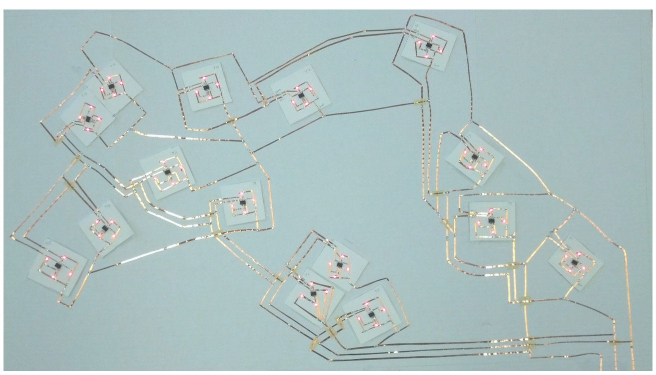

Figure 5. Cherry blossom visualization backend with copper tape connecting the cherry blossom paper circuit blocks.

power. At the core of every node is an ATTINY85 microcontroller that is pre-programmed with a specific node ID and pre-defined behaviors for that particular block. Figure 3 shows a cherry blossom and its associated paper circuit block.

The node requires just three connections to function - power, ground and data. Based on commands received over the data line, the microcontroller actuates the 4 LEDs corresponding to each of the petals in the blossom. To showcase other feedback modalities that could be made in this fashion, we included two birds as part of the painting. The bird seated on the branch chirps and the hummingbird on the far left vibrates in response to user data.

A key aspect of our design lies in the encapsulation of functionality in the individual nodes - a concept borrowed from object-oriented design. While the circuits might be different, the 3-line interface to the node and the core software remains the same. Moreover, the implementation of each type of node is hidden behind a shared interface. This is accomplished through a standardized command set that is common to all the nodes. For example, a command to "actuate" from the master controller, will evoke chirps from the seated bird, vibration from the hummingbird, and illuminated petals from the cherry blossoms depending on which node ID is sent with the command. This way each node is responsible for the appropriate behavior.

The role of the master controller is to issue commands based on the data received wirelessly from the wearable devices. In our implementation, the master controller is an Arduino Uno with a Nordic Semiconductor nRF24L01+ RF module (Figure 4). The Arduino, which is also a part of the painting, communicates with the paper circuit blocks through the copper tape network serving as the common data line. In this broadcast network each message packet is prefixed with a specific node ID. Thus, only the node with the matching ID reacts to the message while the other nodes simply ignore the message. Using this framework, one can create arbitrarily different nodes (potentially actuating an assortment of elements) in a variety of mediums including, fabric, clay, glass, metal, and wood.

Note that the overall point of this example is to illustrate one creative way in which a crafted ambient display can represent personal health information. We chose a cherry blossom tree to showcase how a multitude of nodes can be connected using our framework to represent a particular health metric. Other possibilities could be a fountain that changes its flow rate in response to information from the wearable, or a mechanical device that alters its behavior, or a musical instrument whose timbre changes in response to information. The essential issue, then, is that the wearable device is designed to be integrated with a wide variety of home crafting activities consistent with a broad "maker culture". Indeed, one might argue that the existence of precisely these sorts of wearable devices could act to encourage participation in the maker culture itself. We will return to this issue a bit later in this paper.

Wearable UV Tracker

Coupled with the cherry blossom visualization, we designed and implemented a UV wearable device for recording and transmitting the number of minutes a user spent outside on a given day (Figure 2). The device consists of a 3V 250mAh coin cell battery, an Atmega328P microcontroller base, a UV sensor/display module and a Nordic Semiconductor nRF24L01+ radio transceiver module. The display consists of an RGB LED activated by a push button switch on the microcontroller base. The LED serves as an on-demand wearable indicator of outdoor exposure. Over the course of the day, it transitions from red to green as the user spends more time outside.

In order to achieve a low power system capable of running on a coin cell battery for weeks, we underclocked the microcontroller to 1MHz and employed aggressive power saving modes to sleep the system when it was not in use. We also made the RGB LED on-demand in part to save power. To avoid using an external real-time-clock, we used a watch crystal along with the microcontroller's built in real-time-counter to track time. Additionally, we used the internal 1 KB EEPROM to store data rather than using a external SD Card or EEPROM. In part, due to these techniques, the device is relatively small, low power, and uses a limited number of electronic components.

We separated the UV sensor/display module from the main microcontroller base to make the device plug and play with other future sensors. We chose the UV sensor in part because it was a simple and effective way to showcase our framework, but we always envisioned that the system would support other sensors such as accelerometers for capturing physical activity. In a sense, we see our work as an entry point into the much broader domain of health crafting.

PILOT TESTING

We conducted an initial pilot test of our ambient and wearable system with a convenient student sample of 5 participants. The goals of the pilot study were three fold: 1) To test the functionality of the UV wearable as a standalone low-power device, capable of tracking, storing, and transmitting UV sensor data, without human intervention for an extended period of time, 2) To get participants impressions on crafting the wearable device into their lifestyles and to observe any subsequent effects on adoption, 3) To understand the effectiveness and to gather participants' impressions of the craft-based ambient health visualization. Thus, the aim of our study was to better understand the feasibility of the health crafting approach rather than to motivate behavior change.

The 5 participants (24-34 years) consisted of 4 men and 1 woman. The participants were all proficient users of modern technologies (e.g., smartphones, personal computers) in their daily lives. Three of the five participants described themselves as DIY enthusiasts having performed craft and small home construction projects in the past.

The pilot test lasted 7 days where each participant was asked to wear the UV tracker daily during the day. Initially, when receiving the wearable device, we requested that participants take time to craft the device into an artifact of their choosing, carefully considering their daily lifestyles and their own fashion and artistic sensibilities. We suggested that they choose an artifact they used everyday so that they would not forget the device at home. Additionally, they were instructed on the operation of the device, the location of the sensor, the RGB LED and the button to activate it. This crafting process typically lasted 30 minutes where participants were given all the craft materials they needed (felt, fabric glue, velcro, etc.) to complete the task. During this process, participants were shown the cherry blossom visualization and were informed of its link to their wearable device. Participants were then asked to check in periodically throughout the week as their schedule allowed to evaluate their progress. During these meetings, we conducted brief semi-structured interviews to gather their impressions and thoughts on the pilot study, the device, and the visualization. Typically, these sessions lasted 30 minutes once or twice during the study week.

Figure 6. UV wearable device crafted into a messenger bag with felt, velcro and electric tape.

RESULTS

Overall, the results of the pilot study were encouraging. Participants seemed receptive to the idea of crafting health devices and were engaged while crafting the UV wearable. Though they sometimes struggled with issues like what daily artifact to use, and how best to conceal or display the device, all the participants were able to construct a wearable accessory by the end of the first meeting.

All the male participants chose to craft the device as an accessory to their backpack or messenger bag. They were less inclined to craft a body worn device citing their already existing accessories and their modest fashion sensibilities. As one participant stated,

> *"I'm not quite sure I want to wear something on my body all the time. I have enough things to carry around. I have my keys, my wallet, my phone, and my watch. One more thing would be one too many. I am also not a very fashion conscious person. I am not sure I want to adorn my body with something."*

However, all the male participants were able to identify their backpack as the one bodily extension that they carried around everyday. A couple of the male participants likened the bag accessory to a sticker on a laptop or a stitched cloth decal. A representative example of the UV wearable device crafted into a messenger bag by one of the male participants is shown in Figure 6.

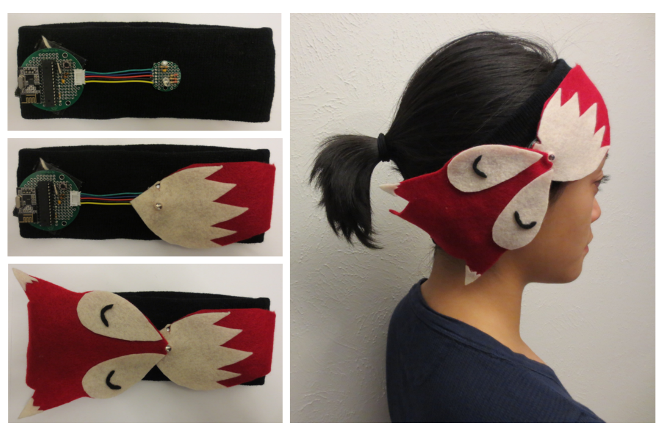

Figure 7. UV wearable device crafted into a fox themed headband with felt, velcro and fabric glue.

In this example, the participant used felt cut-outs matching the colors of his bag to showcase a rudimentary mountain and tree. The RGB LED and the UV sensor are exposed at the base of the tree. Interestingly, this participant who described himself as "not craft oriented" was surprised by the results and remarked that it was not "half as bad" as he had envisioned.

In contrast to the male participants, the single female participant was more open to the idea of creating an accessory that would be worn on her body. She was particularly concerned with creating something that was aesthetically pleasing. After using the internet to brainstorm some ideas, she settled on a fox themed headband. The crafting process and the final result is shown in Figure 7. The RGB LED is located at the tip of the fox's nose and the UV sensor is exposed via a notch on the tail. When we asked the participant why she had chosen a headband instead of other form factors, she astutely pointed out that the UV sensor would gather the best data on the head and that since it was winter she wore the headband regularly to protect her ears against the chill. This design was one of the more beautiful and creative expressions of the wearable device during our pilot study and serves to highlight a design that we, as researchers, had not envisioned.

With respect to the on-demand RGB visualization on the wearable device, we received somewhat mixed reviews. Three of the male participants were glad it was not illuminated all the time, with one describing the device as being "low key" and not garnering much attention from people. The other male participant felt it would be helpful to have it on all the time, but hidden. He cited not pressing the button during the day to check on it and described an alternative solution where the LED would face inward on the other side of the board and into the backpack instead of outward like the UV sensor. This way when he opened the backpack to remove books or his laptop, it would not only illuminate the backpack but also remind him of how much he had been outside. The female participant was initially unsure about whether to have the RGB on demand or have it be persistent, but ultimately decided on a persistent diffused LED with a different color transition scheme. She remarked,

> *"I like the LED and it goes well with my fox design...at the tip of the nose. It makes sense to have it on all the time since it is a part of the piece, but it seems a little bright. I am not sure I want it on all the time...drawing attention. The button press is a good intermediate solution, but I rarely ever pressed it....maybe if it less brighter and subdued. Also since the fox is red, having it go from red to green throughout the day doesn't really fit the design. It would be better if it was hues of red."*

Even though the button and the associated RGB LED did not see much use, participants remembered to wear the crafted device for the duration of the pilot study. A graph of the minutes spent outside by each participant for seven days is shown in Figure 8. The UV wearable was successful in gathering data unattended for a majority of the participants except for P5. In P5's case, the sensor board connection had worked itself loose from the microcontroller base after the fifth day; thus the device was not able to gather data for the last two days. From an initial glance of the graph there does not seem to be any significant patterns to the data other than most participants spent at least the recommended 15-20 minutes outside for most of the work week. After interviewing the participants, we discovered that the undergraduate participants (P2 and P3) had classes that were either Monday-Wednesday-Thursday or Tuesday-Thursday. Thus, for these participants we can see an alternating pattern to the time spent outside which corresponds to similar walking distances between classes for those days. Students P1, P4 and P5, who did not have this alternating course schedule, did not exhibit a similar pattern. An interesting aspect of the sensor data was that participants did not spend as much time outside on the weekends as compared to the weekdays. Participants cited not having to attend school and the cold winter season as the main reason for not venturing outside on the weekends, but also cited not carrying their backpacks for activities such as grocery shopping. Based on the graph (Figure 8), we can observe that the female participant (P3), who crafted the headband, was more successful in accounting these lost minutes due to the headband being a staple of her daily winter outerwear.

With respect to the cherry blossom visualization, we received favorable comments from all of the participants. Most participants during the mid week check-in remarked how beautiful it looked with the blossoms lit. While they understood that the tree had reacted to their sensor data, they were unclear of when exactly the reaction happened. Since the data was automatically transmitted based on proximity to the ambient display, the tree often changed as they were entering the lab space. One participant suggested having a button to initiate the wireless transfer, so the subsequent change in the tree could be explicitly seen. Additionally, since participants did not visit the lab everyday, they often did not remember the tree's prior state. As one participant summarized,

> *"I think it would be better if I were able to look at the tree everyday so I could see it growing in response to*

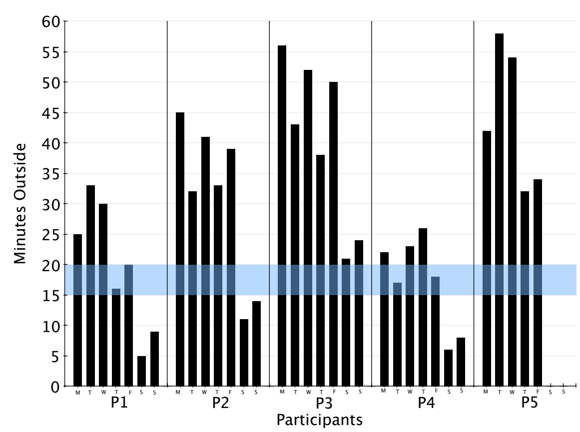

Figure 8. Graph of number of minutes spent outside by each participant for 7 consecutive days from Monday through Sunday. The blue band indicates the recommended time outside.

Product	Sensing	Wearable feedback	Form Factor	Body location
Nike+ Fuelband (nike.com/fuelband)	Physical activity, sleep	LED display	Bracelet	Wrist
Fitbit (fitbit.com)	Physical activity, sleep	OLED display, vibrotactile	Clip or bracelet	Wrist or hip
Misfit Shine (misfitwearables.com)	Physical activity, sleep	LED indicators	Adaptive	Wrist, hip, neck, chest, waist
BodyMedia Fit (bodymedia.com)	Physical activity, perspiration, skin temperature, heat flux, sleep	None	Arm band	Upper arm
Jawbone UP (jawbone.com/up)	Physical activity, sleep	Vibrotacticle	Bracelet	Wrist
Withings Pulse (withings.com/en/pulse)	Physical activity, heart rate, sleep	OLED display	Clip or Bracelet	Wrist, hip
Basis (mybasis.com)	Physical activity, heart rate, perspiration, skin temperature, sleep	LCD	Bracelet	Wrist
Larklife (lark.com)	Physical activity, sleep	LED indicators, vibrotacticle	Bracelet	Wrist
Striiv Play (striiv.com)	Physical activity	OLED display	Clip	Hip

Table 1. Wearable Activity Trackers in the Consumer Market

me. I think it is growing, but it is hard to tell since I don't remember what it was like 2 days ago."

Despite these limitations, participants all agreed that the tree served as an aesthetically pleasing representation of their outdoor exposure. Several participants mentioned how the visualization was a welcome departure from traditional phone or computer based systems. They remarked on how the visualization caught their attention because of qualities such as depth, texture, and tangibility, aspects that could not be replicated on a mobile or computer screen visualization despite skeuomorphic designs.

While our pilot study did not specifically explore the crafting of personal health visualizations, we found that the cherry blossom display served as a wonderful scaffold for fostering creativity in the participants. For example, one participant suggested that instead of using the birds as extra badges of accomplishment in the visualization, they might serve better as an audible reminder system for going outside. Others suggested using the tree in a social context with the flowers on the various limbs of the tree divided among members of a group. This way the health of the tree is tied to a group instead of a single individual thereby leveraging social influence. Another participant proposed crafting three dimensional artifacts. She commented,

"I can also see having something 3-dimensional like instead of a picture of a tree it was an actual figurine that reacted or lights up. I think it would be nice to have in my house because it is beautiful."

RELATED WORK

Having described the design, sample implementation, and initial pilot tests of the health crafting approach, we can now "step back" and take stock of the implications of our early work. In this section, we discuss the research traditions that have influenced our ideas. In many ways, our work is only possible because of parallel advances in the maker movement and in personal health technologies. It is only because of these advances that the concept of users creating their own health technologies seems less ambitious than it would have ten years ago. In discussing prior work, we examine several strands of research, including consumer health and wellness technologies, academic research in personal health technologies, and the maker movement with respect to health and electronic crafting.

Consumer Health Technologies

In the consumer market, wearable activity monitors have seen a meteoric rise in recent years. Table 1 summarizes several prominent offerings in this space. Typically, these devices employ a 3-axis accelerometer and intelligent algorithms to track and distinguish between various activities like walking, running, and biking. A majority of these devices also use the accelerometer to track the quality and duration of sleep. A few, such as the BodyMedia Fit, Withings Pulse, and Basis employ additional sensors to capture health metrics such as heart rate, perspiration (through galvanic skin response), and skin temperature to get accurate measurements of activity intensity and overall caloric expenditure. While the majority of devices provide a small on-demand visual display or vibrotacticle feedback for reminders because of power constraints, they primarily serve to gather data that can later be wirelessly synced to smart phones and online applications.

In many ways, the consumer activity trackers available today are a testament to the advances in low cost, low power sensors and computing platforms. These devices increasingly fit in small attractive form factors and integrate well as fashion accessories. Newer activity trackers such as the Misfit shine are designed like jewelery and can accommodate being worn as a necklace, brooch, or bracelet. However, the key challenge is to not only create a device that users will wear but also remember to carry and use everyday. It is in this aspect that the idea of "crafting your health" might prove to be a valuable contribution. It provides a level of personalization that accommodates individual differences where users can express their own personal ideas of health in terms of crafting the wearable device and the associated visualization. As noted earlier, this element of personalization might well encourage users toward participation in construction and the "maker culture;" at the same time, this personalization may in turn facilitate greater adoption of the health technology since the act of crafting may increase the perceived value and meaning of the crafted object. As Norton et al. argue, "labor increases valuation of completed products not just for consumers who profess an interest in do-it-yourself projects, but even for those who are relatively uninterested [24]." Thus, by building our own health technologies, we attach greater value to them, and are more likely to adopt them in our daily lives.

Academic Research in Health Technologies

Much like the meteoric growth in wearable activity monitors in recent years, there has been an explosion of HCI research on technologies for supporting health behavior change in the last several years. HCI researchers have developed systems for encouraging physical activity [1, 6, 17], improving sleep [13, 2], supporting healthy diets [9, 16], lowering stress [19] and self-regulating emotions [22, 5]. Researchers have even targeted specific audiences, such as attempting to encourage more steps in teen girls [28] or stimulating exercise through music tempo in children [10]. Suffice to say, we could easily dedicate an entire paper to discuss these significant contributions. Instead however, we focus on ideas whose footsteps we follow or have significantly influenced our contribution.

In connecting health and craft, one of our goals is to facilitate aesthetic, meaningful health data abstractions. In this respect, we follow the tradition of a number of prior research projects. The researchers behind Fish 'n' Steps [18] mapped user step counts from pedometers to the growth and emotional state of virtual fish in a fish-tank. The virtual fish served as aesthetic anthropomorphic avatars to relay health information. Similarly, the designers behind UbitFit [7] associated physical activity with the growth of a garden on a mobile phone. Based on activity levels, measured from a hip-worn wearable device, the associated smart phone automatically changed the background display with growing flowers. Additionally, users could set weekly workout goals and were rewarded with a butterfly in the garden when the goal was met. The cherry blossom visualization we presented earlier in this paper follows a similar theme except in the tangible design space. Perhaps a more inspiring example is MoodWings, a wearable butterfly that reacts to a user's stress levels [19]. In this biofeedback device, a high state of arousal precipitates a large flap of the wings while a calmer state results in a gentle hover. In a similar vein, the designers of Breakaway [12] used the body language of a small electronic statue to encourage users to take breaks from a sedentary lifestyle. These types of "ambient influences" [27] make the invisible visible through a fun, aesthetic compelling display that raises awareness in the user for a particular behavior they might normally overlook.

In a sense, our work supports this tradition by helping users create their own tangible, aesthetic representations of health. We envision a goal where users are not limited by the ideas of researchers and designers. By creating modular computing elements that users can craft themselves, we want to empower them to create wearable and ambient technologies more diverse and innovative than what we can imagine, whether it be a tree that grows, a sculpture that moves, or a butterfly that flaps its wings.

Health and Electronic Crafting

The idea of crafting health technologies is possible only because of all the recent advances in open source electronics and personal fabrication. The maker movement has produced cost-effective 3D desktop printers such as the MakerBot (makerbot.com), the Arduino electronic prototyping platform (arduino.cc), cheap programmable computers like the Raspberry Pi (raspberrypi.org), and accessible breakout boards for sensors and chips that were once only available from specialty electronics stores. Growth in these areas, along with a culture of sharing hardware schematics and materials, has given rise to electronic textiles (E-textiles) with wearable platforms such as the LilyPad Arduino [3] and FLORA (adafruit.com/flora). These platforms are already starting to see use in health related projects. While not documented in traditional research literature, projects such as a LED jacket that responds to heart rate are already documented in many blogs and maker sites. Our work follows in these footsteps to make health crafting widely accessible and as easy to assemble as snapping components together.

Traditionally, the practice of electronics building has been separate from the context of crafts, such as carving, sewing, and painting. But recent research in this area, has shown how common craft materials can be used as a medium for carrying traditional electronics [4, 21]. These hybrid and blended craft practices have not only helped make electronics accessible to a wider population but have also enriched and diversified the environments where technology is used. Notable examples include an interactive electronic pop-up book [25], electronics enriched storytelling with conductive ink [11], and paper animation with shape memory alloys [26]. Our paper-based cherry blossom visualization is a direct descendant of work in this area. It employs similar methods, such as the use of copper tape for traces on paper, to showcase how users may develop paper-based electronic visualizations of their health. In this marriage of craft and health, we hope to empower users to craft their way towards healthier lifestyles.

DISCUSSION

From a broader context, our intentions behind the pilot study was to use it as a vehicle to assure us that our ideas were reasonable. In these first steps, we sought to explore the notion of combining health and craft by rethinking how these two domains can be blended together with an example and a subsequent exploration. During these explorations, we recognized that there are in in fact opportunities for the productive detente between these two domains. Indeed, in one view, one of the primary research challenges for each of these two cultures should be how to appropriate the advantages of the other. For the craft community, then, the goal is to provide users with accessible health sensing components and wearable platforms with easily programmable interfaces where users do not have to worry about issues such as power, storage, and communication. For the health technology community, the goal is to integrate health technologies with the powerful aesthetic and intellectual advantages of physical materials. In our work, we showcased an example of this convergence by creating a wearable wireless platform for tracking health data considering issues such as power consumption, time tracking, and networking. Instead of integrating the sensor as part of the platform, we chose to make it a module, so that it could be removed to accommodate other health sensors in the future. In designing the accompanying visualization, we borrowed from the craft technology landscape to create a paper-based electronic painting that used a mixed media approach to health visualization.

In many ways, health and wellness are personal issues requiring a dynamic approach that accommodates an individual's lifestyle and varying motivation levels. Consider that a small change, such as adding a 30 minute run at lunch, requires the individual to re-prioritize and re-structure their daily lives; they have to bring fitness apparel, find a place to shower after exercising, and re-schedule any social obligations, like work lunches. Moreover, uncontrollable circumstances like weather or illness can thwart and disrupt those seeking to establish new behaviors. Indeed, as other researchers have pointed out, one of the problems with current health technologies is their failure to accommodate individual differences [20]. We believe that this confluence of craft and health has the potential to address some of these concerns. Even within our modest study, we observed how some participants were less willing to display their outdoor exposure through the RGB LED, while others were willing to have a hidden or diffused display. This highlights the need to tailor feedback mechanisms based on the sensibilities and privacy concerns of the user. Rather than seeing technology as a solution to the behavior change problem, we argue for a model where users are active agents in designing the feedback mechanisms of ambient and wearable health interfaces.

The previous paragraphs focused on the accessibility and expanding the creative range of technological crafts, and how those crafts can be employed toward the goal of personal health. At the same time, as alluded to in the introduction, there is another benefit of integrating crafts and health namely, novel applications for craft technologies themselves.

Historically, personal craft creations are capable of having sentimental or autobiographical significance: a crafted item might be created as a special gift, memento, or souvenir. These functions are particularly prominent in the case of physical objects; for reasons that are worth speculating on (but beyond the scope of this paper), purely "virtual" objects (animations, simulations, and so forth) seem not to have the same affective power as physical artifacts. Csikzentmihalyi and Rochberg-Halton noted in their foundational book on the subject of personal objects [8] that for many people, the most meaningful possessions are not expensive or "prestige" items (e.g., jewelry or fine art), but rather items that enrich their own sense of narrative history.

With this in mind, it is interesting to imagine potential roles for crafts and homemade design in the realm of personal fitness and health. Perhaps a crafted object could be a memento of a period when a person made a successful commitment to lose weight, or to recuperate from an illness, or to improve performance in a sport. In other words, the blending of crafts and health offers new possibilities for the meaning and power of personal crafts.

In this paper, we use the terms DIY, craft, and making (as in the maker movement) somewhat interchangeably throughout the paper. We acknowledge that there are shades of differences between these terms. However, as other researchers have pointed out, these cultural practices are multi-faceted with significant overlap between communities [15], and it is under this all-inclusive umbrella that we choose to position this research so as not to exclude any particular community.

FUTURE STEPS

Health crafting is still in a relatively nascent stage: our current prototype accommodates a single UV sensor that pairs with one sample visualization. While these examples lay the foundation for future devices and visualizations through the wearable wireless platform and the master-slave network of nodes, there are many improvements and additions we plan to explore.

Fundamentally, we see our current device and visualization as part of a larger, burgeoning technological ecosystem around the activity of health crafting. With respect to the wearable platform, we intend to give users the option of tracking other health metrics such as physical activity (accelerometer) or exercise intensity (heart rate sensor or galvanic skin response). Much like the UV sensor, we intend to implement these sensors as separate modules so users can plug different sensors into the same wearable base. Additionally, we are exploring different locking connectors to make the connections between the modular components more robust for daily use. From a craftability perspective, we would like to provide strong affordances [23] to improve how the devices are secured and crafted to different possible accessories. Apart from stitching and the use of fabric adhesive, we are exploring the use of paired male-female magnetic snaps to secure the devices to daily wear which not only provide strong visual cues, but have physically attracting ends that allows users to easily switch out components. Ultimately, our goal is provide enough affordances [23] as part of the design that users automatically learn the best methods to craft the device to their own liking.

The most important aspect of our future work is to craft as many diverse, modular health visualizations as possible. This includes creating new types of nodes, in addition to the existing ones (LEDs, vibrotactile and buzzer), to actuate different elements such as motors, various shape memory alloys, or speakers. These diverse visualizations, whether it is a desktop water fountain that changes its pattern or a statue that moves, will serve to scaffold participants' creativity during the health crafting process. Also, by continuing to make modular designs (e.g., snapping on extra branches on the tree and connecting more cherry blossoms that are each separate, snapable modules), we can empower people to craft more complex visualizations for their own personal or group health monitoring goals.

CONCLUSION

In this paper, we explored the union of craft and health to empower individuals to craft their own personal meaningful representations of health data. We showcased this idea through an ambient cherry blossom painting that responded to data from a wearable UV tracker. We described a master/slave system for creating arbitrary visualizations with intelligent computing nodes that could be adapted to different feedback modalities. To test the system, we conducted a pilot study with five participants where they crafted the UV tracker into one of their daily accessories and used it for seven days. Overall, the results of the pilot study were encouraging, with participants receptive to the idea of crafting and the cherry blossom serving as scaffold for fostering creativity.

ACKNOWLEDGEMENTS

This work is supported by the National Science Foundation Award No IIS-1231645.

REFERENCES

1. Anderson, I., Maitland, J., Sherwood, S., Barkhuus, L., Chalmers, M., Hall, M., Brown, B., and Muller, H. Shakra: Tracking and sharing daily activity levels with unaugmented mobile phones. *Mob. Netw. Appl. 12*, 2-3 (Mar. 2007), 185–199.
2. Bauer, J. S., Consolvo, S., Greenstein, B., Schooler, J., Wu, E., Watson, N. F., and Kientz, J. Shuteye: Encouraging awareness of healthy sleep recommendations with a mobile, peripheral display. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, ACM (New York, NY, USA, 2012), 1401–1410.
3. Buechley, L., and Eisenberg, M. The lilypad arduino: Toward wearable engineering for everyone. *Pervasive Computing, IEEE 7*, 2 (2008), 12–15.
4. Buechley, L., and Perner-Wilson, H. Crafting technology: Reimagining the processes, materials, and cultures of electronics. *ACM Trans. Comput.-Hum. Interact. 19*, 3 (Oct. 2012), 21:1–21:21.
5. Carroll, E. A., Czerwinski, M., Roseway, A., Kapoor, A., Johns, P., Rowan, K., and m.c. schraefel. Food and mood: Just-in-time support for emotional eating. In *IEEE Affective Computing and Intelligent Interaction* (2013).
6. Consolvo, S., Everitt, K., Smith, I., and Landay, J. A. Design requirements for technologies that encourage physical activity. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '06, ACM (New York, NY, USA, 2006), 457–466.
7. Consolvo, S., Klasnja, P., McDonald, D. W., Avrahami, D., Froehlich, J., LeGrand, L., Libby, R., Mosher, K., and Landay, J. A. Flowers or a robot army?: Encouraging awareness & activity with personal, mobile displays. In *Proceedings of the 10th International Conference on Ubiquitous Computing*, UbiComp '08, ACM (New York, NY, USA, 2008), 54–63.
8. Csikszentmihalyi, M. *The meaning of things: domestic symbols and the self*. Cambridge University Press, Cambridge, 1981.
9. Gasser, R., Brodbeck, D., Degen, M., Luthiger, J., Wyss, R., and Reichlin, S. Persuasiveness of a mobile lifestyle coaching application using social facilitation. In *Proceedings of the First International Conference on Persuasive Technology for Human Well-being*, PERSUASIVE'06, Springer-Verlag (Berlin, Heidelberg, 2006), 27–38.
10. Hartnett, J., Lin, P., Ortiz, L., and Tabas, L. A responsive and persuasive audio device to stimulate exercise and fitness in children. In *CHI '06 extended abstracts on Human factors in computing systems - CHI EA '06* (2006), 1837.
11. Jacoby, S., and Buechley, L. Drawing the electric: Storytelling with conductive ink. In *Proceedings of the 12th International Conference on Interaction Design and Children*, IDC '13, ACM (New York, NY, USA, 2013), 265–268.
12. Jafarinaimi, N., Forlizzi, J., Hurst, A., and Zimmerman, J. Breakaway: An ambient display designed to change human behavior. In *CHI '05 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '05, ACM (New York, NY, USA, 2005), 1945–1948.
13. Kay, M., Choe, E. K., Shepherd, J., Greenstein, B., Watson, N., Consolvo, S., and Kientz, J. A. Lullaby: A capture & access system for understanding the sleep environment. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing*, UbiComp '12, ACM (New York, NY, USA, 2012), 226–234.
14. Klasnja, P., Consolvo, S., and Pratt, W. How to evaluate technologies for health behavior change in hci research. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '11, ACM (New York, NY, USA, 2011), 3063–3072.
15. Kuznetsov, S., and Paulos, E. Rise of the expert amateur: Diy projects, communities, and cultures. In *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries*, NordiCHI '10, ACM (New York, NY, USA, 2010), 295–304.

16. Lee, G., Tsai, C., Griswold, W. G., Raab, F., and Patrick, K. Pmeb: A mobile phone application for monitoring caloric balance. In *CHI '06 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '06, ACM (New York, NY, USA, 2006), 1013–1018.
17. Lim, B. Y., Shick, A., Harrison, C., and Hudson, S. E. Pediluma: Motivating physical activity through contextual information and social influence. In *Proceedings of the Fifth International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '11, ACM (New York, NY, USA, 2011), 173–180.
18. Lin, J. J., Mamykina, L., Lindtner, S., Delajoux, G., and Strub, H. B. Fish'n'steps: Encouraging physical activity with an interactive computer game. In *Proceedings of the 8th International Conference on Ubiquitous Computing*, UbiComp'06, Springer-Verlag (Berlin, Heidelberg, 2006), 261–278.
19. MacLean, D., Roseway, A., and Czerwinski, M. Moodwings: a wearable biofeedback device for real-time stress intervention. In *PETRA*, F. Makedon, M. Betke, M. S. El-Nasr, and I. Maglogiannis, Eds., ACM (2013), 66.
20. Maitland, J., Siek, K. A., and Chalmers, M. Persuasion not Required: Obstacles Faced by Low-Income Caregivers to Improve Dietary Behaviour. In *3rd International Conference on Pervasive Computing Technologies for Healthcare 2009* (2009), 1–8.
21. Mellis, D. A., Jacoby, S., Buechley, L., Perner-Wilson, H., and Qi, J. Microcontrollers as material: Crafting circuits with paper, conductive ink, electronic components, and an "untoolkit". In *Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction*, TEI '13, ACM (New York, NY, USA, 2013), 83–90.
22. Morris, M. E., Kathawala, Q., Leen, T. K., Gorenstein, E. E., Guilak, F., Labhard, M., and Deleeuw, W. Mobile therapy: case study evaluations of a cell phone application for emotional self-awareness., 2010.
23. Norman, D. *The Design of Everyday Things*. Basic Books, 2002.
24. Norton, M. I., Mochon, D., and Ariely, D. The "IKEA effect": When labor leads to love. Tech. Rep. 11-091, Harvard Business School, 2011. http://ssrn.com/abstract=1777100.
25. Qi, J., and Buechley, L. Electronic popables: Exploring paper-based computing through an interactive pop-up book. In *Proceedings of the Fourth International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '10, ACM (New York, NY, USA, 2010), 121–128.
26. Qi, J., and Buechley, L. Animating paper using shape memory alloys. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, ACM (New York, NY, USA, 2012), 749–752.
27. Rogers, Y., Hazlewood, W. R., Marshall, P., Dalton, N., and Hertrich, S. Ambient influence: Can twinkly lights lure and abstract representations trigger behavioral change? In *Proceedings of the 12th ACM International Conference on Ubiquitous Computing*, Ubicomp '10, ACM (New York, NY, USA, 2010), 261–270.
28. Toscos, T., Faber, A., An, S., and Gandhi, M. P. Chick clique: Persuasive technology to motivate teenage girls to exercise. In *CHI '06 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '06, ACM (New York, NY, USA, 2006), 1873–1878.
29. Ward, B. W., and Schiller, J. S. Prevalence of multiple chronic conditions among US adults: estimates from the National Health Interview Survey, 2010. *Preventing chronic disease 10* (Jan. 2013), E65.