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Health Craft: A Computational Toolkit for Motivating Health Awareness in Children

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Health Craft: A Computational Toolkit for Motivating Health Awareness in Children

by

Swaminathan Ananthanarayan

B.S., Rensselaer Polytechnic Institute, 2001
M.S., University of Colorado Boulder, 2010

A thesis submitted to the
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Department of Computer Science

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Health Craft: A Computational Toolkit for Motivating Health Awareness in Children
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The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

IRB protocol #12-0429
Swaminathan Ananthanarayan, (Ph.D., Computer Science and Cognitive Science)

Health Craft: A Computational Toolkit for Motivating Health Awareness in Children

Thesis directed by Prof. Michael Eisenberg

Children are increasingly at risk for a vast array of health problems. The rise in obesity has opened the door to life threatening chronic conditions such as diabetes, high blood pressure, and depression. In many ways, these problems are reflective of major changes in children’s lifestyles over the past 30 years. The rise of fast-food and an increase in sedentary play has led to poor dietary habits and a decrease in physical activity. Therefore, helping children become conscious of their health related decisions is crucial to our future. Since children are increasingly comfortable with technology at younger ages, researchers have started exploring its role in motivating healthy behaviors. Within the span of a few years, a burgeoning landscape of wearable and mobile health technologies have emerged; these technologies have focused on delivering pre-built or off-the-shelf solutions in the form of activity trackers or fitness applications. While these solutions have had some measure of success, there is also evidence to suggest that children are not adopting the types of fitness implements that adults find useful. In our work, we offer an alternative view, where health technology is not defined in terms of products to purchase and use, but rather in a way that integrates craft and healthful activities. We introduce a toolkit of ambient and wearable computing where children can craft their own personal visualizations of health. Specifically, children can use the toolkit to craft a wearable device that tracks a particular health or wellness metric and wirelessly relay that information to a set of ambient computationally enhanced building blocks. These blocks abstract the wearable sensor data into a variety of feedback modalities such as light, sound and movement. Thus, children can create different health visualizations by combining these blocks in highly personalized and expressive ways. We conducted three user studies with early adolescents to evaluate our approach. We discovered that children were less responsive to adult notions of health and preferred to track self-selected wellness habits such as reading and sketching. The idea of
crafting health technologies was well received by children, with participants creating an electronic health mural to reflect their self-selected behaviors. More importantly, over time, we observed a few participants taking small steps towards self-regulation. The results suggest that craft could potentially serve as a gateway to healthful thinking in children.
Dedication

To all the teachers who have shaped me over the years.
Acknowledgements

I feel very fortunate to have found both Mike Eisenberg and Katie Siek during my academic tenure. Katie convinced me to pursue my graduate studies and helped me understand the value of organization and structure. Her candid feedback and guidance were invaluable to my growth. In Mike, I found a truly gifted scholar, a wonderfully warm and supportive person, and a kindred spirit. His depth of thought and insight changed my perspective on research. I am especially thankful to the Craft Technology Lab, particularly Ann Eisenberg, for providing such fertile ground for all my unusual explorations; without her the lab would fall apart. To all my lab mates in the past (Chris Schaefbauer, Danish Khan, Ben Leduc-Mills, Nwanua Elumeze) and present (Hyunjoo Oh, Jeeun Kim), I owe a debt of gratitude for always lending me a helping hand and keeping me on track. A special thanks to Jeff Hoehl for helping me sound out ideas and giving me excellent suggestions. The amazing undergraduate students I have worked with over the years—Miranda Sheh, Alice Chien, Nathan Lapinski, Thomas Erickson—also deserve special thanks for their assistance. I am thankful to my committee members for providing insightful feedback and advise. The Gold Crown staff—Anna, Galen, Victor, Adrian, Fran—were invaluable during the user studies. I am also grateful to Amy Le for being incredibly patient and supportive during my graduate studies. To my family, I am forever indebted; without their love and support, none of this would have been possible. Finally, I would like to thank the National Science Foundation (Award No IIS-1231645) for funding my research.
## Contents

### Chapter

1. **Introduction**  
   1.1 Overview of Dissertation  

2. **Related Work**  
   2.1 Consumer Health Technologies  
   2.2 Academic Health Technologies  
   2.3 Ambient and Tangible Visualizations  
   2.4 Health and Electronic Crafting  
   2.5 Theoretical Foundations  

3. **System Design**  
   3.1 Framework  
   3.2 Wearable Base  
   3.2.1 First Iteration: Off-the-shelf Components  
   3.2.2 Second Iteration: Protoboards  
   3.2.3 Third Iteration: Custom PCB  
   3.3 Ambient Modules  
   3.3.1 Construction Methods  
   3.4 Communication Protocols  
   3.5 Programming Environment
3.6 Illustrative Examples .................................................. 30
  3.6.1 Lotus Blossom ................................................... 30
  3.6.2 Terra Cotta Water Fountain ................................. 31
  3.6.3 Origami Windmills ............................................ 32
  3.6.4 Cherry Blossom Tree ........................................ 33

4 Evaluation Approach .................................................. 35
  4.1 Ages & Stages ...................................................... 36
  4.2 Health Behavior Change .......................................... 37
  4.3 Studies Overview ................................................ 38

5 Study 1: System Test .................................................. 39
  5.1 Participants ....................................................... 39
  5.2 Methods ........................................................ 39
  5.3 Results .......................................................... 40
  5.4 Discussion ....................................................... 45

6 Study 2: Reflections on Health and Crafting ...................... 48
  6.1 Study Location ................................................... 48
  6.2 Participants ...................................................... 49
  6.3 Methods ........................................................ 49
  6.4 Results .......................................................... 51
    6.4.1 Children’s Health Perspectives ........................ 51
    6.4.2 Participant Mockups ...................................... 52
  6.5 Discussion ....................................................... 56

7 Study 3: Field Trial .................................................... 59
  7.1 Study Location ................................................... 59
  7.2 Participants ...................................................... 60
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.3 Methods</td>
<td>61</td>
</tr>
<tr>
<td>7.4 Results</td>
<td>62</td>
</tr>
<tr>
<td>7.4.1 Initial Brainstorming Sessions</td>
<td>63</td>
</tr>
<tr>
<td>7.4.2 Notions of Health</td>
<td>64</td>
</tr>
<tr>
<td>7.4.3 Health Mural</td>
<td>66</td>
</tr>
<tr>
<td>7.4.4 Wearables</td>
<td>68</td>
</tr>
<tr>
<td>7.4.5 Crafting and Programming</td>
<td>72</td>
</tr>
<tr>
<td>7.4.6 System Usage</td>
<td>73</td>
</tr>
<tr>
<td>7.4.7 One Month Follow-up</td>
<td>75</td>
</tr>
<tr>
<td>7.5 Discussion</td>
<td>76</td>
</tr>
<tr>
<td>7.5.1 Is it Really Health?</td>
<td>76</td>
</tr>
<tr>
<td>7.5.2 Wearable Device Design: Context and Automation</td>
<td>77</td>
</tr>
<tr>
<td>7.5.3 Personal Valuation and Meaning</td>
<td>78</td>
</tr>
<tr>
<td>8 Study 4: Case Studies</td>
<td>80</td>
</tr>
<tr>
<td>8.1 Study Location</td>
<td>80</td>
</tr>
<tr>
<td>8.2 Participants</td>
<td>81</td>
</tr>
<tr>
<td>8.3 Methods</td>
<td>81</td>
</tr>
<tr>
<td>8.4 Results</td>
<td>82</td>
</tr>
<tr>
<td>8.4.1 Marvin</td>
<td>84</td>
</tr>
<tr>
<td>8.4.2 Lisa</td>
<td>87</td>
</tr>
<tr>
<td>8.4.3 Macey</td>
<td>91</td>
</tr>
<tr>
<td>8.4.4 Spencer</td>
<td>95</td>
</tr>
<tr>
<td>8.4.5 eCrafting Survey</td>
<td>99</td>
</tr>
<tr>
<td>8.5 Discussion</td>
<td>102</td>
</tr>
<tr>
<td>8.5.1 Engaging Children in Health</td>
<td>102</td>
</tr>
<tr>
<td>8.5.2 Public and Social Health Crafting</td>
<td>103</td>
</tr>
</tbody>
</table>
8.5.3 Binary Measures ......................................................... 104

9 Discussion ................................................................. 105

9.1 Self-selected Behaviors ............................................... 106

9.2 Building Blocks for Healthful Thinking ............................. 106

9.3 A Trojan Horse Approach to Health Technology Design ........ 108

9.4 Designing for Flexible Usage ......................................... 109

9.5 Supporting Creativity in Health Maintenance ...................... 110

9.6 “Pleasantly Frustrating” Experiences ............................... 111

10 Future Work ............................................................... 113

10.1 Hardware Platform .................................................... 113

10.2 Programming Environment .......................................... 114

10.3 Health Education ...................................................... 115

11 Conclusion ........................................................................ 116

Bibliography ........................................................................ 118

Appendix

A Wearable Base Schematic and Board .................................. 126

B Ambient Modules Schematics and Boards ......................... 128

C Using a Desktop Vinyl/Paper Cutter to Cut Copper Circuits .. 133

D Background Questionnaire ................................................. 140

E Study 4: Background Interview Questions ............................ 144
F  eCrafting Pre-Survey  146

G  eCrafting Post-Survey  149

H  Study 4: Tinker Time Interview Questions  152
Tables

Table

2.1 Wearable activity trackers in the consumer market ............................................. 9

3.1 AVR fuse settings for ATmega328P ................................................................. 21

3.2 Typical power consumption of wearable tracker ................................................. 21

3.3 Battery life based on sleep duration ................................................................. 22

7.1 Study 3 participant details ................................................................................. 65

8.1 Study 4 participant demographics ................................................................. 81

8.2 Mural artifacts created by 4 participants in study 4 .............................................. 83
Figures

Figure

2.1 Misfit Shine Wearing Locations ........................................ 8

3.1 System diagram for wearable and ambient devices .................... 17

3.2 First iteration of the wearable tracker .................................. 19

3.3 Second iteration of the wearable tracker ................................ 20

3.4 Third iteration of the wearable tracker ................................ 23

3.5 Wearable kit with microcontroller base, sensors, and case .......... 23

3.6 Ambient paper based modules for visualizing health data .......... 25

3.7 Early paper circuit block with 2.5mm copper traces ................. 26

3.8 RGB LED module constructed using silver ink circuit printer ....... 27

3.9 Packet structure for ambient nodes ................................... 28

3.10 Arduino IDE modified to support health craft construction kit .... 29

3.11 Paper based lotus blossom with RGB module ....................... 30

3.12 Terra cotta water fountain with motor module ..................... 31

3.13 Three origami windmills utilizing motor modules .................. 32

3.14 Electronic cherry blossom painting utilizing LED modules ....... 33

4.1 Simple paper circuits for instruction and demos ..................... 36

5.1 UV wearable device crafted into messenger bag ..................... 41

5.2 UV wearable device crafted into a fox themed headband ........... 42
5.3 Outdoor exposure in minutes for 7 days (5 participants) .......................... 43
6.1 Origami cranes intended to track physical conditioning exercises .................. 53
6.2 Ambient chains intended to track outdoor activity ................................. 54
6.3 Ambient wallpaper based visualizations for outdoor play ......................... 54
6.4 An wearable sleep bracelet to track quality of sleep .............................. 55
7.1 Communal poster for brainstorming mural ideas .................................. 63
7.2 Artistic brainstorming of mural themes ............................................... 64
7.3 Electronic health mural created using ambient modules ......................... 66
7.4 Pencil pouch flower for tracking coloring/drawing habits ....................... 68
7.5 Sports themed book that houses a wellness tracker ............................... 69
7.6 A panda bear backpack accessory for tracking playing time .................. 70
7.7 A “guitar hand” backpack accessory for tracking music playing habits .... 70
7.8 Wearable tracker stored in a bag and in a pocket ................................. 71
8.1 Updated version of the electronic health mural created in study 3 ............. 83
8.2 Marvin’s fire breathing dragon with RGB module ............................... 85
8.3 Marvin’s guitar playing punch card graph ........................................ 86
8.4 Marvin’s accelerometer based activity tracker .................................... 86
8.5 Marvin’s physical activity bar graph ................................................ 87
8.6 Lisa’s Tweety bird using the sound module ....................................... 89
8.7 Lisa’s flower accessory with button tracker ...................................... 90
8.8 Lisa’s knitting punch card for 4 weeks .......................................... 90
8.9 Lisa’s knitting activity bar graph .................................................. 91
8.10 Macey’s push tooth doll with button tracker .................................... 93
8.11 Macey’s skull with RGB LED module .......................................... 93
8.12 Macey’s teeth brushing punch card for 4 weeks ................................ 94
8.13 Macey’s brushing activity bar graph ........................................... 95
8.14 Spencer’s RGB LED lantern and associated button tracker ................. 97
8.15 Spencer’s reading punch card for 4 weeks .................................. 98
8.16 Spencer’s reading bar graph for 4 weeks .................................. 98
8.17 Marvin’s eCrafting pre and post survey results ............................ 100
8.18 Lisa’s eCrafting pre and post survey results ............................... 100
8.19 Macey’s eCrafting pre and post survey results ............................ 101
8.20 Spencer’s eCrafting pre and post survey results ............................ 101

10.1 Ardublock graphical programming environment .......................... 114

A.1 Schematic view of wearable base ............................................. 126
A.2 Board view of wearable base (Top layer) .................................. 127
A.3 Board view of wearable base (Bottom layer) .............................. 127

B.1 Schematic of motor module .................................................. 128
B.2 Board view of motor module (top and bottom layers) ..................... 129
B.3 Schematic of sound (piezo) module ....................................... 129
B.4 Board view of sound (piezo) module (top layer) ........................ 130
B.5 Schematic of RGB LED module ........................................... 130
B.6 Board view of RGB LED module (top layer) ............................. 131
B.7 Schematic of vibration motor module .................................... 131
B.8 Board view of vibration motor module (top and bottom layers) ....... 132

C.1 Circuit image for RGB module ............................................. 134
C.2 Selecting the trace function in Silhouette Studio ........................ 135
C.3 Tracing the circuit in Silhouette Studio .................................. 135
C.4 Outline of traced circuit ................................................... 136
C.5 Outline of traced circuit with original image removed ................. 137
C.6 Craft cutter loaded with copper sheet ........................................... 137
C.7 Silhouette Studio cut settings ................................................................. 138
C.8 Copper trace transfer process ................................................................. 139
Chapter 1

Introduction

Increasingly, our children are facing a broad range of health problems that were not commonly seen until adulthood. In the past three decades, obesity has tripled among children and adolescents [15]. This has opened the door to life threatening chronic conditions such as diabetes, high blood pressure and elevated cholesterol levels [37, 26]. Moreover, obese children tend to be obese adults [9]. Apart from the physical health issues they face, a recent report by the CDC suggests that mental disorders among children are also on the rise [76]. Needless to say, instilling health awareness and “healthful thinking” in children are more essential than ever.

Part of the problem is that there have been major changes in children’s lifestyles over the past 30 years. Kids now consume more fast-food and sugar-loaded beverages and spend less time enjoying family meals than they did in the past [32]. To make matters worse, $1.6 billion is spent annually on food advertising directed to children and adolescents [18]. The end result is poor dietary habits.

Concurrently, there has been a marked decrease in physical activity for both children and adults. Increasingly, children are driven by car or take the bus instead of walking or biking to school [60]. This is exacerbated by an increase in “screen time” as children spend more time watching television, using tablets, or playing videogames instead of engaging in physical activity outside. Cultural historian Steven Mintz noted in his book on American childhood this gradual shift over the past century in childrens lifestyles from outdoors to bedrooms, and from improvised toys to fantasy toys [65]. These shifts have led to an increase in sedentary, electronically mediated
play and a decline in unstructured play [65]. Fundamentally, what we are faced with are health issues, but they are issues that are tightly knit with present culture. Our goal therefore is to perturb and counteract prevalent culture.

Since children are increasingly comfortable with technologies such as mobile phones, portable music players, and tablet computers at a much younger age, a natural starting point for researchers is to explore the role of technology in encouraging healthy behaviors. In recent years, the idea of using technology for promoting general health and wellness has certainly come to fruition for adults. Due to the high penetration, low cost, and small form factors of technologies such as mobile phones and wearable sensors, the average consumer has available numerous activity trackers (e.g., FitBit) and mobile phone health applications (e.g., MyFitnessPal) for adopting and sustaining healthy behaviors. The increasing prevalence of these technologies have even given rise to movements such as the *quantified self* movement, where individuals regularly track all aspects of their lives from food consumed to quality of surrounding air. Although health technologies on the consumer side have only been in the forefront for a few years, researchers have long been exploring their use for a variety of health goals from physical activity [54, 19] and diet [43, 29] to sleep [42, 5].

In the past few years, these general health and wellness technologies have started making their way to children. Activity trackers coupled with online gaming and rewards platforms (e.g., Sqord, iBitz, Striiv) are now available on the consumer market for kids. Increasingly, there are also motion gaming consoles such as Microsoft Kinect, Nintendo Wii, Sony PlayStation Move that utilize motions based on player movements to interact with characters on-screen. Many researchers have used these commercial activity trackers and motion consoles to create exertion interfaces [7, 36] and to test social theories of behavior change with children [63, 92].

These commercial health technologies and research platforms are enjoying some measure of success with children, especially when designed with social and peer support in mind [63]. However, there is also evidence to suggest that kids are not naturally taking to the types of fitness implements that adults commonly use. In a recent Northwestern University study on teens’ use of technology for health, they found that only 7% of teens used wearable health devices and only 1% reported any
behavior change from their use [94]. In focus group conversations from the same study, researchers found that teens considered such devices as an “adult thing.” A 11th-grade female from the focus group reported, “I got the FitBit for Christmas and wore it for a while and the bracelet fit my wrist weird and hurt. I was like forget it and then I stopped using it. Also it’s not cute and it’s just kind of weird and mostly males use it. All my friends’ dads have it and I’m like thank God I don’t wear that anymore” [94].

It seems that what is needed is a different way of thinking about health technologies for children. In our work, we offer an alternative view, where craft, an activity that is already a part of children’s culture, is integrated with health. In this “you build it” approach to health technology, the emphasis is on personal expressiveness, construction, and health education through craft. Essentially, what we are proposing is a new type of craft, a health craft, where children can build their own personal meaningful visualizations of health. In order to empower children towards this goal, we introduce a system of ambient and wearable components. The components in the system include sensors, microcontrollers, and various embedded electronics packaged in a plug-and-play fashion that abstract away the necessary electronics knowledge. These components serve as the building blocks for empowering children towards healthful thinking by providing a framework for designing health input and presentation technologies.

Ten years ago, the concept of children building their own health technologies might have seemed far fetched. However, recent advances in open source electronic platforms (e.g., Arduino, Raspberry Pi, Little Bits) and personal fabrication (e.g., Makerbot), has facilitated the rise of the DIY and Maker movements. As a result, disciplines that have typically been separate have blended to create hybrid practices. The confluence of craft and electronics is one noteworthy example; common craft materials have come to serve as mediums for traditional electronics [61] and electronics in turn have been designed for specific crafting purposes [12].

As a consequence of these advances, we are at a point where we can democratize health technologies. Thus, health technologies can become more expressive, individually meaningful and even aesthetically appealing. And craft technology can explore novel problems, information spaces,
and applications by being applied to the realm of health and wellness. It is in this burgeoning landscape of *health crafting* that we are interested in seeding, with particular attention to children-centered design, guided by insights from computational and cognitive science.

This thesis represents the first exploratory steps in the union of craft and health. Some of the guiding questions of our work include:

- How do we design wearable and ambient components for monitoring and visualizing health that are easy to build for children?
- What kind of representations and interactions helps children visualize health and wellness?
- How do children use our system? How does the act of crafting health systems influence children’s perceptions and health awareness?

To answer these questions, we prototyped a wearable and ambient health toolkit for children. The wearable toolkit is comprised of a low power microcontroller base which connects to swappable sensor modules (UV sensor, button, accelerometer). The microcontroller, tracks time, logs sensor data and can run on a single coin cell battery for multiple weeks. It is also capable of wirelessly communicating sensor data to a set of ambient computationally enhanced blocks. The ambient blocks include: 1) RGB LED, 2) DC motor, 3) Piezo speaker, 4) Vibration motor. These blocks abstract the information from the wearable and present them to the child using a variety of feedback modalities such as light, sound, or movement. Thus, children can create different health visualizations by combining and crafting these blocks in unique highly personalized ways.

To evaluate the health crafting approach, we conducted four user studies, one with a college population and three with children aged between 11-14. In the first user study, we conducted a week-long system test with five college students, where they crafted a UV tracker into one of their daily accessories and used it for seven days. The tracker communicated with an electronic cherry blossom visualization (created with our ambient modules) where the blossoms increasingly illuminated as participants spent more time outside. Overall, the results of study were encouraging, with participants receptive to the idea of crafting and the cherry blossom serving as a scaffold for
fostering creativity. Moreover, the UV tracker worked well as a standalone low-power device without human intervention for an extended period of time.

In the second user study, we conducted a 90 minute needs assessment workshop with 8 children to gather their perceptions of health and their ideas on crafting health technologies. In addition to semi-structured interviews, children created tangible mock-ups of wearable and ambient devices for tracking self-selected health metrics. The results were promising; the idea of crafting wearable devices was favorably received. Children’s self-perceptions of health were remarkably positive despite the fact that we were working with an at-risk population. More importantly, participants seemed less responsive to adult notions of physical activity. The majority of children created health visualizations that were ambient in nature. This study helped us identify the four ambient modules we later designed.

The third study was a full 6-week field trial of our ambient and wearable toolkits. In this field trial, we explored health crafting in practice with 9 children as part of an after school clubhouse. Participants created a health mural where aspects of the mural responded to each child’s wearable device. The majority of children typically chose health measures outside of diet and physical activity. We also observed that participants who invested more time crafting their wearable also used it to a greater extent when compared to their less devoted counterparts. These participants either had a clear sentimental attachment to the device or contextually crafted the device so it was convenient to use. Children generally had a tendency to use the wearable more the day they attended the clubhouse.

In the fourth study, we conducted an in-depth 2-month evaluation of our toolkit with 4 participants. Children crafted their wearables and visualizations for 3 weeks and evaluated them for 5 weeks. While we expected participants to build separate individual visualizations, three of the four participants continued working on the mural from the previous study. These participants were more interested in the public and social nature of crafting. Children chose to monitor self-selected habits including reading, knitting, dental brushing, guitar playing and physical activity. More importantly, we observed participants moving towards self-regulatory behavior.
1.1 Overview of Dissertation

The rest of the dissertation is organized as follows: Chapter 2 describes related work and the theoretical foundations of our research. We explore health and wellness technologies developed by industry and academia followed by a discussion of influential ambient and tangible visualizations. We then highlight the craft technology origins from where our work derives, and the constructionist foundation on which our work clearly rests. Chapter 3 provides a detailed technical description of the wearable and ambient modules as well as the framework on which they are based. We also showcase four illustrative examples built using the system. Chapter 4 discusses our evaluation approach, particularly, our rationale for choosing early adolescents as well as why behavior change is a prohibitive metric for exploratory work. Chapters 5, 6, 7, 8 detail the studies we briefly summarized earlier. We then explore several key themes that have emerged from our experiences and observations in Chapter 9. Chapter 10 provides a vision for immediate future work on our system as well as a more expansive vision of possibilities inherent in health crafting. Finally, Chapter 11 ends the thesis with concluding thoughts.
Chapter 2

Related Work

There are several strands of research that have strongly influenced the design and motivation of our work. In many ways, the idea of health crafting is only possible because of recent growth in the maker movement and the rise of personal health technologies. It is because of these parallel advances that our ideas sound less ambitious than they would have ten years ago. In the subsequent sections, we examine a subset of prior work, including consumer health and wellness technologies, academic research in personal health technologies, ambient and tangible visualizations, the maker movement with respect to health and electronic crafting, and the theoretical underpinnings that guided our approach.

2.1 Consumer Health Technologies

In recent years, health and wellness technologies in the consumer space have seen meteoric growth. The activity trackers available today are a testament to advances in low cost, low power sensors and computing platforms. While some of the first wearable devices might have seemed bulky and less capable of integrating into people’s lifestyles, some of the newer activity trackers such as the Misfit Shine (misfit.com) are designed like jewelry and can accommodate being worn in a variety of configurations (Figure 2.1). The increasing prevalence of these on-the-body sensing technologies have 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.
In this section, we concentrate on general (non-medical) health and wellness technologies since it is closer in line to our own work. Table 2.1 summarizes several prominent offerings in the consumer space. It is divided into two sections (denoted by the double line of demarcation) with technologies for adults and children respectively occupying the top and bottom halves. The majority of wearable systems in the consumer market employ a 3-axis accelerometer to detect physical activity, although a few (e.g., Basis, BodyMedia Fit) utilize other sensors to detect heart rate, perspiration and temperature. Typically, these devices provide a small on-demand visual display or vibrotactile feedback, however because of power constraints, they primarily serve to gather data to transmit to smart phones or online applications.
<table>
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<th>Sensing</th>
<th>Feedback</th>
<th>Form Factor</th>
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<td>Physical activity, sleep</td>
<td>LED display</td>
<td>Bracelet</td>
</tr>
<tr>
<td>Fitbit (fitbit.com)</td>
<td>Physical activity, sleep</td>
<td>OLED display, vibrotactile</td>
<td>Clip or bracelet</td>
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<td>LED indicators</td>
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<td>Physical activity, sleep</td>
<td>Vibrotactile</td>
<td>Bracelet</td>
</tr>
<tr>
<td>Withings Pulse (withings.com/en/pulse)</td>
<td>Physical activity, heart rate, sleep</td>
<td>OLED display</td>
<td>Clip or Bracelet</td>
</tr>
<tr>
<td>Basis (mybasis.com)</td>
<td>Physical activity, heart rate, perspiration, skin temperature, sleep</td>
<td>LCD</td>
<td>Bracelet</td>
</tr>
<tr>
<td>Larklife (lark.com)</td>
<td>Physical activity, sleep</td>
<td>LED indicators, vibrotactile</td>
<td>Bracelet</td>
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<td>OLED display</td>
<td>Clip</td>
</tr>
<tr>
<td>Microsoft Band (microsoft.com/microsoft-band)</td>
<td>Physical activity, heart rate, sleep, UV monitor, skin temperature, perspiration</td>
<td>AMOLED display</td>
<td>Bracelet</td>
</tr>
<tr>
<td>Leaf (bellabeat.com)</td>
<td>Physical activity, sleep</td>
<td>Vibrotactile</td>
<td>Adaptive</td>
</tr>
<tr>
<td>Sqord (sqord.com)</td>
<td>Physical activity</td>
<td>Online social network</td>
<td>Bracelet</td>
</tr>
<tr>
<td>Agoyo, I ♥ jellyfish (agoyo.com)</td>
<td>Heart rate</td>
<td>Mobile application</td>
<td>Patch</td>
</tr>
<tr>
<td>Ibitz by GeoPalz (ibitz.com)</td>
<td>Step count</td>
<td>Mobile application</td>
<td>Clip</td>
</tr>
<tr>
<td>Zamzee (zamzee.com)</td>
<td>Physical activity</td>
<td>Online game</td>
<td>Clip</td>
</tr>
</tbody>
</table>

Table 2.1: Wearable activity trackers in the consumer market

In terms of technology, the activity trackers for children are not considerably different from those for adults. The primary difference is in the mobile or online application that is paired with the device. Sqord, for example, employs an online application where kids can create their own avatar to earn medals and points in an socially networked system. Similarly, Agoyo connects the bioluminescence of a virtual jellyfish to an individual’s heart rate. In a skillful combination of heart beats per minute and mobile phone tilts, the player steers their way through an aquatic world with obstacles and challenges. While a majority of health interventions for children present themselves as games, a few such as Zamzee (zamzee.com) and Geopalz (geopalz.com) utilize a wearable tracker with an online rewards platform. Children, in this case, use points earned from physical activity
to buy various prizes and items at online stores.

While existing devices in the consumer market have enjoyed some measure of success, there is growing skepticism regarding these technologies and their ability to inspire and sustain health habits [34]. A recent white paper by a market consulting firm suggests that a third of all Americans who purchased a wearable self-monitoring product abandoned it after 6 months of use [50]. A subsequent study found that the most common reason for abandonment was a mismatch between users’ expectations and the capabilities of the device [16]. The authors highlight, “[Our results] suggests that personal health-tracking technologies are used in complex dynamic social environments and need to fit within individuals existing, messy practices.” They further suggest more grounded approaches for engaging individuals in the analysis of data collected through self-monitoring. We feel our health crafting work is one such approach where users can play an active role in developing health data visualizations. Although we focus on children, our ideas on personal, individually meaningful, and crafted health technologies can be extended beyond a target population.

### 2.2 Academic Health Technologies

In many ways, academic research into general health technologies predates work in the consumer space. Researchers have examined wearable and mobile health technologies for encouraging general physical activity [2, 19, 54], supporting exercise routines [69, 23, 8], improving sleep [42, 5], supporting healthy diets [29, 51], lowering stress [57] and self-regulating emotions [66, 14]. Some of the outcomes and visualizations have even been integrated into commercial devices. For example, the Fitbit pedometer shows a flower growing in response to increased step counts; this idea was originally pioneered by the UbiFit Garden project which had a similar visualization [20].

Although much of the work in promoting healthy lifestyles has been with adults, in recent years, researchers have started examining health technologies for children, specifically in the areas of diet and physical activity. Perhaps the most common device appropriated for promoting physical activity in children has been the pedometer. Persuasive Audio, for example, used a simple pedometer to control and vary music tempo based on activity level [33]. It delivered increased
exercise under the guise of fun and recreation. Chick Clique [92] on the other hand, leveraged community and social interaction among a group of 4 girls to motivate higher step counts. While the girls in the study felt supported and motivated by their friends, such small-group systems may be challenging to scale. To address the scalability issue, the researchers behind StepStream [63], developed a pedometer based microblog for a school-based fitness program. They found that their technology mediated social support system enabled a sense of non-competitive collective purpose towards physical activity.

Other adolescent health technologies in HCI have focused on incorporating a gaming element into their systems. Snack Educator [43] for example, aimed to improve the snacking habits of low socioeconomic children through a set of playful and culturally sensitive mobile phone games. In the realm of physical activity promotion, Berkovsky et al.’s Play Mate! system [7], leveraged a Nintendo Wii console to sense players’ movements and move an on-screen marble through a 3D world. Although these types of exertion interfaces [68] were originally developed for adults, they have been increasingly used to motivate children since the release of gaming platforms such as Nintendo Wii, Microsoft Kinect, and PlayStation Move. In an early international survey, researchers found that teenagers who played a popular dance game (Dance Dance Revolution) were motivated to exercise, improved their body image, and lost weight [36].

In many ways, work in health technologies has become a staple of HCI literature, with some papers even focusing on how best to evaluate the outcomes [45]. We certainly see our own work as part of this rich tradition, however, rather than focusing on a particular health outcome, such as increased physical activity or improved snacking, our goal is to empower a child towards healthful thinking. In this perspective, we see health as a self-discovery and self-learning process. Our aim is to accomplish this through craft, an activity that is already a part of children’s culture. Personal crafted health technologies could become meaningful possessions that could enrich a child’s sense of narrative history. Technology in this case, is capable of having sentimental or autobiographical significance. It is in this aspect that the blending of craft and health might prove to be a valuable contribution.
2.3 Ambient and Tangible Visualizations

One of the goals of the health crafting approach is to help children in creating aesthetic, meaningful health data representations. In this respect, we were guided by the concept of “ambient influences” [83], where the invisible is made visible through a fun, aesthetic compelling display that not only raises awareness but also presents information in an intuitive abstraction. A good example of this concept in the health technology domain is Fish ‘n’ Steps [55], where user step counts from pedometers were mapped to the growth and emotional state of virtual fish in a fish-tank (much like the Agoyo bioluminescence jellyfish discussed in Section 2.1). The virtual fish served as an aesthetic anthropomorphic avatars to relay health information. Similarly, the designers behind UbitFit [20] associated physical activity information from their hip-worn device to the growth of a virtual garden on a mobile phone. It is this kind of work where the aim is to make health information more salient to the user, that has subsequently set the stage for the kind of intuitive abstractions that our research seeks to produce. Except rather than define these abstractions ourselves, we envision a goal where the children are the designers of these health representations. Thus, children are not limited by the ideas of researchers and designers and are free to create wearable and ambient technologies more diverse and innovative than what we can imagine.

The majority of existing approaches to health and wellness technologies target the virtual medium. Although, these screen based interfaces support dynamic data updates and favorable data visualization constructs, they focus primarily on the visual and auditory system. As Ullmer and Ishi point out these virtual interfaces often neglect the other senses [93]. While physical objects have long been used for information presentation, they have only recently been adopted for health data. Two recent examples include, SweatAtoms [44], and Activity Sculptures [90]. In both cases, physical activity data was transformed into 3D printed artifacts. The researchers found that material artifacts made participants more conscious of their physical activity involvement. Prior work has also examined the use of tangible metaphors to motivate healthy outcomes. BreakAway [39] employed the body language of a small desktop sculpture to make people aware of their sedentary
lifestyle. In a similar vein, MoodWings [57], utilized a small wearable butterfly to make users aware of their stress levels. In this biofeedback device, a high stress level precipitated a large flap of the wings while a calmer state resulted in a gentle hover.

Specifically for children, Parés’ work on the Interactive Slide [87] and the Interactive Water Installation [75] highlights tangible and interactive playground designs that couple physical activity with social interaction. With the Interactive Slide, children had to slide down at the right time to intercept a moving object projected on the slide. This work was further extended by Landry et al. to encourage specific types of movements in children [48]. The research team identified a game system variable called “Interaction Tempo” that they could use to modulate physical activity in children [49]. In a similar line of research emphasizing interactive play in playgrounds and public spaces, Tieben et al. designed a set of “wiggle benches” that could be wiggled by teenagers [91]. These benches in turn wiggled other benches and controlled a light in the playground space. Researchers have also examined enhancing existing outdoor games such as “capture the flag” with heart rate monitors and handheld devices [58]. In this computer mediated version of the game, a player whose heart rate exceeded a certain threshold automatically received the location of opposing team members. It is important to note that all the public space designs presented here presume that children are already spending time outside. As American historian Steven Mintz highlights, this culture of playing outside has been slowly diminishing over the past century [65] in the United States.

Despite the shift away from unstructured outdoor play, the ambient visualizations and Parés’ playground designs are compelling examples because they blend sensory stimuli, such as sights, sounds, textures, aromas and motion, aspects that are hard to replicate on a mobile phone or computer screen. Moreover, the concreteness of artifacts offers various social affordances that virtual objects typically don’t. Among children for example, tangible objects can be traded, or put on shelf for display.
2.4 Health and Electronic Crafting

Perhaps the most important precursor to our work has been the remarkable growth 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 Lily-Pad Arduino [12] 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. These sites (e.g., instructables.com) often serve as starting points for teachers and children who want to explore a project based approach to learning. Already, within the span of a few years, a variety of child friendly smart construction kits are available, including peel-and-stick electronic circuits for interactive craft [35], sewable electronic modules for wearable systems [40], and magnetic modular electronics for young inventors [6]. These examples follow a rich line [85] of physical computing kits (e.g., PicoCricket, Lego Mindstorms, etc.) that present novel approaches to the construction of tangible, interactive prototypes that require minimal wiring and programming. Our health crafting work is another such general purpose platform, though one aimed for helping children construct their own health technologies.

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 [13, 61]. 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 [77], electronics enriched storytelling with conductive
ink [38], and paper animation with shape memory alloys [78]. Our effort is a direct descendant of work in the craft technology space. We employ and build on existing methods in the design of our health construction kit. Our ambient visualization modules, for example, discussed in Section 3.3, are paper based and utilize copper traces cut using a common desktop craft cutter (Appendix C).

2.5 Theoretical Foundations

Broadly speaking, our work is clearly undertaken in the tradition of “constructionism” pioneered by Seymour Papert and descended from Piaget’s constructivism [74]. Learners in this view are seen as constructors of their own knowledge. Thus, materials and concepts are supposed to help children to construct personally meaningful “objects to think with” that bridge the gap between the sensory and abstract worlds [74]. Moreover, children are likely to become engaged in an activity and learn things from it when they are active and creative participants. An important element of Papert’s philosophy includes the public nature (the presentation and sharing) of artifacts that children create. Simply put, making something to share with others aids children in constructing knowledge.

Papert’s ideas have been particularly influential in the field of child-computer interaction, most notably in the area of computationally enhanced construction kits. Construction kits in this view help children explore important concepts and domains through their expressive activities [81]. The learning objective then is not to “teach” explicitly, but rather to empower children towards real world activities. Papert describes this notion of empowerment as the opposite of “learning by being taught” [73]. Thus, the aim of our work is to offer children potentially rewarding health learning experiences with novel tangible technologies. By health learning, we do not mean the absorbing of health facts, but rather a personal exploration into what it means to be healthy. This paradigm focuses less on adult views of health and more on children’s voices.

The concept of empowerment is important because children often lack direct control of their environment and crafting gives them the opportunity to be producers rather than consumers. In this fundamentally low risk activity, children become active learners in a dynamic learning process that
gives them “freedom of intelligence” [24]. Central to this perspective, is the concept of mediation which allows individuals to modify and interact with their environment through tools. While language has been viewed as the most critical psychological tool, physical artifacts also inform intellectual development as they enable higher mental functions [17]. In our case, the wearable and ambient technology serves as the mediating artifact(s) that guides the development of health awareness. By providing the tools to craft these health technologies, we help children become co-designers of their own health; they decide what they want to track and actively built it. As James Gee suggests, this may be a key part of motivation and may aid in long term adoption of these devices because the created artifacts become infused with personal and cultural meaning [30].

Complementary to Papert’s constructionism are the many sociocultural approaches to learning stemming from Lev Vygotsky’s research in the early 20th century. In these approaches, technology is sometimes seen as a potential scaffold [95] when learning or completing a task. Early work by Soloway et al. for example, explored how software could support learners in scientific investigatory activities normally out of their reach [88]. But more importantly, sociocultural approaches view knowledge as something that is constructed socially in the world rather than individually in the mind [28]. Thus, children are studied in a given socioeconomic and cultural context rather than individually in isolation. Our user studies (specifically studies 3 and 4) reflect this approach.

Health crafting provides a level of personalization that accommodates individual differences where children can express their own personal ideas of health in terms of crafting the wearable device and the associated visualization. This personalization may also facilitate greater adoption of the technology since 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 [70].” This cognitive bias, dubbed the “IKEA effect,” is likely to be true for health crafted technologies as well.
In order to design ambient and wearable computing components that are easily accessible to children with no prior knowledge of electronics, we abstracted away the hardware layers to make modular plug-and-play components. In the following subsections, we discuss the framework for creating a modular health technology ecosystem followed by illustrative examples that showcase the system architecture. It should be noted that the ecosystem is by no means complete. We see our current implementation as part of a larger, burgeoning landscape of health crafting.

3.1 Framework

The framework is comprised of two parts, a wearable wireless device that tracks a particular health metric or habit, and an ambient visualization that reacts to data from the wearable device. Both aspects of the system are modular and craftable. A system architecture diagram for potential
health systems in this domain is shown in Figure 3.1. Essentially, the wearable device tracks time and communicates aggregated sensor data to the ambient visualization wirelessly. Based on the data, the master controller on the visualization issues commands to a set of feedback nodes on a shared serial communication network. These feedback nodes actuate devices such as DC motors, buzzers, LEDs or vibration motors to help visualize the data. A detailed technical discussion of the wearable and ambient modules are provided in sections 3.2 and 3.3.

Before delving into the details, we provide a simple scenario of how a child might use the system to track outdoor exposure and reflect that data in an origami windmill. The child begins by crafting the wearable device with the UV sensor into an accessory that she can carry, attach or wear. Then she crafts the origami windmill utilizing the ambient motor module. Next, she wears or carries the wearable with her and spends a certain amount of time outside. Then as she returns home and approaches the origami windmill the cumulative time spent outside is communicated wirelessly from the wearable to the motor module. In this example, the motor module and thus the origami windmill spins faster as more time is spent outside.

3.2 Wearable Base

Our goal in developing the wearable wireless tracker was to enable children to track a particular health metric or habit through a set of modular sensors. We envisioned an electronic kit where children could plug in a sensor, add a battery, do a bit of programming, and craft the wearable into an artifact of their choosing. From a research perspective, we also wanted a wearable that could reliably and continuously gather data for multi-week studies without much intervention (i.e., battery changes). The wearable tracker has undergone three iterations since the inception of our research.

3.2.1 First Iteration: Off-the-shelf Components

The first prototype of our wearable tracker, shown in Figure 3.2, tracks outdoor exposure using a UV sensor. The design utilized a low voltage (3.3V) Arduino Mini along with a discrete
real-time clock (RTC) module for tracking time and a SD card for storing sensor data. As part of the sensor module, we also integrated a RGB LED to serve as a wearable feedback mechanism. The RGB LED transitioned from red to green as the user spent more time outside. Lastly, we used a 1000 mAh lithium ion battery to power the wearable tracker. In this design, we leveraged as many off-the-shelf components and break-out boards as possible to create a fully functional prototype. However, the resulting implementation consumed too much power. This was in part due to the built-in voltage regulator and the default power LED on the Arduino Mini, both of which while useful for the DIY community, wasted power for our purposes. The separate SD card module also posed a problem, since its power consumption varied widely from 25 mA to 80 mA depending on the manufacturer. While our first implementation served well to showcase our modular design, it was not suited for the rigors of a multi-week study. Moreover, the wearable device was somewhat unwieldy due to its size, weight, and multi-wire connectors. Our first prototype did not feature wireless communication.

3.2.2 Second Iteration: Protoboards

To address the size and power issues, we designed our own Arduino based system on a 2 inch circular protoboard (Figure 3.3). In this iteration, we included an off-the-shelf Nordic
Semiconductor nRF24L01+ radio transceiver for wireless communication. We chose the Nordic transceiver because it was low power, had good sleep modes, and was well supported by the open source community. We also considered using the newer Bluetooth Low Energy (BLE), but it was less widely available during our design phase. In this second version, we moved the UV sensor/RGB display module to a much smaller one inch protoboard to limit the overall size of the wearable. The RGB LED was activated by a push button switch on the microcontroller base. We transitioned to an on-demand display from a persistent display to save power. In this implementation, we used a through-hole (or DIP) version of the same ATmega328P microcontroller used in the Arduino Mini without the voltage regulating circuitry or the external clock crystal. Typically, an external crystal is used to ensure accurate frequency and frequency stability. This is useful for driving communication (e.g., UART, SPI, I2C) at high speeds. However, it is also possible to use the internal 8 MHz resonator (built-in the ATmega328p) accurately with lower communication BAUD rates. In our case, since UART was only used to upload code, we could afford the minor (10%) clock inaccuracy. Using the internal oscillator allowed us to use the two XTAL pins (typically reserved for an external crystal) for a 32.768 kHz watch crystal. Coupled with the microcontroller’s built-in real time counter (Timer2), we were able to use the watch crystal to keep track of time without the use of an external real-time clock module. This was accomplished by having the counter overflow periodically (based on the crystal) and generate an interrupt service routine (ISR). We saved considerable power by putting the microcontroller to sleep in between the ISRs, thereby
allowing us to run the entire device on a coin cell battery (CR2032). Additionally, we used the internal 1KB EEPROM to store aggregated sensor data rather than using an external SD card as in the first version.

The microcontroller fuse configuration for the power saving and EEPROM features is shown in Table 3.1. Specifically, it uses the internal RC oscillator, preserves EEPROM memory through a chip erase cycle, and disables the brown-out detector. It should be noted that the brown-out detector, which monitors supply voltage during operation, typically consumes 15-20 µA. While this is a useful feature to have, it consumes too much power for our purposes. Undefined behavior as a result of the voltage dropping two low can be avoided by changing the battery every 2-3 weeks regardless of battery voltage depending on the sleep duration.

The typical power consumption values of the circuit are given in Table 3.2. Based on these values, the expected battery life (CR2032 coin cell) for different sleep durations are given in Table 3.3. It must be noted in these estimates that the capacity is derated by 15% to account for some self-discharge. At the very least, where the microcontroller wakes up every second, the battery will last a little over 2 weeks. If we choose to wake up every 2 seconds, we get close to a month of usage. The sleep duration is based on fixed prescalers available on the microcontroller’s timer. On the ATmega328P we employed TIMER2 which works asynchronously even in power save mode.

In our second iteration, we addressed many of the power and size issues we faced with our

<table>
<thead>
<tr>
<th>Capacity Rating of Battery (CR2032)</th>
<th>250 mAh</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Consumption during Sleep</td>
<td>0.14 mA</td>
</tr>
<tr>
<td>Current Consumption during Wake</td>
<td>13.57 mA</td>
</tr>
<tr>
<td>Duration of Wake Time</td>
<td>27 ms</td>
</tr>
</tbody>
</table>
Table 3.3: Battery life based on sleep duration

<table>
<thead>
<tr>
<th>Sleep Duration</th>
<th>Battery Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 second (prescaler = 128)</td>
<td>17.62 days</td>
</tr>
<tr>
<td>2 seconds (prescaler = 256)</td>
<td>27.56 days</td>
</tr>
<tr>
<td>8 seconds (prescaler = 1024)</td>
<td>47.78 days</td>
</tr>
</tbody>
</table>

first prototype. However, we found the protoboard design too time consuming to hand assemble. Assembly required manually soldering and hard wiring all the connections. The wireless transceiver was permanently fixed to the board, which made it very difficult to replace in case of any malfunction. Moreover, the board was also dual sided with the coin cell battery holder on the back of the board. This, increased the height of the board and prevented it from laying flat on any craftable surfaces such as baseball caps or backpacks. Lastly, the design did not expose any of the microcontroller’s input/output pins for future sensors.

3.2.3 Third Iteration: Custom PCB

In our final iteration, we focused on addressing some of the limitations we faced with the second prototype. We also wanted to develop a more robust wearable data collection platform that other researchers could potentially use in the future. Existing off-the-shelf platforms such as the Lilypad (lilypadarduino.org) and Flora (adafruit.com/flora) were originally designed to facilitate the design of soft interactive e-textiles rather than serve as a data collection platforms for multi-week studies. While these existing platforms could be modified to accommodate our needs, the result would end up being bulky and less modular. Thus, we created our own PCB with surface mount components to create a smaller and more fully integrated wearable.

Figure 3.4 shows the latest iteration of the wearable tracker. The single sided PCB has the ATmega328P microcontroller, a coin cell battery holder, headers for the nRF24L01+ wireless radio transceiver, and an optional lithium ion battery header and charging circuit. We added the lithium ion circuitry to accommodate longer autonomous operation and future sensors that might require more power. A detailed circuit diagram along with the top and bottom layers of the board are
provided in Appendix A. The overall functionality of this board (apart from the optional lithium ion circuitry) is similar to our second prototype.

A complete kit including the wearable tracker is shown in Figure 3.5. It includes the microcontroller base (with the wireless transceiver), a UV sensor module for tracking time spent outside, a button for manually tracking various user-defined health habits (Figure 1), and an optional 3D printed case for housing the wearable. The case was designed primarily for users less inclined to craft the wearable into an artifact or clothing. We added the button to record health related activities that do not typically lend themselves to automated sensing (e.g., servings of fruits and vegetables). It should be noted that we originally started with the UV sensor and slowly added other sensors based on the needs of participants.
The entire kit, including all components, sensors, and boards costs approximately 30 dollars. We used a Kapton laser cut stencil, solder paste, and a reflow skillet to assemble the main wearable board. Compared to the second protoboard design, where we hand soldered all the components and connections, this approach was far less time consuming and forgiving. Perhaps the only limitation of this design was the increased height of the board due to the wireless transceiver header. This however was a consequence of how the off-the-shelf wireless module was designed, an aspect we could not control.

3.3 Ambient Modules

The ambient visualization portion of this system is comprised of a master microcontroller (Arduino UNO) coupled with a wireless transceiver that receives aggregated sensor data from the wearable tracker. Based on the data, the master controller issues commands to a set of feedback nodes on a shared serial communication network. These feedback nodes in turn actuate devices such as DC motors, buzzers, speakers, LEDs or vibration motors to help visualize the health data.

A key aspect of our design lies in the object oriented concept of polymorphism, the ability (in programming) to represent the same interface for different underlying forms. In our case, the concept is implemented in paper circuit blocks where each block is controlled by a tiny microcontroller (ATtiny85) that is pre-programmed with a specific node ID and pre-defined behaviors for that particular block. Figure 3.6 shows the four node types that are part of the system. The nodes actuate a DC motor, a piezo speaker, a RGB LED, and a vibration motor. The shape of each module suggests its use; for example, the motor module is shaped like a gear and the sound module is shaped like a loudspeaker. Detailed schematic and board diagrams for each node are provided in Appendix B.

In order to function, each node typically requires just three connections: power, ground, and data. Once power and ground are connected, the node automatically displays its default behavior. For example, the motor module slowly increases its rotational speed; the RGB module cycles through all the colors; the sound module plays the built in animal sounds; and the vibration module
slowly oscillates faster. We employ magnetic connectors to facilitate easy solder-less connections to the nodes. The copper encased neodymium magnets not only help hold the module against a surface, but also provide sound electrical connections. Thus, nodes can be combined or used individually to create a health visualization.

From a software perspective, each node is responsible for actuating the feedback modality it controls based on data received over the serial bus. In the case of the RGB LED node, it transitions from red to green to indicate a positive health behavior. It accomplishes this task by mapping the red to green color gradient to the wearable sensor value range. In a similar fashion, the motor node maps its rotational speed to the sensor value range. Thus, across different node types we get consistent, appropriate behavior for the health data received from the wearable device.

While the individual nodes might be different, the interface and the core software remain the same. Each node simply listens for its ID on the shared, broadcast serial bus connected to the master controller and actuates based on the data it receives. The only difference between nodes is the minor circuitry required by the feedback modality they control and the associated actuation
code. Using this framework, we can envision arbitrarily different nodes, actuating an assortment of elements from LEDs to shape memory alloys. Much like the wearable, the nodes also use the Arduino platform for programming.

A notable aspect of our design is the division of labor between the wearable device that tracks health data and the ambient modules that help visualize that data. This separation increases the breadth of possible visualizations by opening up the full craft domain. Additionally, it also allows us to offload some of the power limitations faced by wearable devices in general.

### 3.3.1 Construction Methods

One of the design decisions we made early in our research was to use paper (as opposed to custom PCBs) as the basis for the ambient nodes. This decision was based in part by the success of prior work [61] that had shown paper to be an extremely versatile, cost-effective, craft-friendly, and expressive medium for electronics. Moreover, since we were ultimately going to run user studies with children, we wanted a medium that was child-friendly and could tolerate mishaps that tend to occur while children are playing or learning. Thus, each node was constructed from laser cut card stock.

We initially created the circuit traces on the card stock with 2.5mm thick copper tape by manually cutting and soldering them to the electronic components. Figure 3.7 shows an early multi-LED module for a cherry blossom visualization (Section 3.6.4). While this method works well for creating simple circuits with minimal components (e.g. light up LED, make a switch),

![Figure 3.7: Early paper circuit block with 2.5mm copper tape traces](image)
it soon becomes very time consuming and error prone to create even slightly complicated circuits that employ SMD parts or microcontrollers. To solve this problem, researchers and makers have typically used desktop vinyl cutters to cut out copper circuits from adhesive backed copper foil. This is usually accomplished through an expensive vinyl cutter such as the Roland GX-24 ( $1500). In our research, we replicated this process with a less expensive ($200) desktop craft cutter available in most arts and crafts stores. The entire process is detailed in Appendix C.

Figure 3.8: RGB LED module constructed using silver ink circuit printer

We also experimented with silver ink traces based on recent research described in [41]. Figure 3.8 shows the RGB LED module constructed using these methods. The traces were printed using a regular inkjet printer installed with conductive silver ink cartridges. Components were then secured to the circuit using silver epoxy. While this method seemed promising at first, the silver epoxy was not as physically strong as one might think for the name “epoxy.” In our experience, circuit components often dislodged with minor use.

3.4 Communication Protocols

The ability to communicate might arguably be the most important attribute the wearable device and the ambient modules possess. There are essentially two communication protocols in use by the system (Figure 3.1). The first wireless protocol serves to transfer stored sensor data from the wearable device to the ambient master controller. The second serial protocol allows the
master controller to communicate the wireless data to individual ambient module(s). Since we used off-the-shelf wireless modules (Nordic Semiconductor nRF24L01+), we were able to leverage existing open source libraries for this aspect of the system.

For communication between the master controller and the ambient module(s), we developed our own serial protocol. We developed our own protocol because we needed a reliable method for a master microcontroller to send commands to a set of uniquely identified slave nodes. In this network, the master microcontroller (Arduino Uno based on the ATmega328p) communicates with the slave nodes (ATtiny85) by broadcasting the unique node identifier along with a set of commands for that particular node on a shared serial line. Thus, only the node whose ID matches, alters its behavior while the rest discard the data. While we can send human readable communications (e.g. Node ID: 5, Command:Blink, Buzz) across the serial line, this method is often resource and bandwidth intensive, especially for smaller microcontrollers. In our particular case, the ATtiny85 slave nodes were also running on their internal oscillators and simulating serial in software. As we found out, this particular approach is sensitive to transfer errors since the internal oscillators are less accurate than their external counterparts. Thus, we also needed some form of error control.

To address these issues, we created a small protocol called SimplePacket that forms binary data packets for software serial communication. While the library is written for software serial, it can be easily modified to accommodate other methods such as I2C. The library essentially forms a packet structure as shown in Figure 3.9. It includes a start and end flag to frame the user data along with a XOR checksum to address any transfer errors. The library itself is fairly simple and consists of three functions: init, send, and receive. The only restriction is that the data structure between the sender and receiver remains the same.
3.5 Programming Environment

We utilized the Arduino integrated development environment (IDE) for programming both the wearable and ambient modules. The Arduino platform which includes both hardware and software was designed to introduce novices to physical computing. Since its inception, the hardware platforms that support Arduino have grown considerably. We see our own work as part of this growing ecosystem. The Arduino IDE allows users write programs in C that control the Arduino board, or, in our case, the health craft construction kit.

To enable the wearable device and ambient modules to communicate with the Arduino IDE, we modified the open source IDE to specifically support our hardware configuration. Figure 3.10 shows the modified Arduino IDE that supports our boards. The “Turtle 8MHz” board is used by the wearable device and the “ATtiny85 @ 8MHz” board is utilized by the ambient modules. To facilitate user programming, we developed several libraries to control the wearable and ambient modules. An off-the-shelf USB-to-Serial programmer (FTDI Basic Breakout 3.3V or Tiny AVR programmer) that clipped to the devices aided in uploading the software.

Though a simpler, more tailored programming environment would have probably been easier for children, we decided against this approach for several reasons. First, we wanted to focus our efforts on exploring the intersection of health and craft with children. Second, we wanted our tools to be accessible to as wide an audience as possible. One the issues we faced early on was in not
having a wearable platform that could continuously gather data (without much intervention) for multi-week studies. We hoped that by developing this platform, future researchers could leverage our work and use it as a starting point. By using the Arduino software, we made use not only of professional-grade software and documentation, but also the vibrant and growing community of Arduino users. We felt the practical, social, and open source benefits of the Arduino development environment were important and would only help facilitate future research in this area.

### 3.6 Illustrative Examples

We developed four illustrative examples to showcase the modular framework. These examples employ the ambient feedback modules described in Section 3.3 to highlight the diversity of crafted health artifacts than can be created within this developing ecosystem. These visualizations were also used to generate interest among participants in studies 3 and 4 (chapters 7 and 8 respectively) and to show children how the ambient modules could be used with the wearable device. For the purposes of illustration, we describe the visualizations below as reacting to data from the UV sensor even though the system can accommodate other sensors.

#### 3.6.1 Lotus Blossom

![Lotus Blossom](image)

Figure 3.11: Paper based lotus blossom with RGB module that transitions from red to green to indicate positive health behavior
In the first of our four examples, we showcase a paper-based lotus blossom (Figure 3.11) using the RGB LED module. The blossom which is made from laser cut strips of cardstock enclose paper stamens. The neutral colored stamens in contrast to the water-colored petals diffuse the light from the RGB LED module located in the center of the flower. In this example, the RGB LED slowly changes color from red to green as the user spends more time outside (based on UV sensor data from the wearable).

In this visualization, we wanted to highlight a simple, elegant design that is within reach of the average individual. While the individual might not have access to a laser cutter to create the precise petal strips, they can easily employ scissors to cut out the petal shapes. With common craft materials and a single node, we can create a tangible visualization that could perhaps rest on an individual's desk at home or office.

### 3.6.2 Terra Cotta Water Fountain

![Terra Cotta Water Fountain](image)

Figure 3.12: Terra cotta water fountain that changes its flow rate based on health data

A slightly more complex example than the lotus blossom is the terra cotta water fountain shown in Figure 3.12. This desktop water fountain which is approximately 45 cm (18 inches) in diameter consists of off-the-shelf terra cotta pots and saucers that have been waterproofed to support a cascading water fall. The decorative rocks and the grooved saucers provide a natural path...
for the flow of water. Underneath, the largest pot is a DC water pump that is controlled through a motor module similar to the one discussed in section 3.3. For obvious reasons, the module is not paper based in this particular instance, although the circuitry is the same. In this example, the flow of the water (i.e. pump flow rate), increases as the user spends more time outside.

This particular health visualization underscores how existing craft or DIY projects can be reappropriated to support health data in very intuitive ways. Additionally, we wanted to showcase the diversity of mediums that can be used to create unique visualizations.

3.6.3 Origami Windmills

![Origami Windmills](image)

Figure 3.13: Origami windmills that can be used to visualize individual or group health data

In our third example, we illustrate an origami windmill painting that utilizes a simple paper layering technique to add dimension and texture to the scene (Figure 3.13). The visualization is approximately 60 cm x 91 cm (24 inches x 35 inches) and consists of thick card stock at different levels. The swirls in the painting suggest wind and the whole scene is somewhat reminiscent of a day at the beach. In this scene, the origami windmills are connected to three motor modules that spin the windmills at different rates depending on data received from the wearable. The motor modules can be used to represent one individual’s outdoor exposure or a group of three individuals. In the case of one individual, the nodes successively spin from the smallest windmill to the largest,
as more time is spent outside. With three individuals, each user's outdoor exposure is responsible for the spin rate of one of the origami windmills; thus the greater the exposure, the faster the speed.

In this playful visualization, we highlight the use of multiple nodes to create a social work of art that could potentially be used by a family or a classroom. In a family setting, the windmills could represent the health data of a father, mother, and child. In a classroom setting, one can envision a much larger mural comprised of each child's unique origami representation of health. Irrespective of use, individual or group, these ambient modules can be used flexibly to visualize health in both personally and socially meaningful ways.

3.6.4 Cherry Blossom Tree

![Cherry Blossom Tree](image.png)

Figure 3.14: Cherry blossom painting where the darker blossoms increasingly illuminate in response to positive health behavior

The cherry blossom painting shown in Figure 3.14 depicts our last illustrative example. This electronic visualization, which is approximately 91 cm x 122 cm (36 inches x 48 inches), consists of craft paper overlaid on a display board. The board houses 15 cherry blossom LED modules in alignment to the darker blossoms in painting. The LED modules, similar in design to the RGB module discussed earlier, actuate 4 red LEDs corresponding to each of the petals in the blossom. In addition to the LED modules, there is a sound module that produces chirping noises for the seated
bird and a vibration module that provides a muted humming for the hummingbird on the left. Thus, as the user spends more time outside, the darker blossoms in the tree increasingly illuminate and the birds come to life.

In this larger, more artistic endeavor, we highlight the use of multiple feedback modalities in a single visualization. Additionally, we illustrate that crafted visualizations need not be limited to a handful of nodes.
Over the course of three years, we conducted four user studies to evaluate various iterations of the health crafting system (Chapter 3). Much of our evaluation work was exploratory and qualitative in nature, since we were uncertain how health crafting would be received by children. Our goals were to investigate children’s use of the system without too many explicit expectations. While we had general guidelines and procedures for each of the studies, we were accommodative of participants’ fluctuating needs and lifestyles. For example, in studies three and four, we found that children were hesitant to be videotaped. During semi-structured interviews they were often shy and less open about their opinions and experiences. As a result, we immediately stopped the practice and relied primarily on observations, notes, and informal interviews. Allison Druin, a senior researcher in child-computer interaction, cites a similar experience, “Our team does not find video cameras to be successful in capturing data for contextual inquiry purposes. We found that when children saw a video camera in the room, they tended to perform or to freeze” [27].

It is also worth noting that our attitudes and approach to research with children has evolved over the duration of the project. They reflect a marked realization that real-life studies invariably take place in a social context and are often messy, subject to the moods and attitudes of participants on any given day. We discovered, that it is better to have a more open-ended approach when working with children. This shift from setting up video cameras and conducting formal interviews in separate rooms to talking naturally with children and taking part in the craft experience is reflected in the study designs. As education psychologist Anne Brown notes, “Making this shift
laboratory to classrooms] involves an increasing trade-off between experimental control and richness and reality” [10]. Based on our experience, we found that it is better to aim for the later (richness and reality) when conducting exploratory work, especially with children. This sociocultural approach we feel provides realistic results based on the vantage point of children.

### 4.1 Ages & Stages

As we were developing the health crafting system, we informally explored different age groups of children that might be well suited for our work. We briefly volunteered at El Pueblo Mágico: a technology-mediated after-school program at Alicia Sanchez International Elementary School affiliated with CU Boulder. We developed simple paper based circuits with LEDs, copper tape, and coin cell batteries as examples to researchers and children(Figure 4.1). In our experience, older elementary school children approaching middle school were more successful at making simple light-up greeting cards than younger children. Some of the younger children did not have the dexterity to handle the smaller components. As a result, we shifted focus towards middle school children, specifically children aged 11-14.

We excluded older teens (high school) because they may be more interested in testing the bounds of the system [25]. Teenage risk taking behavior is a well studied issue and there is strong
evidence to suggest that it is a natural and necessary part of growing up [53]. Thus, teenagers may be less prone to crafting and displaying positive health behaviors.

It is interesting to note that middle school children seem much more sophisticated than their earlier historical counterparts. This phenomenon called “age compression,” coined by the toy industry, describes the modern trend of children moving through play stages faster than they did in the past. Consequently, it is now in the middle school years that kids are self-conscious about appearance and embrace new forms of technology such as instant messaging, mobile phones, and the Internet. Therefore, middle school may be the right time to be discussing health and introducing health technologies.

4.2 Health Behavior Change

The role of health technology in behavior change is an issue that often comes up within the context of HCI research especially with systems designed to change people’s habits. Naturally, as researchers, we want our technological interventions to work especially when it comes to motivating healthy behaviors. However, assessing true long-term behavior change requires large studies and significant resources. Anyone who has conducted even a small field study with 8-10 individuals over a few weeks knows how challenging it can be to control for factors such as social pressure, attrition, and technology novelty. To be able to unequivocally show behavior change requires a large sample, more time, and careful experimental design. For early research technologies such as ours, we strongly feel that behavior change is a prohibitive metric for evaluation.

Behavior change is a highly complex ongoing process interspersed with lapses and setbacks. For example, the relapse rate for smoking only reduces to 7 percent after 5 years of abstinence [82]. Therefore, longitudinal studies are unavoidable if we really want to examine lifestyle changes. As Klasnja et al. argue, “although the desire to demonstrate behavior change is understandable, as an aim for evaluations in HCI research, it is often not feasible...To convincingly demonstrate that a technology contributed to such a process requires large-scale, long-term studies that can typically not be done with early-stage and error-prone systems frequently developed in HCI. But such studies
are also limited from the perspective of HCI. Even when such studies are done as they are in health sciences they often do not reveal why the technology that is being evaluated worked or did not work” [45]. This passage is worth quoting at some length because it so aptly reflects our stance. In our evaluations, we concentrate on understanding children’s health crafting experiences rather than motivating (or assessing) any particular health behavior change. Ultimately, our goal is to help researchers understand the benefits and limitations of our particular approach. Even if behavior change were to occur in our relatively short studies, it could easily be attributed to the observer or novelty effect. In many ways, we view our early work as a step towards asking the right questions.

4.3 Studies Overview

Our studies followed a natural progression starting with a system test and ending with an in-depth evaluation. In the first pilot study, which lasted a week, we tested our wearable devices with college students to ensure our system was working correctly and our ideas were reasonable. Study two, a 90 minute after school workshop, served as a needs assessment to investigate children’s perceptions of health and their amenability to health crafting. We also identified the visualization primitives that informed the technical development of the ambient modules. We conducted study three once we had a full system implementation. In this study, we evaluated the ambient and wearable health toolkits with children for six weeks. Children crafted their health systems for a month and then evaluated them for two weeks. In the last study, we conducted an in-depth evaluation of our system with four children for two months. Children crafted their health systems for three weeks and evaluated them for five weeks. The participants informed four individual case studies.
In this first week-long study, we wanted to better understand the feasibility of the health crafting approach with a small group of participants. At the time, we had just finished the second iteration of our wearable tracker (Chapter 3, Section 3.2.2), and developed the cherry blossom visualization (Chapter 3, Section 3.6.4) as an example. We had not created the general purpose ambient modules discussed in Chapter 3, Section 3.3. Our goals were to: 1) Test the functionality of the wearable base with the UV sensor as a standalone system capable of gathering, storing and transmitting sensor data without human intervention, 2) Get initial impressions on crafting the wearable device into an accessory, 3) Gather participants impressions of the cherry blossom as a viable health visualization.

5.1 Participants

We recruited 5 students (21-34 years) consisting of 4 men and 1 woman from the college population. All participants were proficient users of modern technologies, such as smartphones and 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.

5.2 Methods

The study lasted 7 days where each participant was asked to wear the UV tracker daily during the day. In the initial meeting, we requested that participants craft the device into a
wearable accessory or artifact that they could integrate into their daily lifestyles. We encouraged them to explore their own artistic and fashion sensibilities. During the crafting process, which lasted approximately 30 minutes, we suggested that participants choose an object (e.g., backpack, hat, etc.) they carried or used everyday so they would not forget the device at home. We provided all the materials they needed including felt, fabric, glue, velcro and various other crafting supplies. We instructed participants on how to activate the on-demand RGB LED and the location of the UV sensor during the crafting process. Since the participants did not craft the cherry blossom visualization, we described its link to the wearable and how it would reflect their outdoor exposure data.

We asked participants to periodically check in over the course of the week to view the cherry blossom visualization as their schedule permitted. During these weekly meetings, we conducted brief semi-structured interviews to gather their overall impressions of the system and document any issues they faced. The weekly meetings typically lasted for 30 minutes once or twice during the week long study.

5.3 Results

Overall, participants were receptive to the idea of crafting health devices and were engaged while crafting the UV wearable. All the participants were able to craft a wearable accessory by the end of the first meeting. However, they did sometimes struggle with what daily artifact to use and how best to conceal or display the device.

The male participants crafted the UV wearable as an accessory to their backpack or messenger bag. They cited the many existing accessories they had to carry as a reason why they were less inclined to craft a boy worn device. Moreover, a body worn device was not agreeable to their more 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." The backpack,
however, was one bodily extension they all carried everyday as college students and could readily accept for crafting. Two of the male participants associated the UV bag accessory to a sticker on a laptop or a stitched cloth decal. Figure 5.1, showcases a representative example of the UV wearable crafted into a messenger bag by one of the male participants.

![Figure 5.1: UV wearable device crafted into a messenger bag with felt, velcro and electric tape [1].](image)

In this particular example, a rudimentary mountain and tree, representative of the Colorado landscape, was cut out from felt fabric colors that matched the bag; the RGB LED and the UV sensor are exposed at the base of the tree. We showcase this particular example because this participant described himself as “not craft oriented” and was ultimately surprised by the results. He described the result as not “half as bad” as he envisioned.
Perhaps one of the more beautiful and creative designs in our study was created by the single female participant. Unlike the male participants, she was more open to the idea of creating a body worn accessory. She was particularly concerned with creating something that was aesthetically pleasing. After using the internet to brainstorm some ideas, she designed a fox themed UV headband. The intermediate stages and the ultimate final result of the crafting process are shown in Figure 5.2. In this example, the RGB LED is located at the tip of the fox’s nose, and the UV sensor is exposed via a notch in the tail. The participant astutely chose a headband instead of other form factors because it would gather the best data on the head and also because it was a hair accessory she wore regularly to protect her ears against the winter chill. The fox themed headband was one design we had not envisioned as researchers.

We received somewhat mixed reviews about the on-demand RGB visualization. Three of the male participants appreciated that it was not constantly illuminated. One of the three described the device as “low key” and was thankful that it did not garner much attention. The one other male participant felt it would have been nice to have a persistent hidden display. He 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 who was initially undecided about a persistent or on-demand RGB display, 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.”

![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 [1].](image)

Participants remembered to wear the crafted UV device for the duration of the study. However, the button and the associated RGB LED did not see much use. Figure 5.3 shows a graph of the minutes spent outside by each participant for the seven days of the study. The UV wearable
was successful in gathering data unattended for all but one participant. For P5, the sensor board connector came loose from the microcontroller base after the fifth day. As a result, the device did not collect any data for the last two days of the study.

A cursory glance of the usage graph does not reveal any significant patterns. Most participants spent at least the recommended 15-20 minutes outside for the majority of the work week. However upon interviewing the participants, we learned that the undergraduate participants (P2 and P3) had classes on alternate days of the week (e.g., classes that were either Monday-Wednesday-Friday or Tuesday-Thursday. We can see an alternating pattern for these participants that corresponds to similar walking distances between classes for those days. Participants, P1, P4, and P5, did not exhibit a similar pattern because they did not have this alternating course schedule. Interestingly, participants did not spend as much time outside on the weekends as compared to the weekdays. The interview revealed that this was in part due to the cold winter season and not having to attend school for classes. The male participants also cited not having to carry their backpacks on weekends for activities such as grocery shopping. The female participant (P3) however, was more successful in accounting these lost weekend minutes (Figure 5.3) due to the headband being a staple of her daily winter outerwear.

The cherry blossom visualization made a favorable impression on all the participants. During the mid-week check-in, participants remarked how beautiful it looked with the blossoms lit. The automatic wireless transmission of sensor data however caused some confusion. This was because the data from the wearable was automatically transmitted based on proximity to the ambient display; the tree often changed just before participants entered the lab space. Since they were not aware of the transition in the display, one participant suggested having a button to initiate the wireless transfer. This way the change could be explicitly seen. Moreover, the majority of participants did not remember the tree’s prior state since they did not visit the lab everyday. 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 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 enjoyed the aesthetically pleasing representation of their outdoor exposure. A number of participants commented on how the craft-based visualization was a welcome departure from the traditional phone and computer screens. Particularly, they appreciated the depth, texture and tangibility of the display, aspects that cannot be replicated on a mobile or computer screen despite skeuomorphic designs.

We found that the cherry blossom display served as a wonderful scaffold for fostering creativity in the participants even though we did not specifically explore the crafting of personal health visualizations. One participant suggested using the birds in the display as an audible reminder system to go outside instead of as badges of accomplishment. 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. Used in this fashion, the health of the tree is tied to a group rather than a single individual, thereby leveraging social influence. Yet another participant proposed the crafting of three dimensional health 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.”

5.4 Discussion

In this preliminary study, we wanted to ensure that our ideas of combining health and craft were reasonable. To that end, we explored how these two traditionally disparate domains could be blended together. During these explorations, we recognized that there are opportunities for the productive detente between these two fields. Undeniably, one of the primary research challenges for each of these two cultures is how best to appropriate the advantages of the other. For the health community, the goal is to integrate health technologies with the powerful aesthetic, tactile, and intellectual advantages of physical materials. For the craft community, the goal is to provide users with health platforms and components that are easily programmable and accessible where the average user with a bit of knowledge can put together a health system. We showcased an example of this convergence by creating a power conscious wearable wireless platform that is capable of tracking
time, recording sensor data, and wirelessly transmitting that data to an ambient visualization. We chose to make the sensor a separate module in order to accommodate other health sensors in the future. In developing the ambient visualization, we heavily borrowed from the craft technology landscape to create paper-based LED modules for a mixed media health visualization.

A favorable aspect of our system is its dynamic approach to health and wellness. Health is an issue that is often personal and relative to a particular individual. On any given day, a person’s motivation levels can vary depending on situation, context, and a variety of other factors. Even implementing a small change, such as adding a 30-minute run at lunch, requires the individual to re-structure their daily lives, from bringing fitness apparel to rescheduling social obligations. Making these types of changes is particularly harder in the case of children since they often lack direct control over their environment and circumstances. Moreover, unexpected circumstances like weather or illness can disrupt those seeking to establish new behaviors. As other researchers have identified, one of the problems with current health technologies is their failure to adjust to individual differences [59]. Health crafting has the potential to address some of these concerns.

Even with our modest study, we observed personal preferences with respect to the RGB LED display. Most notably, some participants preferred a hidden or diffused display while others simply did not want an overt notification. This highlights the need to tailor feedback mechanisms based on the sensibilities and privacy concerns of the user. In a sense, we are arguing for a model where users are active agents in the design of ambient and wearable health interfaces rather than viewing them as passive users of an off-the-shelf solution. We feel that the former model is perhaps more sustainable for long-term behavior change.

In the previous paragraph, we focused on re-imagining health technology in a way that integrates craft-work. At the same time, there is another benefit of integrating crafts and health namely, novel applications for craft technologies themselves that extend beyond the typical examples of craft-work (e.g., personal adornment or utility items). Historically, a crafted item is capable of having a great deal of personal significance; it could be a special gift from a loved one, a memento of a person or a keepsake from an experience. These functions are particularly prominent in the case
of physical objects. Purely virtual objects such as animations and simulations do not seem to have the same emotive power as their physical counterparts. As Csikzentmihalyi and Rochberg-Halton note in their foundational book *The Meaning of Things: Domestic Symbols and the Self*, the most cherished objects in a home are often items that enrich a personal sense of narrative history [21].

With this perspective, it is interesting to imagine potential roles for homemade crafted artifacts in the realm of personal fitness and health. A crafted visualization could be a souvenir from 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. Put differently, the blending of crafts and health offers new possibilities for the meaning and power of personal crafts.

While we use the terms DIY, craft, and making (as in the maker movement) somewhat interchangeably in our discussion, we acknowledge that there are shades of differences between these terms. However, as other researchers have pointed out, these cultural practices are multifaceted with significant overlap between communities [46], and it is under this all-inclusive umbrella that we choose to position this research so as not to exclude any particular community.
Chapter 6

Study 2: Reflections on Health and Crafting

Perhaps the first question that arises when discussing health crafting and children is: do children even want to craft health technologies? We designed the initial version of the system based on the success of craft technology with children in the education domain. However, it was unclear if crafting would be successful with children when introducing health and wellness. Therefore, in this second study, our aim was to discover health related issues that children considered important. Additionally, we facilitated tangible mock-ups of wearable and ambient devices they might potentially use for tracking their health. This would help confirm that children are indeed amenable to health crafting and also elicit the kind of feedback primitives (e.g., light, sound, movement) children consider helpful in visualizing health. This 90 minute workshop was used to complement the technical development of the system.

6.1 Study Location

The participants for this study were recruited from Sheridan Health Center, a nurse-managed clinic operated in partnership by the Sheridan School District and University of Colorado Denver College of Nursing. Over 67% of the children in the Sheridan schools are Hispanic. Almost 41% of the individuals in the service area live under 200% of the federal poverty level, according to extrapolations based on the 2000 US Census and the 2006 Community Survey. In 2011, 80% of Sheridan students qualified for free and reduced lunch. Based on research with this population and clinic records, it is estimated that 87% of Latino youth within the Sheridan community will be at
high-risk for early onset of cardiovascular disease and other chronic illnesses such as diabetes [4]. Because the Sheridan Health Center is located within the Sheridan Middle School and focuses its services on the school district’s students, the participants were likely from low socioeconomic status families and at high risk for illness.

6.2 Participants

We recruited 8 participants, two boys and four girls, between the ages of 12 and 14. We had 7 participants who identified with either Hispanic or Latino and 1 that was Caucasian. All the participants owned a computer at home and had some confidence in using it for music, email, or photos. Participants however, were generally more confident using mobile phones even though only 3 of them actually owned one. All of the children had prior experience with basic electronics and all but one had crafted, tinkered, or made some artifact for themselves or someone else. The majority of the children were not involved in any after school activities save for a couple that were involved in robotics and soccer.

6.3 Methods

We designed the study as a 90 minute after school workshop in Sheridan Middle School. As the children arrived, we conducted a brief background survey to get demographic information and prior experiences with technology and crafting (Appendix D). During the first 15 minutes of the workshop, we explored issues related to children’s health. Specifically, we explored what it meant to be healthy from a child’s perspective, what they were interested in knowing about their health, whether they considered activity to be important in their lives, and the types of health metrics they were interested in tracking. Following this discussion, children were encouraged to start paper prototyping their ambient and wearable devices in groups of 2 or 3. To scaffold the brainstorming and crafting process, 4 stations were setup where each station focused on a specific question and provided the necessary tools and components for answering that question. This way the wearable or ambient mockups could be built incrementally. The central questions for each station were as
follows,

(1) What do you want to monitor? In this station, we explored the types of metrics that children wanted to track. We provided examples, such as tracking inside versus outside, knowing how much you played today, etc. While we were not be able to account for all the different types of metrics they want to monitor, we provided mocked up placeholders for the prototyping session.

(2) How do you want to wear the device? In this station, we examined the different containers that children could use for their wearable devices such as bracelets, belt buckles, and brooches. Children were provided different craft materials to prototype their own temporary containers.

(3) How do you want the device to notify you? In this station, we investigated the types of feedback mechanisms that children preferred to use in their wearables or ambient devices. They were provided small battery powered LEDs, vibration motors, and buzzers to integrate into their designs.

(4) What do you like about the device you created? In this last station, we helped children reflect on the prototyping activity. We asked them to describe their prototype and what aspects of it they liked, disliked, or would have liked to improve.

We video recorded the workshop and conducted semi-structured interviews during and after the crafting process. Participants received a $15 retail store (e.g. Target) gift card as an incentive at the end of the study. Since the study was qualitative in nature, we collected participant observations including photos and notes, artifacts from the workshops (images, sketches, any mockups that children are willing to share), notes of brief contextual interviews about the mockups they built and any recordings of the group discussion for further analysis.
6.4 Results

Participants were initially hesitant to share their opinions in a group setting because it was the first time either of us had met. However, as the study progressed and the crafting process began, children were better at voicing their opinions. Children generally worked in groups of two, although there were a couple of participants who chose to work by themselves.

6.4.1 Children’s Health Perspectives

In the group discussion, children cited diet and physical activity as the two most important attributes for good health. Participants dietary knowledge was typically derived from their parents and health education classes in school. Children generally acknowledged the need to eat more fruits and vegetables even though they sometimes preferred to eat unhealthy snacks. One of the female participants explained, “I love eating chips but my parents are always telling me to eat a banana. But bananas [laughs] don’t taste so good.” While there was a general awareness of key dietary messages (e.g., eating more fruits and vegetables, and cutting sugary and fatty foods), children often had creative interpretations about the healthiness of different foods. One of the 13-year-old boys expressed, “One of my favorite things to eat is Fruit Roll-Ups. It is really good because it is tasty and also has fruits in it.” Another girl revealed that her morning breakfast was often a couple of blueberry Pop-Tarts (pre-baked toaster pastries) which she considered to be fairly healthy. A balanced meal was sometimes interpreted as an equal combination of healthy and unhealthy foods. For example, a 12-year-old girl said, “Sometimes I mix and match you know...like if I want to eat chocolate...I also have an apple or something.”

With respect to physical activity, the two boys in the study were focused on sports and exercise. They highlighted soccer as their main sport and discussed some of their favorite players. They also expressed an interest in physical conditioning early in the morning. As one them mentioned, “I think doing push-ups and sit-ups everyday in the morning is good for you. It makes you strong. I try to do them, but sometimes I forget.” The majority of girls were interested in playing outside
with their friends. They commented on “hanging out” and socializing as key motivators. When we asked what it meant to play outside, one girl explained, “I don’t know...we just run around sometimes or play with [hula] hoops and stuff.” Overall, the common theme across both genders was the idea that body movement equals physical activity. The labels “fun” and “play” often appeared in the conversation with the girls expressing the idea as one without any fulfillment of purpose or outcome while expending energy. There was a general separation between exercise and playing, with exercise as a more formal activity. Although exercise could be fun and play, it was also not always so.

When we discussed health in general and what it means to be healthy, children cited a lack of illness and “feeling good.” This allowed them to participate in activities they considered important. A 12-year-old girl expressed, “You know when you are not sick and stuff...and can hangout with friends.” Another boy commented, “I think if you [are] in a good mood and can do stuff you are healthy.” Aspects of mental health also appeared in our conversation with the participants. One female participant, who was especially concerned with quantity and quality of sleep. She mentioned it was of personal concern to her due to family issues and stress. One of the 14-year-old boys mentioned how his brother often made him mad and it was hard not to fight back. Remarkably, even though we were conducting the study with an at-risk population, the children all perceived themselves as fairly healthy. This opinion was consistent across both the boys and the girls. Compared to the boys, the girls were more conscious of their bodies and highlighted the need to maintain a healthy weight for appearance purposes.

6.4.2 Participant Mockups

The idea of crafting wearable devices was received favorably, with all the participants successfully prototyping an artifact that tracked and reflected some aspect of their health. In fact, they were more comfortable with crafting than talking to researchers. There were three groups of two participants each and two participants that worked alone.
The two male participants, who had previously expressed interest in physical conditioning, chose to monitor their morning exercise habits. They mocked-up a set of origami cranes that would help them keep track of various exercises such as push-ups, pull-ups and sit-ups (Figure 6.1). The participants fitted one of the cranes with LEDs and a small vibration motor to indicate various completion levels. While they didn’t have time to model a wearable, they discussed how they could possibly use a button to track the number of repetitions for each exercise.

Another group of girls, designed a set of ambient electronic chains to model their outdoor activity (Figure 6.2). Each LED fitted link corresponded to a day of the week and would illuminate if a minimum quota of activity was completed. Thus, their goals were to successively illuminate the links through outdoor activity and “not break the chain” of good habit. The participants however were a little unclear on what outdoor activities they wanted to track. As one of them said, “I don’t know...I think just being outside with my friends is good enough. Sometimes we play in the park other times we just walk around.”
Perhaps one of the more elaborate designs was the octopus wallpaper shown in Figure 6.3. This particular participant simply wanted to track whether she was inside or outside, since being outside automatically implied play and activity. Thus, she prototyped a wearable bracelet that communicated the amount of time spent outside to an ambient octopus wallpaper that served as an alarm system for when she failed to play outside. In this example, the eyes of the octopus
illuminate as a first warning, followed by sound from a buzzer near the mouth. Finally, if neither of those feedback mechanisms were heeded, the tentacles would illuminate. Another female participant with similar tracking goals designed a circular wallpaper disk with a traffic light type representation (Figure 6.3); the red, green and blue LEDs represented no play (outside), moderate play, and “great” play, respectively.

![Figure 6.3: A wearable octopus wallpaper disk with LED indicators to track play levels](image)

Figure 6.3: A wearable octopus wallpaper disk with LED indicators to track play levels

The female participant who was especially concerned with the quality of her sleep designed a personal sleep bracelet (Figure 6.4) that would track how well she slept the night before. The different LEDs marked various stages of her sleep that she could reflect on the following morning.

![Figure 6.4: A wearable sleep bracelet with LED indicators to track quality of sleep](image)

Figure 6.4: A wearable sleep bracelet with LED indicators to track quality of sleep

The female participant who was especially concerned with the quality of her sleep designed a personal sleep bracelet (Figure 6.4) that would track how well she slept the night before. The different LEDs marked various stages of her sleep that she could reflect on the following morning.

Overall, we found that participants were generally hesitant to have any displays or visualizations on the wearable itself. They often cited the need to “fit in” with other students especially if the wearable was worn in public. Even when we questioned participants who had designed wearables with feedback mechanisms, they highlighted a difference between public and personal designs. The girl who designed the octopus wallpaper (Figure 6.3) observed, “It is different...between making something you wear around your friends and something that you make just for yourself. I don't know....maybe I wouldn't wear the bracelet with the blinky stuff.” The girl who designed the sleep
tracker also commented on the privacy of her design. She said, “Well this is the bracelet I wear when I go to sleep...no one is gonna to see it anyway.”

6.5 Discussion

Although our study was fairly modest in size and duration, we received fairly interesting results regarding children’s perceptions of health and their ideas on crafting health technologies. In this section, we cover what we believe to be some of the more compelling implications of our experiences and how they informed the design of our system.

Children’s perceptions of their own health were remarkably positive in nature. This was somewhat alarming considering that we were working primarily with an at-risk, low socioeconomic status population. Of the 8 participants recruited for the study, 7 identified themselves as Hispanic. In the Sheridan community, where the study was conducted, Hispanic students are highly susceptible to early cardiovascular disease or diabetes [4]. This misperception of health is in line with national research which recently concluded that 30% of children and adolescents aged 8-15 years in the United States misperceive their weight status; this problem is more pronounced with Hispanic children [84]. Coupled with the children’s creative interpretation of food nutrition and meal balance, there is definitely a need for better health education for children. We acknowledge that there are many intractable variables, such as income, environment, lack of transportation that are major barriers to healthy lifestyles in low socioeconomic populations. However, from a children’s health education perspective, we could offer a constructivist [74] view to teaching and learning health. Children may be more likely to become engaged in health and learn about themselves if they are active and creative participants in crafting their own health technologies.

A compelling result of our study was that children seemed to be less responsive to adult notions of physical activity and diet. Participants seemed to have their own ideas on why they should monitor various health metrics. The female participants for example, were interested in monitoring time spent outside, not for any particular physical activity, but because they felt socializing or playing with their friends was a healthy pastime. In a sense, they simply wanted to track their
own cultural habits as children. This seems to suggest that specific fitness-promotion technologies without consideration of children’s attitudes and culture might not be as persuasive. Even the two boys who wanted to track physical conditioning exercises were interested in them because they wanted to be strong, not particularly because of any health reason. Although we wouldn’t want to push this idea too far, it is fair to say that any health technology for children must consider their culture.

It was also interesting to note the blurring of age norms in our study. This phenomenon known as “age compression,” which we alluded to earlier (Chapter 4, Section 4.1), was striking to see in middle school children. The female participants were much more conscious of their bodies and their appearance. Moreover, they expressed the need for modest visualizations on wearable devices citing the need to “fit in” existing social norms. In future work, it might be interesting to explore health from this perspective by helping children build healthy ideas of body image.

From a health crafting viewpoint, one of our goals was to understand the different kinds of feedback primitives that children might find useful in crafting future health visualizations. Interestingly, the majority of visualizations that participants created were ambient in nature, expected to reside in their personal space at home or school locker. This was a somewhat unanticipated finding since we originally envisioned accommodating different kinds of visualizations on the wearable device itself. However, separate ambient modules for displaying health data was a fortuitous outcome because displays tend to be power hungry and wearable technologies are already severely power constrained. By off-loading the health visualization aspect to an ambient artifact, we can save considerable power on the wearable. We identified four potential ambient modules from this study. They include a motor module for movement, a vibration module for vibro-tactile feedback, speaker module for sound, and a LED module for display.

Lastly, while our study was useful in confirming children’s amenability to health crafting, it was simply too short for anything else. Many of the children did not have enough time to craft wearables in addition to their ambient visualizations. Moreover, since the children did not know each other, we were unable to explore socially interactive crafting practices on a larger scale.
Crafting health technologies within a close knit social group could potentially be a more rewarding experience with better outcomes. However, to observe such behavior, we would need to partner with a community or after-school program. Although we partnered with Sheridan Health Clinic for this study, the students were recruited individually and were not part of a social context (e.g., clubhouse or program). Since they did not know us or each other prior to the study, it is possible that they were less candid with their feedback. As a result, we strongly feel it is important to build rapport with a community through volunteering, mentoring, or tutoring prior to conducting any qualitative studies.
Chapter 7

Study 3: Field Trial

The overall objective of the third study was to conduct a field trial of our ambient and wearable toolkits with children. At the time of this study, we had a full system implementation of our system as described in chapter 3. Specifically, we had just finished the third iteration of the wearable (Section 3.2.3) and had developed the 4 ambient modules discussed in section 3.3. We had two sensors as part of the system, the UV sensor for detecting outdoor exposure and a button for tracking user-defined health habits. Since this was our first field trial with the intended population, we were fairly open-ended in our approach and wanted to explore how children would utilize our system. We were particularly interested in their perceptions of health, any difficulties they faced during the construction process, the types of visualizations they created for representing health, and the subsequent use of the system. Lastly, we also wanted to explore if there were any social aspects to the crafting process with children potentially co-crafting a single ambient visualization.

7.1 Study Location

Our study was conducted in collaboration with a local after school program called Gold Crown Enrichment in Lakewood, Colorado. It serves youth from the neighboring Sheridan corridor from eastern parts of Jefferson County and western parts of the County of Denver. The after school clubhouse at Gold Crown provides interest based education in arts and technology for children aged 10-18. The children are typically from low income families, as evidenced by the free and reduced lunch participation rates at area schools - most of which are over 60 percent. To better understand
the cultural and social practices within the clubhouse, we volunteered over 150 hours over the span of a year tutoring and mentoring children prior to conducting the study. Volunteering also helped build trust and rapport with the youth and the clubhouse staff members.

Children typically attend the clubhouse on a drop-in basis Monday through Friday from 3 p.m. to 7 p.m. While the clubhouse serves a wide age range of children, the demographic is skewed towards middle school children who mix freely with those younger and older than themselves. The clubhouse has minimal structure and students individually identify projects that are important to them, and set out learning how to use various art and technology skills to complete the project. The adult instructors and mentors merely help facilitate student interests. The clubhouse follows a democratic education process where learning is self-initiated and self-motivated. We observed a strong maker culture that revolves around the practice of creating fine and graphic visual art pieces. This practice is slowly starting to incorporate 3D sculptures with the recent addition of a 3D printer.

During our volunteering sessions over the year, we conducted both formal and informal workshops on paper circuits, soldering, and Arduino programming based on clubhouse members’ requests. In many ways, these sessions laid the foundation for the study by introducing children to basic electronics and programming.

### 7.2 Participants

After IRB and clubhouse approval, clubhouse staff, helped us recruit 11 participants between the ages of 11 and 14 with a regular attendance record. Unfortunately, only 9 participants, consisting of 6 boys and 3 girls, completed the full study; one participant moved to a different part of the state, and the other withdrew due to family issues. Participants already had some exposure to modern technologies having used personal computers for digital art projects at the clubhouse. Moreover, a majority of them reported owning a computer at home and using it for videos, music, and photos. All of the children had prior experience with basic electronics and crafting, either through courses at the clubhouse or personal projects.
7.3 Methods

We acquainted children with our work three months prior to the study during clubhouse meetings based on advice from staff members. During these meetings, we showcased the modules, the wearable, the sample visualizations (Section 3.6), and answered children’s questions. This not only helped generate interest, but also identified potential participants.

After recruitment, we conducted two 45 minute design sessions with the participants to facilitate ideation and to better understand how they might use our system. During these group discussions, children explored health related issues, such as what it means to be healthy, activities they considered important, and metrics they would like to monitor. Participants also investigated potential visualizations for their health activities. A communal poster served as a focal point for the discussion and the sketches.

The design sessions were followed by a month long prototyping and development phase where children crafted and programmed their wearables and associated visualizations. We initially allotted only 2 weeks for this process, but found that children usually attended the clubhouse on alternating days of the week (Monday and Wednesday or Tuesday and Thursday) and required more time to craft their systems. Before crafting the wearable, we asked children to set a reasonable self-defined goal for a self-selected healthy behavior or activity. So for example, if a participant wanted to track time spent outside, we would ask, how long they wanted to play everyday? If a participant wanted to track fruit consumption, we would ask, how many fruits servings they aimed for per day? These self-defined limits were then programmed by the children into an ambient module of their choosing. The limits would essentially allow the ambient module to provide the appropriate feedback respective to their goals. It should be noted that the programming task is not extremely complicated. It involves customizing pre-defined behaviors (commenting out existing code) and setting variables. A more detailed discussion of how the system works is provided Section 3.3.

After the initial programming task, we asked children to take time crafting the wearable device into an artifact of their choosing (e.g., backpack, headband), 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, and the location of the sensor. In the case of the button, they were taught how to activate it.

During this time period, participants also crafted tangible visualizations using the various ambient modules. Children decided what modules they wanted to use, how it would visualize data from the wearable (e.g., should the motor spin faster or slower?), and what story it would tell. Participants were given all the craft materials they needed (felt, fabric glue, Velcro, cardstock, etc.) to complete these tasks. Moreover, researchers and clubhouse staff were always on hand to assist children with crafting, programming, and debugging.

Following the development phase, children used the systems they created for 2 weeks. Participants took the crafted wearable home with them, while their visualizations remained at the clubhouse. The main reason for this decision was to minimize any technical issues children might face and to ensure proper functioning of the system. To avoid collisions between different wearables and visualizations, we programmed unique identifiers into each child’s wearable and ambient module(s). This way, the visualizations only responded to the associated wearable.

The entire study lasted approximately 2 months. Typically, children took one to two weeks (2 to 4 clubhouse sessions) to craft the wearable and two to three weeks (4 to 6 clubhouse sessions) for the ambient visualization. We conducted contextual and semi-structured interviews, maintained field notes, and video recorded children’s experiences during the development and evaluation phases. At the end of the study, participants were given a $15 dollar Amazon gift card for their time and effort. A month after the study, we contacted participants again to gather their overall impressions and experiences with health crafting. This post-study interview lasted approximately 30 minutes.

7.4 Results

Overall, the health crafting approach was positively received by the Gold Crown community, with participants creating an electronic health mural using the ambient modules. Children were
generally less interested in adult notions of health and tracked self-selected behaviors they considered to be healthy. Volunteering and building rapport with the clubhouse community was helpful in gathering candid feedback from the children. In this section, we discuss the ambient visualization that children created, the wearables they crafted, and their ideas of health during the process.

7.4.1 Initial Brainstorming Sessions

It was clear from the initial design sessions that the participants were part of a tightly knit social group. Thus, it did not come as much of a surprise when children suggested building a clubhouse mural that represented the community at large. They proposed an electronic mural where each participant could contribute a crafted ambient module that adhered to a common larger theme. The modules in this vision would only react to the respective owner’s wearable device.

Figure 7.1: Communal poster used to help children brainstorm common themes for the electronic mural
During these design sessions, participants brainstormed various common themes for the mural where they attempted to complete the sentence, “Our clubhouse is like a...”. The answers included, human body system, solar system, ocean, rain forest, gang of super heroes, Christmas tree, and jungle. An initial communal poster used during the brainstorming session and discussion is shown in Figure 7.1. In subsequent meetings, these ideas coalesced into a core set of themes that included an ocean, a night sky, and a jungle. Figure 7.2 depicts an artistic exploration of these themes by the children on a poster board. One of the participants drew a giant shark to demarcate different zones of the poster. Within these zones, children drew various land creatures, robots, planets and star systems. Participants however, could not agree on a single theme for the final mural. As a result, they decided to include all the core themes (ocean, night sky, and jungle) in the final visualization.

![Figure 7.2: Artistic exploration of common themes for the electronic mural](image)

### 7.4.2 Notions of Health

Central to our work is the idea of health and what it means to be healthy. While as adults, we subscribe to the common mantras of diet and exercise, it was clear from the beginning of our study that children had somewhat different notions. In our initial group discussions with children,
participants often cited diet and physical activity as the two most important attributes of good health. However, when we asked kids why they really thought so, they often mentioned their parents or health education classes at school as the source. Although they acknowledged that they needed to eat more fruits and vegetables, and exercise frequently, they were less interested in these traditional behavioral indicators. A 12-year-old girl (P9) commented, “I know exercise is good for you. My mom is always telling me to go play outside, but sometimes my friends aren’t there. What am I supposed to do? Run around? That is no fun.” In general, participants had very little concern over their health and described themselves as fairly healthy. As one 13-year-old boy (P3) candidly summarized, “Listen [researcher’s name], honestly [pause] I am not all that interested in health. I like this project because I like playing with electronics and gadgets.” In our study, this participant chose to track his reading habits instead. He expressed, “I been trying to read more. I like it because it makes me feel good afterwards.”

<table>
<thead>
<tr>
<th>Participant</th>
<th>Sex</th>
<th>Age</th>
<th>Health Metric</th>
<th>Mural Artifact</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>Male</td>
<td>12</td>
<td>Fruit consumption</td>
<td>Pinwheel (Motor)</td>
</tr>
<tr>
<td>P2</td>
<td>Male</td>
<td>11</td>
<td>Water consumption</td>
<td>Tiki Mask (Vibration)</td>
</tr>
<tr>
<td>P3</td>
<td>Male</td>
<td>13</td>
<td>Reading</td>
<td>Octopus (LED)</td>
</tr>
<tr>
<td>P4</td>
<td>Male</td>
<td>12</td>
<td>Music, guitar</td>
<td>Nemo (LED)</td>
</tr>
<tr>
<td>P5</td>
<td>Male</td>
<td>13</td>
<td>Playing outside</td>
<td>Cosmo (LED)</td>
</tr>
<tr>
<td>P6</td>
<td>Male</td>
<td>14</td>
<td>Sketching</td>
<td>Self-portrait (Sound)</td>
</tr>
<tr>
<td>P7</td>
<td>Female</td>
<td>11</td>
<td>Playing outside</td>
<td>Galaxy (Motor)</td>
</tr>
<tr>
<td>P8</td>
<td>Female</td>
<td>12</td>
<td>Coloring, drawing</td>
<td>Ariel (Sound)</td>
</tr>
<tr>
<td>P9</td>
<td>Female</td>
<td>12</td>
<td>Music, making tunes</td>
<td>Sun (LED)</td>
</tr>
</tbody>
</table>

Table 7.1: Participant information along with health metric they chose to track and the mural artifact they created

Perhaps the single central idea that children commonly voiced about health was the ability to participate in activities which they considered important. In their view, being able to perform these activities served as markers of health. Thus, the majority of participants chose activities related to their well-being. Table 7.1 summarizes the health/wellness metric each participant chose to track. Only two participants in this table (P1 and P2) chose traditional dietary measures. Even in the case of P2, his desire for tracking the number of times he drank water everyday was somewhat
misinformed. When we asked him why he wanted to track water consumption, he explained, “I heard in school that our bodies are mostly made of water. So putting water in must be good.” The 12-year-old male participant (P1) however, clearly identified a health case for eating fruits. He said, “Well eating fruits is better than eating Cheez-Its. This way you don’t get fat.”

Regardless of the metric children chose, they welcomed the idea of crafting their health. When asked to discuss why they preferred this approach as opposed to being given an off-the-shelf pedometer or activity tracker, they cited the expressive nature of the project. As one participant (P2) commented, “You put the stuff that you like on it...it expresses how I feel. Instead of other people doing all the work, it has the stuff that I like...that I put on.”

7.4.3 Health Mural

Figure 7.3: Electronic health mural created by middle school children using ambient modules. Each module reacts to the respective owner’s wearable device. Examples of each of the four types of modules are highlighted on the left and right sides of the mural. On the left, the galaxy spins using the motor module and the boy seated on the beach plays a tune using the sound module. On the right, the mask vibrates and the octopus changes color.
The mural created by the children is shown in Figure 7.3. It is approximately 6’ x 4’ (1.83m x 1.22m) and is composed of 3 pieces of tempered hardboard. It houses various ambient modules that magnetically connect to the surface of the acrylic painting. Small holes in the hardboard connect the modules to the copper tape based circuitry housed in the back. Thus, participants were able to craft their visualizations independently of the mural and magnetically connect them as they finished. Children decided where to place their modules and clubhouse staff members facilitated the connections to the circuitry in the back.

The images on the left and right side of Figure 7.3 showcase individual visualizations created using each type of module. For the sake of illustration, the crafted card stock pieces are placed next to the module rather than on top as shown in the mural. The galaxy on the upper left utilizes the motor module to spin at a different rate based on data from the UV sensor. The young boy seated on the beach (a self-portrait) employs the sound module to play increasing bars of the Mario Brothers theme song as its owner creates more drawings in his sketchbook (tracked with the button). The visualization on the top right, is a 11-year-old boy’s version of a vibrating Tiki mask; it responds to the number of cups of water he drinks in a given day. Lastly, the eye of the octopus changes color from red to green as its owner spends more time reading. Table 7.1 highlights the mural artifacts created by each of the participants.

The mural was very well received by the children, with participants describing it as “awesome” and “cool.” Two of the participants were keen on showing it to their parents as they came to pick them up. Although progress on the mural was initially slow, it gradually intensified over time since contributions were publicly visible. The sample visualizations (Section 3.6) were helpful in scaffolding creativity and seeding initial ideas. It should be noted that even though we only recruited 9 participants, the mural was a clubhouse effort. Children younger and older contributed to various aspects of the mural, such as painting the background, even though they were not involved in the study.

We definitely observed a great deal of social interaction around the mural, especially as it was starting to take shape. Participants would often be motivated by each others work. P4 and P5, who
were close friends, would often see the progress of the other and work on their own ambient modules. P4 would often ask, “What did [P5] work on last time? His thing [Cosmo cartoon character] is getting better every time I see it.” Children also learned from each other on the best ways to accomplish various goals. For example, with the RGB LED module, we taught a few children how to diffuse light using vellum paper (a type of translucent paper). These children were often helpful in disseminating this knowledge to others working on similar LED modules. Even when children were finished with their respective modules, they would contribute to other aspects of the mural, such as painting bushes, flowers or adding stars. As one 11-year-old girl (P7) summarized, “It is nice to make something for the clubhouse together. We spend so much time here.”

7.4.4 Wearables

The idea of crafting wearable devices to track health received a somewhat mixed response. Individual designs in this space generally fell into two camps: those that focused exclusively on functionality; and those driven by appearance and aesthetics. Generally, the students who had favorable prior experiences with electronics (5 participants) from robotics clubs or otherwise focused on functionality, while crafters and artists (4 participants) identified with aesthetics.

![Figure 7.4: Pencil pouch with a felt flower design that houses the button and microcontroller base. The button is hidden in the eye of the flower.](image)

The participants who associated with appearance and aesthetics were hesitant to start craft-
ing the wearable citing their minimal experience with electronics and programming. However, once it was explained to them that the wearable was already mostly programmed and that it only required their choice of sensor, they were much more willing. Participants who were uncomfortable with electronics definitely needed some assurance that staff members and researchers would be there to help them if they were stuck. This group produced some of the most beautiful designs of the study. Figure 7.4, showcases a pencil pouch with a felt flower designed by a 12-year-old girl (P8) who was interested in tracking her drawing and coloring habits. The button that is used to track the habit is artfully hidden in the pistil or eye of the flower. Since the pencil pouch holds her coloring pencils, the flower accessory is aptly placed as a reminder.

Figure 7.5: A sports themed book cover for a sketch book that houses the button and microcontroller base. The button and wireless module extend through the felt.

Similarly, another burgeoning artist (14-year-old boy, P6), designed a felt book cover for his sketchbook (Figure 7.5) to track his daily sketching practice. As an avid sports fan, the book cover highlights his favorite sports team mascot. A somewhat more playful design by a 11-year-old girl (P7) is shown in Figure 7.6. This panda backpack accessory, created with felt, fabric glue, and safety pins utilizes the UV sensor to track her time spent playing outside. Rather than permanently fastening the wearable device to her backpack, the participant wanted something she could easily transfer from bag to bag.
In a similarly inspired design, as a consequence of interaction between P7 and P4, P4 used a felt cutout of his own hand 7.7 to house the wearable for tracking his daily guitar playing habits. When asked why he chose his own hand shape, he remarked, “Well I play the guitar with this hand, so it makes sense to have it be my hand...to remind me.” The participant however chose to carry the artifact in his backpack rather than secure it to the front like P7.

Participants who were primarily interested in the functionality of the device did not spend as much time crafting the wearable. They wrapped their devices inconspicuously using whatever materials were furnished or used the provided case. Figure 7.8 shows how two participants less
interested in crafting the wearable chose to integrate it into their lives. P2, on the left, stored the tracker in his shoulder bag which he always carried, and P3 used the provided 3D printed case to carry the device in his pocket. Although the wearable did not require much programming, other than selecting the necessary sensor in the Arduino programming environment, functionality-driven participants were more willing to experiment and see how it worked with their crafted visualizations.

Figure 7.8: Wearable tracker stored in a shoulder bag and utilized with 3D printed case for pocket use

Perhaps, the most interesting aspect of the wearable device was that it was hardly used (strictly speaking) as a “wearable.” Children primarily used it as an accessory to items they already had or carried it like their mobile phones. When we probed into this issue, children cited the difficulty of making something truly wearable. As one participant (P7) commented, “Well if I want to add it to my shoe, I gotta think about all sorts of things...if I add to my backpack, it is just a lot easier.” Another participant (P3) brought up the issue of context and articulated, “Why would I want to make it wearable? I want to track how much I read.”

Overall, while the wearables worked as expected, we did face a number of issues while deploying them. Children often did not securely fasten the wearables. As a result, we had to replace two of the wearable boards due to accidents. Another issue we experienced was with the button module; there was a tendency for a lot of false positives since the button could be easily triggered. The pencil pouch and the book examples faced this issue since they were usually carried with other
items in a backpack. We had to create a small plastic cover to protect the button in these cases.

### 7.4.5 Crafting and Programming

Children were very comfortable with crafting the wearable and the ambient modules. As one 12-year-old girl (P8) said, “Well I have painted, glued stuff, and sewed and done all these things before at the clubhouse, so it wasn’t that hard.” There was however, a tendency to focus on the ambient modules more than the wearable. We attributed this outcome to the social and public aspects associated with creating the mural as opposed to the individual nature of crafting the wearable. This idea was endorsed by P6, the oldest participant, who commented, “Well I spent a lot more time drawing the self portrait on the computer because it was something others would see and I wanted it to look good. The Denver Broncos cover on my sketching book, that was just for me.”

Although children were expressive and creative with the craft portion surrounding the technology, they were less inclined to modify or program the technology itself. With the ambient modules, children often accepted the default behaviors changing only minor aspects of the system such as the color transition scheme of the RGB LED module or the spin rate of the motor in the Arduino programming environment. A few participants however, did spend considerable time customizing their ambient modules. For example, P6 and P8 wanted the sound modules to play specific theme songs. P6 wanted the Mario theme song played for the self-portrait he had created and P8 wanted the Little Mermaid theme song played for Ariel the mermaid. While the participants found the theme songs online and converted it to usable tones for use with the ambient microcontroller (with help from Gold Crown staff), they needed considerable help programming the ambient module. They found the programming aspect frustrating and confusing at times, but these two participants were heavily motivated to get their songs playing. The resulting modules however, received many accolades from their peers. P8 remarked, “Oh my god, my friends thought this was so cool! I can’t believe I made that!”

With respect to the wearable, participants often chose the default behavior associated with
the UV sensor or the button. Even though the wearable base could store sensor data for multiple weeks, and the ambient modules could respond to aggregated weekly data, participants chose only to reflect the current day’s data. Thus, the ambient module would only respond to the button presses or the outdoor exposure data for the prevailing day. In a sense, children expected the wearable and ambient modules to simply work. Although children in our study were generally less interested in programming the system, they were appreciative of being able to track what was important to them. As one 12-year-old boy (P4) commented, “I’ve been trying to get better at playing the guitar for a while now. Sometimes I forget, sometimes I have too much homework. It is nice that I can use this [referring to the wearable and the Nemo ambient module] to remind me.”

7.4.6 System Usage

During the 2-week trial, we observed a general excitement around the mural as children approached and examined their ambient artifacts. Participants were well aware of their connection to the mural and often commented on how the artifact changed in response to their behavior. P8 remarked, “I drew and colored today...and I noticed that after I pressed the button, the Little Mermaid theme song played more.” Children had a tendency to use the wearable more the day they were attending the clubhouse. For some participants this was because they were more likely to perform their self-selected activities during clubhouse hours. Activities such as drawing/sketching (P6, P8), painting/coloring (P8), or recording music (P9) were generally clubhouse related activities. For other participants, the clubhouse and the mural served as a reminder to work on their self-selected wellness habits. As P1 articulated, “I ate 3 fruits today. I knew this thing [referring to the pinwheel] wouldn’t spin otherwise.”

We also observed that participants who invested more time crafting the wearable, generally used\textsuperscript{1} it to a greater extent when compared to their less devoted counterparts; this was true of

\textsuperscript{1} Usage was defined with respect to each participant’s goals. So for example, if a child’s used the button to track a personal goal of 3 fruit servings per day, and she pressed the button 3 times on any given day, we would label that as sufficient or good use of the system. We acknowledge that this an imperfect method of measurement given that we don’t have an established baseline for each participant. However, it is useful for just getting a general relative idea of usage.
all 4 participants who spent more than 90 minutes (approximately two clubhouse visits) crafting their wearable. The children who produced the 4 artistic designs showcased in Section 7.4.4 were the same children who used the wearable the most. We identified two reasons why usage was higher with this group: 1) The device was contextually crafted and was convenient to use; and 2) Participants had a clear sentimental or personal attachment to the crafted object. For both P6 and P8, the button for tracking their respective sketching and coloring habits was located on the object required for their practice; in the case of P8 the button was conveniently located on the color pencil bag (Figure 7.4) and for P6 the button was on the sketching book itself (Figure 7.5). As P6 confirmed, “It is hard not to press the button...it is right there [referring to the sketching book].” The other two participants, P7 and P4, expressed a more sentimental attachment to their crafted devices. The 11-year-old girl (P7), who crafted the panda bear backpack accessory (Figure 7.6) expressed, “It is so cute. I love carrying it around”. The 12-year-old boy (P4), who crafted the guitar hand (Figure 7.7), recalled a memory of clay hand prints he made with his siblings when he was younger. His crafted felt hand, often reminded him of that wonderful occasion.

We saw light to moderate use of the system with participants who were less interested in crafting the wearable. We noticed that personal goals were occasionally met, especially on clubhouse days. Participants who used the button to track self-selected behaviors, tended to use the device in batch mode, often pressing the button multiple times at the end of the day. Initially, we were concerned that children were perhaps gaming the system, or had some misplaced sense of obligation to us. However, when we questioned them as to their usage patterns, they often cited misplacing the device at home or forgetting to press the button. As one of our most straightforward participants, P3, remarked, “I did read my book 3 times today. I just forgot to take it [the wearable] with me in the morning. So I pressed the button 3 times at night before bed.”

When we asked participants to reflect on their health crafting experiences, they expressed joy at being able to see a personalized reaction from the mural. From a wellness perspective, one participant likened the mural to a reminder system. P9 commented, “Well it is nice to see something change because you did something. Sometimes you forget and it helps you remember.”
"I know my galaxy didn't spin for a couple of days, cause I didn't do nothing [laughs]" Another 13-year-old boy (P5) mentioned the tangible and public nature of the mural, "I mean it is huge and it is right there. Everyone can see if your piece ain't shinin, that you didn't do anything." Lastly, during the two week evaluation, we observed a slight decline in system use as children became acclimated to the mural. However, by the end of the study, many of the participants were already considering making modifications or adding other ambient modules.

7.4.7 One Month Follow-up

We received mostly favorable feedback from the participants a month after the study. In fact, some of the participants were still working on the mural and adding ambient components. Although we still continued to receive data from the wearables, it was somewhat sporadic. When we asked participants to reflect on their experience, they mostly expressed how fun it was. They often gestured at the mural, and pointed to their particular contribution. Some of the responses included:

“That was a good project. It took a while, but it is nice that it is mounted on the wall now.” (P2, 11-year-old boy)

“My friends think it is soooo cool. I keep telling them not to touch the pieces [ambient modules]. I’m afraid they will break.” (P8, 12-year-old girl)

“This was way better than the bottle cap mural we did.” (P1, 12-year-old-boy)

When we asked participants if the system was helpful in tracking their self-selected behaviors, we received very candid and thoughtful responses. P2 remarked, “I know I drank more water. Not all the time but at least some time.” The oldest participant (P6) was somewhat unsure of his answer. He commented, “Hmmm...I think so. I mean it was easy for me to choose sketching because it is something I like doing and just wanted to do more of anyway [long pause] it might have helped.” Other participants reflected on how they were too optimistic in their goal setting. P3, who wanted to read more, had this to say, “I think I got it wrong when I said I wanted to read
3 times a day. Reading can be hard and sometimes it can take a while. I should have said like 2 times.” For one participant (P1), the system simply did not work as he envisioned. He remarked, “I was eating more fruits in the beginning and once I saw how fast the motor could go, I just kind of stopped. I liked making the mural though.”

In general, participants had mostly positive comments regarding their health crafting experience. Unsurprisingly, the few negative comments dealt with the programming aspect of the system. P9, a 12-year-old girl, expressed, “I just had so much trouble with the programming part. It was not easy for me.” Another participant (P2) suggested making the wearable smaller, citing that it was at times too big to carry around in his pocket.

7.5 Discussion

Overall, our study provided promising results in support of the health crafting approach for middle school children. Although the craft portion of the study was more popular among children, we did find healthful thinking among participants. Several key themes emerged from our experiences and observations.

7.5.1 Is it Really Health?

Much like the children in our preliminary prototyping study (Chapter 6), participants perceived themselves to be relatively healthy. One 13-year-old boy (P3) was extremely clear that he wasn’t all that interested in his health (Section 7.4.2). While this may seem startling from an adult perspective, past studies have shown that this mis-perception of health, especially weight status, is highly likely among children [84].

In our study, this notion of health and what it means to be healthy was questioned and interpreted differently by children. Traditional adult measures such as diet and physical activity often took a backseat to more personal wellness metrics. Children chose, coloring habits, time spent playing outside, or playing musical instruments as representative measures of health. While one may argue that this is not health, we strongly feel that it is important to start thinking about health
from a child’s perspective. Moreover, it could be argued that the wellness metrics that children chose are an important aspect of mental health. Reading because you “feel good afterwards” (P3) or wanting to play the guitar more (P4) are holistic measures that account for individual and personal habits. Even as adults, we have habits that might not be related to physical health but are crucial to our well being. Talking to our grandparents for example, or building airplane models might very well be the activities that give different individuals a sense of calmness in their daily lives.

For children, these wellness metrics may be a great starting point for thinking about more traditional health metrics in the future. Rather than forcing a particular health agenda on children, we strongly feel that having them think about their own health, in a manner they are comfortable with, is a necessary stepping stone towards the types of health activities (e.g., running, eating more fruits and vegetables) we as adults consider necessary. Strategies such as goal setting learned by children during this process are transferable to other activities in the future. A child that learns how to set reasonable goals for improving their sketching habits, may use that same skill in learning how to eat more vegetables in the future. Even in our modest study, there was some evidence of children reflecting on their goal setting processes. The 13-year-old boy who wanted to improve his reading habits reflected on how he should have set his daily reading goal to twice rather than thrice a day. We argue that this awareness and understanding of one’s own thought processes is important for establishing any kind of health behavior in the future.

7.5.2 Wearable Device Design: Context and Automation

As alluded to earlier, an interesting result of our study was that the wearable device was scarcely used as a wearable. To some extent, this was a consequence of the types of activities children wanted to monitor. Monitoring your fruit consumption habits, as one 12-year-old boy wanted (P1), hardly requires a wearable tracker. However, what stuck us as fascinating was how important context was to the successful use of the device. With two of our children, the wearable was crafted directly to an object related to the activity they wanted to track. The pencil pouch with
the felt flower design for tracking coloring habits and the sports themed book cover for tracking sketching habits were both wonderful examples of context sensitive design. Both these participants were excellent users of the system despite having to enter all their data manually.

One of the issues with manual data entry is that users often forget to enter their activity or write down their progress. To address these issues, technologists and researchers have raced towards automating data collection. However, another approach might be to attach electronic devices to artifacts that are contextually related to the activity. Instead of having a mobile phone and entering data periodically, a simple device attached to an contextually related object might serve as an good reminder to enter data for activities that are typically hard to automatically track.

Additionally, the manual entry of data might help users ultimately reflect on the activity they are doing. We must acknowledge, however, that there is a tradeoff here; if we do not automate data collection enough, then we place a heavier burden on the user to manually track the information. But if we automate too much, then we rob the user of opportunities for reflection. It may be that children who did not contextually craft the device may have benefited from automated data collection. However, other researchers in the area of personal informatics have found that a full automated system sometimes hinders users from keeping track of and making sense of their physical activity data [52]. The researchers suggested areas for further study including the need to explore an appropriate balance of automated technology and user control. In the case of children, a manual approach might be helpful in guiding them in the habits of reflection.

7.5.3 Personal Valuation and Meaning

Perhaps, one of the several strands of research that have influenced our ideas has been the work of Norton et al. on the valuation of self-made products [70]. In a series of experiments where consumers assembled IKEA boxes, folded origami, and built sets of Legos, they found that people empowered to make their own objects value these objects as much as expert made objects. This finding, called the “IKEA effect,” is true even for people who profess less interest in “do-it-yourself” projects [70]. Based on this finding, it seemed reasonable to expect that children would also value
their self-made health technologies. It was unclear however, if value would translate to increased usage. In our study, we found some preliminary evidence that participants who spent more time crafting the wearable also used it more in their daily lives. We hesitate to push this finding too far since we only had 4 participants craft their wearable for over 90 minutes. Moreover, we only had a short 2-week evaluation period where participants actually used the device. Nonetheless, the idea of crafting personalized health technologies might have potential for facilitating greater adoption.

While adoption is important, the health crafting idea is salient because it gives children a sense of control over their environment and health. The health artifacts they created supported personalized habits and had the capacity of sentimental value. The felt guitar hand brought back fond memories to the 12-year-old boy; it was symbolic of existing relationships and family. Although, this sense of meaning can exist with non-crafted objects (“Why We Need Things” essay in [56]), crafting tangible objects has the added benefit of facilitating learning and “sense making” in the real world [74]. Moreover, since the health mural was public in nature, children were able to see each other’s ideas, borrow from them and present their own in a community atmosphere. Seen from this lens, health crafting also has the ability to support a cultural and social approach to health.
Chapter 8

Study 4: Case Studies

In our previous study (Chapter 7), we explored health crafting from a social perspective where children in a tightly-knit community crafted a health mural for tracking self-selected behaviors. In this study, we wanted to examine health crafting from a personal, private and individual perspective. We thought these two studies would form an interesting juxtaposition of different use cases. We briefly debated whether we should design the study as part of a health education curriculum, however, we found the phenomenon of self-selected wellness behaviors interesting enough to continue exploring further. We wanted to see if children would tinker with their wearable and ambient modules further and if this would lead to other healthful thinking or behaviors. Thus, the objective of this study was to examine health crafting with a small number of participants (n=4) for a longer period of time (1-month evaluation). Ultimately, these four participants would inform individual case studies into the health crafting approach.

8.1 Study Location

Our study was conducted in collaboration with Gold Crown Enrichment, an after school program in Lakewood, Colorado. This was the same study site used in our previous field trial (Chapter 7). A more detailed description of the after school clubhouse is provided in Section 7.1. At the time of this study, we had already volunteered over 180 hours mentoring and tutoring children in the clubhouse. We had an excellent relationship with both the clubhouse staff and children.
8.2 Participants

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<th>Name</th>
<th>Sex</th>
<th>Age</th>
<th>Ethnicity/Race</th>
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<tbody>
<tr>
<td>Marvin</td>
<td>Male</td>
<td>12</td>
<td>Hispanic</td>
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<tr>
<td>Lisa</td>
<td>Female</td>
<td>11</td>
<td>White</td>
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<tr>
<td>Macey</td>
<td>Female</td>
<td>12</td>
<td>White</td>
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<tr>
<td>Spencer</td>
<td>Male</td>
<td>13</td>
<td>African American</td>
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Table 8.1: Study 4 participant demographics

We recruited 4 participants, 2 boys and 2 girls, between the ages of 11 and 13. The children in this study had participated in our previous field trial of the system (Chapter 7). We recruited them based on their willingness to continue with a longer study. Table 8.1 summarizes the demographic information for each participant. All student names have been changed to preserve anonymity.

8.3 Methods

We scheduled the study for 6 weeks, allotting 2 weeks for crafting and development, and 4 weeks for the evaluation. We began the study with a brief semi-structured interview exploring each participant’s background and life. The sample questions used for this session is provided in Appendix E. Our goal here was to obtain a holistic picture of each child to better situate the future results. We also asked participants to fill out a brief survey to get an idea of their technology habits and what they thought about computing and programming in general (Appendix F).

During the 2-week development phase, children crafted and programmed their wearables and associated visualizations. We individually discussed their health or self-selected activity goals during this process. We asked children to set a reasonable goal for the activity they wanted to track. These goals were then programmed into the ambient modules. The limits they provided (e.g., “I want to read 3 times a day”) would help the ambient modules provide the appropriate feedback based on data from the wearable. We provided all the craft materials participants needed and were always available to help children with crafting, programming, or debugging. The procedures for the design and development phase of this study were similar to that of Study 3 (Section 7.3). Since
participants were already familiar with our system (having participated in the previous field trial), a detailed introduction to our wearable and ambient modules was not needed.

In the subsequent 4 weeks, we conducted an evaluation of children’s systems and held weekly Tinker Time workshops. We used these workshops to facilitate any enhancements, modifications or fixes to participant’s original designs. Tinker Time workshops were informal children could come anytime during the 3 hour period to work on their prototypes. We reminded participants that during this time, they could work on their prototypes, change batteries, download usage data, or just talk about electronics, computing, or their projects. No survey instruments were administered, but we recorded who attended and took observational notes. Some of the sample questions we asked during the Tinker Time workshops are provided in Appendix H.

During the first half of the evaluation, children took the crafted device home while their visualization remained at the clubhouse. In the second half, participants took their wearable device as well as their visualizations home. Our goal here was to elicit any system usage differences between a public (clubhouse) and a private (home) display. At the end of the study, we asked participants to fill out a brief survey (Appendix G) to see if their attitudes on computing and technology had changed (due to the study) and to obtain their overall impressions of the study. Participants received a $15 dollar gift card to Amazon for each 2-week period of the study for a total of $45 dollars for the full 6 week study.

8.4 Results

Originally, our study was scheduled to last 6 weeks. However, due to scheduling issues and various summer camp activities, the entire study took approximately 2 months. Children took roughly 3 weeks for the development phase and 5 weeks for the evaluation. It should be noted that this study was conducted in the summer of 2015. During this time children attended the clubhouse on a drop-in basis Monday through Friday from 1 p.m. to 5 p.m. Typically, participants frequented the clubhouse 2 days a week.
Figure 8.1: An updated version of the electronic health mural crafted originally in study 3. Three of the participants in the present study continued working on the mural and adding new components.

<table>
<thead>
<tr>
<th>Name</th>
<th>Study 3 Mural Artifact</th>
<th>Study 4 Mural Artifact</th>
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<tbody>
<tr>
<td>Marvin</td>
<td>RGB LED: Nemo</td>
<td>RGB LED: Dragon</td>
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<tr>
<td>Lisa</td>
<td>RGB LED: Sun</td>
<td>Sound: Tweety Bird</td>
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<tr>
<td>Macey</td>
<td>Sound: Little Mermaid</td>
<td>RGB LED: Skull</td>
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<tr>
<td>Spencer</td>
<td>RGB LED: Octopus</td>
<td>None - Home artifact</td>
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Table 8.2: Mural artifacts created by the four participants in studies 3 and 4

As part of our previous field trial, the four children in this study along with five others had participated in creating a health mural to reflect self-selected wellness habits (Chapter 7, Figure 7.3). Individual ambient modules helped visualize data from the wearable. We highlight the mural again because all the children except Spencer showed renewed enthusiasm in working on it again. The majority of participants chose to craft another ambient module for the mural rather than craft
an individual artifact to take home with them. Thus, we were unable to do the 2-week at home evaluation as specified in the methods. Figure 8.1 shows an updated version of the mural with new modules added by three of the participants in the study. Table 8.2 highlights the different modules created by the 4 children in both studies. In the subsequent subsections, we provide detailed results from the four participants in this study.

8.4.1 Marvin

Marvin, is a boisterous 12-year-old boy perpetually running around the clubhouse going somewhere. He is currently in the seventh grade and his favorite classes are “gym and music.” He has a mobile phone but is only allowed to use it to call his parents. Although he has a computer at home, he prefers the computers in the clubhouse because they are generally faster. One of his favorite software applications is Sculptris (pixologic.com/sculptris/), a digital sculpting program he used to win the virtual Halloween pumpkin contest last year. Minecraft (minecraft.net) is another popular computer game he likes to play but it seems to have lost favor this year. Marvin describes himself as an “ok student” and considers school to be a boring place since all he does is “sit there.”

Marvin has one younger brother who he describes as a complete menace. His brother is “always breaking things” in his opinion and doesn’t get disciplined by his parents nearly as much. Playing the guitar is one of Marvin’s favorite hobbies and he has been trying to get better at it for 2 years now. In our previous field trial, he designed the felt hand and the Little Nemo fish for tracking his guitar playing habits.

From a health perspective, Marvin describes himself as a fairly strong and robust individual. He likes playing basketball with his friends during gym hours and rides his bike twice a week to the clubhouse from his home. His favorite foods include Hot Cheetos (a cheese flavored puffed cornmeal snack) and pizza. Although he is aware that Hot Cheetos is unhealthy, he rationalizes his physical activity as compensation for this unhealthy eating habits. He commented, “I mean I run around so much, so it really doesn’t matter right. I haven’t put on fat or anything.”
During the initial design phase of the study, Marvin wanted to continue manually tracking his guitar playing habits with the felt hand backpack accessory he developed in the previous field trial (Chapter 7, Figure 7.7). He remarked, “I did so well and played guitar like everyday. I wanna keep doing it.” However, he wanted to change his mural module since he felt that the Little Nemo fish (Figure 8.1, middle bottom) was “lame.” He wanted something much bigger and imposing. When we asked why he wanted to continue working on the mural instead of building a personal display to take home, he exclaimed, “Are you crazy? My little brother will destroy it.” He also liked the public nature of the mural and commented how not as many people would see it at home. Figure 8.2 shows the fire breathing dragon he created for the mural using the ambient RGB module. The light from the module is diffused through vellum in the dragon’s fire. Unlike the previous field trial this particular module tracked his guitar playing habits weekly instead of daily. He asked, “Well last time I did it, it would just change because I played [guitar] that day. Either on or off. Can I make the fire brighter as I play more in the week?” Marvin’s personal goal was to play everyday, but as the punch card graph in Figure 8.3 shows, he was able to play four times a week for two weeks.
Figure 8.3: Punch card graph of Marvin’s guitar playing for the first 2 weeks. He started the evaluation on a Tuesday. He played the guitar 4 times a week.

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Figure 8.4: Marvin’s accelerometer based activity tracker decorated with electrical tape and Batman sticker

We show only a 2-week time period in the graph (Figure 8.3) because Marvin decided he wanted to track his physical activity instead of his musical habit midway through the study. In one of the Tinker Time sessions, he explained, “I can get it (dragon’s fire) to light up pretty good. I think it might be [time] to change and do something else [pause] maybe nice to know how much I move around and stuff.” At this point, we quickly added an accelerometer module and some rudimentary activity tracking code to the wearable platform. We continued the study after a brief two day development hiatus. Figure 8.4 shows the accelerometer module along with the microcontroller base in a 3D printed case. Marvin, decorated the case with black electrical tape and added a batman sticker. He carried the device in his pocket and his daily goal was to do 3 hours of physical activity as measured by his general walking movement. Initially, when he received the new device, he ran around the clubhouse for an extended period of time to make the dragon fire illuminate. He switched the dragon module at this point to reflect daily rather than weekly
activity since he wanted more immediate feedback.

Figure 8.5 shows Marvin’s physical activity data (downloaded from the tracker) for the subsequent two week evaluation. On the days where there is no activity, he simply forgot the device at home. We can clearly see that he overestimated his 3 hour physical activity goal. There is also a clear Tuesday and Thursday pattern of activity; these are also the days he attends the clubhouse. Towards the end of the evaluation, Marvin reflected, “I think the button was a lot easier. You press it because you did something. Here, I am not sure how much I actually did.”

Figure 8.5: Bar graph of Marvin’s physical activity for a 2-week period. His target goal was 3 hours of physical activity.

8.4.2 Lisa

Lisa is a 11-year-old girl who describes herself as complex and classy. She is very articulate and outspoken and is often seen managing disputes in the clubhouse. As a sixth grader her favorite classes include art and social studies. In her own words, “I like art because it can be whatever you want it to be. There is no right or wrong. I like social studies because you learn about how different people live their lives. There are also a lot of field trips with social studies.” She considers herself an average student and dislikes doing homework more than anything. Lisa’s parents recently gave
her a mobile phone for emergency purposes but she uses it to text her friends. She would “much rather talk to her friends than sit in front of a computer all day”. When she does use a computer (either at home or at the clubhouse), she mostly watches Youtube music videos, searches for design ideas on Google images, or reads tutorials for craft projects.

Lisa has a “nosy” younger sister who according to her “always follows her around like a puppy.” They both live with their mom in a single parent family. She is very close to her mom but finds it difficult to spend time with her because her mom works multiple jobs. When they do find time together, their favorite activities include cooking, baking and knitting. Lisa doesn’t play a musical instrument but spends at least an hour daily listening to music or watching music videos. Her current favorite song is “Uptown Funk” by Mark Ronson. In our previous field trial, Lisa designed the panda backpack accessory and the color changing sun to track her playing time outside.

Although Lisa considers herself healthy, she is very conscious of her appearance and personal hygiene. She reports washing her hair everyday and always wearing fresh clothes. With respect to diet and exercise she has mixed feelings. She commented, “I don’t want to be fat. But I also like eating cookies. I think it [is] important [to] exercise if you eat bad stuff.” Exercise in her view (much like Marvin) is a type of remuneration for unhealthy eating. However, exercise by itself makes less sense to her unless it is also with friends in a social setting, such as playing tag outside.

Lisa’s initial interest in this study was focused around the mural. In the previous field trial, her best friend Macey had developed the mermaid module that played increasing bars of the Little Mermaid theme song. She expressed wanting to do something similar with the sound module. When she learned that the sound module had some default built in sounds (e.g., cats meowing, birds tweeting, dogs barking), she decided to build a Tweety module; Tweety is an animated fictional yellow canary. The module she designed for the mural is shown in Figure 8.6.
Figure 8.6: Lisa’s Tweety Bird using the sound module. The bird’s chirps are tied to her knitting practice.

Much like Marvin, Lisa also appreciated the public and social nature of the mural. She remarked, “It is nice that everyone can see it. Also Macey and I can work on it together.” She definitely found programming the module difficult and commented, “This is really hard. I’ve never done anything like this before. I am glad you (referring to researcher) are here.” She was encouraged however by Macey who had prior success with the mermaid module and was determined to get the bird tweeting. For this study, she chose to have the bird reflect her knitting activity. Her personal goal was to knit at least 4 times a week. Although knitting was a personal hobby of hers she commented on how it was an activity she enjoyed with her mom. She expressed, “Well my mom works a lot. So when we have time together this (knitting) is one of those things we do.” Knitting was perceived as a binary activity; she either knit on a given day or she didn’t. As a result, she chose to have the bird tweet the number of times she knit for the week. Since she changed her tracked habit from time spent outdoors (field trial) to knitting, we asked her for possible reasons for the change. She disclosed that she simply lost interest in the other metric and wanted to do
something new.

Lisa crafted a felt flower with the button and microcontroller to track her knitting hobby (Figure 8.7). The flower is constructed in layers based on a pattern she found on the internet. The button is located in the center of the flower. She carried the flower accessory in her backpack and mentioned how she would keep it by her “knitting stuff” at home.

![Figure 8.7: Lisa’s button tracker in the shape of a flower for monitoring her knitting hobby.](image)

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Figure 8.8: Lisa’s knitting punch card for 4 weeks. She started the evaluation on a Wednesday.

Figure 8.8 shows Lisa’s knitting punch card for the four week evaluation based on data from the tracker. She knitted sporadically through the work week and at least one of the days on the weekend. She remarked, “The weekends are nice because my mom is usually home at night so we can knit together.” A bar graph of the same data is provided in Figure 8.9; the start day for each week was Wednesday. Lisa was able to knit at most three times a week and during the last two weeks there is a slight drop-off on the number of knitting sessions.
Towards the end of the study, Lisa reflected, “I guess 4 times [a week for knitting] is kind of a lot. I thought I could do it but maybe I should do like 3 or something.” With respect to the chirping bird module, she remarked how it was nice to hear the bird chirp on the days she brought in the module from home. She remarked, “When I came to clubhouse and heard it chirp...I was like oh yeah I should knit today.” The ambient module served not only as feedback module to her knitting habits but also as a kind of basic reminder system. She also added how it might have been nice to have a similar bird at home to remind her to knit everyday.

8.4.3 Macey

Macey is a tall, soft-spoken 12-year-old girl, with strong artistic sensibilities. She is almost always sketching, coloring or painting on a variety of materials. One of the clubhouse staff members describes her as, “artistically gifted for her age.” She is currently in sixth grade and her favorite class as expected is art. She remarked, “I really like drawing and painting ’cause you can express how you feel. Sometimes when you are sad your drawings are also sad. When you are happy, it is also happy.” Apart from art, Macey finds most of the classes in school hard and uninteresting. She
Macey has a younger brother who she often takes to the park near their home. She enjoys spending time with him and remarked, “I wish he could come to the clubhouse with me, but he is a little too young.” During clubhouse hours, she spends most of her time with Lisa (same as in the study), her best friend. In our previous field trial, Macey tracked her drawing and coloring habits manually (e.g., button) with a pencil pouch accessory. The accessory communicated with a sound module that played increasing bars of the Little Mermaid theme song.

From a health perspective, Macey has a tendency to conflate thinness with healthiness. She commented, “I am pretty thin. I can eat whatever I want and I can’t get fat.” While she understands that fruits and vegetables are good for her, they are less a part of school culture and meeting with friends. She remarked, “When I’m with my friends, I mostly eat whatever. But at home with my parents they make sure I eat veggies and stuff. So it is not so bad that I eat other things.” Parents in her view are responsible for preparing healthy meals, providing some justification for her unhealthy eating habits between meals. With respect to physical activity, she considers her social activity with her friends to be enough.

During our initial conversations with Macey, she revealed that she had four dental cavities based on a recent visit to the dentist. She expressed concern over her lack of good brushing habits. She commented, “I always forget to brush my teeth. Sometimes at night I just fall asleep without brushing. When the dentist told me I had four cavities I was worried my teeth would fall out.” Her desire to brush more regularly was also inspired by her wish to be a better role model to her younger brother. She remarked, “My little brother always does whatever I do. If I don’t brush he won’t either. He is a little butt sometimes.” As a result, Macey concentrated on the button tracker first before developing the ambient visualization. She created a plush felt tooth (Figure 8.10) with clothing buttons for eyes and the tracker’s button as the nose; the tooth is filled with a small amount of polyester fiber stuffing to create the soft plush effect. She carried the plush toy in her backpack.
Figure 8.10: Macey’s plush tooth doll with button tracker. The green button serves as the nose of the doll and is used to track her dental brushing habit.

Figure 8.11: Macey’s skull utilizing the RGB LED module. The right eye is covered in vellum paper and diffuses the light from the module. The module responds to her dental brushing habit.

Macey created an artistic skull (Figure 8.11) for the mural to visualize the data from the plush felt tooth. The skull, inscribed with the motto “Don’t let life pass u by,” utilized the RGB LED module behind the right eye. A small piece of vellum paper helped diffuse the light from the module. Macey’s goal was to brush her teeth twice a day and have the ambient module serve
as a reminder system for the given day (as opposed to weekly). The module used a simple traffic light pattern with red, yellow, and green representing 0, 1, 2 brushing sessions respectively. While working on the ambient module she commented, “After the mermaid (referring to her previous mural module in the field trial), this should be a snap.” Although a separate ambient visualization, one that could be taken home, would have served her daily needs better, Macey was enthusiastic about working on the mural with her friend Lisa.

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Figure 8.12: Macey’s teeth brushing punch card for 4 weeks. She started the evaluation on a Monday. Orange means she brushed her teeth once for that day and green means twice.

Figure 8.12 shows Macey’s dental brushing punch card for the 4-week evaluation. The general pattern of brushing at least once Monday, Wednesday and Fridays coincides with her clubhouse days. She commented on her behavior, “When I come to the clubhouse I remember…oh I am doing this thing. I should probably brush my teeth. At home, I don’t have the skull to remind me, so I forget to push the button. Sometimes though just having the tooth reminds me. I look at it and I am like oh I gotta do that.” Even though the tooth doll itself served as a gentle reminder, Lisa was only able to hit her daily goal 2 or 3 days of the week. A bar graph from a weekly perspective shows a general decline in either system use or dental brushings over the four weeks (Figure 8.13).
At the end of the study Macey reflected, “I think having something at home makes more sense. I mean if I had the thing by my bed table I would see it right before I go to bed.” The recognition that perhaps a different approach might satisfy her needs prompted a general discussion about the overall system. She remarked, “Well it is really nice that you can make your own stuff. I mean if one thing doesn’t work you try something else. Also if you like making and drawing and coloring like me then this is great. The tooth doll was so cute and cool.”

8.4.4 Spencer

Spencer is a quiet, undemonstrative 13-year-old boy who is liked by all clubhouse staff members for his polite manners. He is currently in eighth grade and lists English and science among his favorite classes. He describes himself as a fairly good student and tries to finish his homework as soon as he returns home. Although he does not have a mobile phone, he often uses his father’s phone to play games. Spencer is fond of computers and electronics and has experimented with Scratch and Arduino in the past. As a member of the clubhouse robotics program, he participated
in the middle school Lego Mindstorms competition this year. While the team didn’t get very far, he describes the experience as “fun and hard.”

Spencer does not have any siblings but has a pet goldfish he overfeeds. He reports that he has had to replace the goldfish thrice. Some of his favorite hobbies include reading and playing video games on the computer. Although he doesn’t play a musical instrument, he has often thought of taking up the violin. In our previous field trial, Spencer tracked his reading habits and reflected the data in an RGB LED octopus.

When it comes to health, Spencer candidly admits his lack of interest (Section 7.4.2) in the subject. He does not consider himself extremely healthy or unhealthy; he feels he is somewhere in the middle. While he enjoys playing basketball with his friends, he does so infrequently and concedes that he is “not very good at it.” With respect to diet, Spencer is somewhat ambivalent. He comments, “I mean I know eating fruits and veggies are good for you, but I also really like hot dogs. I think it is ok though. I don’t eat too many hot dogs.”

During the initial development phase of the study, Spencer expressed a renewed interest in tracking his reading habits. In the previous field trial, where he tracked the same habit, he reflected on how he was perhaps too optimistic in his goals. He remarked, “I think last time (field trial), I did it all wrong. I said I wanted to read 3 times a day but when it should have been 1 time. Even 1 time is hard to do on some days.” Thus, his goal for this evaluation was to read at least once a day. He was particularly excited about reading the Harry Potter novels he had been gifted. He mentioned, “It would be great if I could read a little every day before bed.” Spencer was also the only participant to express an interest in developing a personal standalone visualization. When we explored the issue further, he commented, “So last time, the octopus (the ambient mural module he made) was here in the clubhouse. I had to come to the clubhouse to see it change. Sometimes I hadn’t read for the day yet, so it didn’t do anything. It makes more sense if I have it at home. This way it can remind me.”
In keeping with the Harry Potter theme, Spencer created an LED lantern for tracking his daily reading habit (Figure 8.14). The lantern is based on a design he found on the internet. It is made from a clear plastic gift container with crushed red tissue paper decoupaged to the surface. A small piece of jute cord tied around the top accents the lantern. The RGB LED module along with the associated circuitry is located inside the lantern, and it is powered with a 5V wall adapter that is fed to the circuitry through a small hole in the back. The associated tracker, also pictured in Figure 8.14 is similar to Spencer’s previous design in the field trial. For this iteration however, he decided to move the button out of the provided case; he also decorated the case with stickers and yellow tape to give it a more rustic look. He designed the lantern and tracker to reside in his room and exposed the button to make it easier to activate, especially since he no longer needed to carry it in his pocket. Since, Spencer’s goal was to read at least once a day, he decided it would make more sense if he tracked his reading habits weekly. Thus, the lantern would transition from
red to blue as he read throughout the week.

Figure 8.15 shows Spencer’s reading punch card for the 4-week evaluation. It displays promising effort on the weekdays and a small drop-off on the weekends. Spencer explained that he often had family outings or commitments on the weekends that prevented him from reading regularly. Figure 8.16 shows a weekly bar graph of the same punch card data. Although he did not hit his weekly goal, his performance was fairly consistent apart from the small decline in week three.

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Figure 8.15: Spencer’s reading punch card for 4 weeks. He started the evaluation on a Friday.

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Figure 8.16: Bar graph of Spencer’s reading activity for a 4-week period. His target goal was to read everyday.

At the end of the study, Spencer reflected on the nature of his reading habits. He remarked, “Sometimes I only read for like 15 minutes. But sometimes I was so caught up, I read for like an
hour and I thought, this should count for more than once.” He also commented on how nice it was to have the system at home. He expressed, “I put the button right next to my book. It was hard to miss. I would hit it and read. It was nice to have it so close.” With respect to his reading goals, he seemed keenly aware that he had perhaps set them too high again. He explained, “Well some weeks I didn’t make it all the way to the blue (referring to the lantern color). Maybe next time I set it to 5 times a week.”

8.4.5 eCrafting Survey

An auxiliary goal of our work was to examine children’s changes in attitude towards computing as a consequence of the study. We used eCrafting pre and post surveys (Appendix F, G) developed at the University of Pennsylvania for this purpose. We observed an overall increase in computing interest from our group of participants. However, we have too small a sample to warrant any general conclusions. We view the results as suggestive, but very preliminary.

In our analysis, we included 11 of the 15 statements from the survey that we felt were relevant to our age group. We excluded statements such as, “I am interested in a career in computing,” simply because participants did not know how to answer and had not given their careers much thought. In the graphs that follow, the negatively-keyed statements (e.g., lower score is better) are marked with a “n”.

Results from the surveys (Figures 8.17, 8.18, 8.19, 8.20) indicate that all participants made significant gains from pre to post in their reported self-efficacy in computing (‘I am good at computing” or “I know more than my friends about computers”), and their view that computing is less difficult than they initially conceived (“Programming is hard”). Marvin also made meaningful gains in his perception of computing as enjoyable and useful (Figure 8.17). Lisa, who was hesitant with programming and electronics in the study, shifted from a neutral view to enjoying computing and having confidence at it (Figure 8.18).
Figure 8.17: Marvin’s eCrafting pre and post survey results

Figure 8.18: Lisa’s eCrafting pre and post survey results
Computers are fun
Programming is hard (n)
Girls can have jobs in computing
Boys can have jobs in computing
Computer jobs are boring (n)
I am good at computing
I like computing
I know more than my friends about computers
I can become good at computing
I am good at computing
I like the challenge of computing
I think computing is useful
Computers are fun

Figure 8.19: Macey’s eCrafting pre and post survey results

Spencer
Pre  Post

I think computing is useful
I like the challenge of computing
I can become good at computing
I know more than my friends about computers
I like computing
I am good at computing
Computer jobs are boring (n)
Boys can have jobs in computing
Girls can have jobs in computing
Programming is hard (n)
Computers are fun

Figure 8.20: Spencer’s eCrafting pre and post survey results
Perhaps, the most notable pre to post changes belonged to Macey, who posted a 2 point improvement for questions related to computing self-efficacy and programming (Figure 8.19). Lastly, Spencer, maintained or improved his already favorable views on computing (Figure 8.20). This was unsurprising considering that he was the only participant with prior programming experience having participated in clubhouse robotics competitions. We want to stress that these results are by no means comprehensive. Rather they are exciting indications that the health crafting approach might be helpful in computer science education and in increasing students’ interest and engagement.

8.5 Discussion

When we initially designed this study, we wanted to explore health crafting from an individual perspective. We had hoped that children would craft personal visualizations that they could display both in the clubhouse and take home. However, we discovered that the majority of participants were more interested in the public and social nature of crafting. We could have asked children to build separate ambient visualizations for the purposes of the study, but as alluded to earlier (Chapter 4) real-life studies rarely follow a prescribed path (particularly with children) and take place in a social context. Having an open-ended approach, especially with exploratory work, leads to insights that might have been overlooked or missed in a more exacting study. In this section, we discuss some of our discoveries and situate the results within relevant literature.

8.5.1 Engaging Children in Health

First and foremost, we found it interesting that four of the nine children who participated in the previous 6-week field trial wanted to continue with a 2-month study. In many ways, this outcome is very telling of the engagement potential of the health crafting approach. We offer two reasons for this engagement. First, crafting is already an activity that is a part of children’s culture. Making is a form of expression which gives children control over their environment. Second, children have the ability to track activities that are important to them. Knitting with mom (Lisa), worrying over loss of teeth (Macey) or being a good role model to a younger sibling (Macey) are personally
relevant issues. Self-selected activities that stem from these issues are strongly tied to a state of mental and social well-being. Health crafting in this sense provides a holistic outlet for expressing health. It offers multiple entry points, either through craft or a personally relevant activity, for healthful thinking. In our study, Lisa’s initial interest was focused on the mural while Macey was concerned about her dental habits and concentrated on the button tracker.

This brings us to another crucial aspect of our work: the ability to support children’s changing needs and interest levels. None of the four participants in this study used their old mural modules from the field trial; they preferred to create new visualizations. Marvin described his old Little Nemo module as “lame” and Lisa lost interest in tracking her outdoor exposure (from the previous field trial). Moreover, Spencer was interested in developing a personal standalone visualization. This speaks to children’s dynamic and somewhat impulsive needs. Thus, health systems designed for them need to adapt to their experimental and playful nature. It may be that they arrive at a meaningful wellness metric after much trial and error. Marvin for example, initially wanted to track his guitar playing habits but then transitioned to physical activity half way through the study. While the transition didn’t necessarily lead to better results, it was a step in the right direction. Viewed this way, health is really a learning process that takes time. As Macey highlighted, “if one thing doesn’t work, you try something else.” The important element then is for technology to support kids in this learning process.

### 8.5.2 Public and Social Health Crafting

A pleasant outcome of our study was children’s continued interest in the mural. Marvin, Lisa, and Macey all decided to create new artifacts for the mural rather than design separate individual visualizations. This may have been due to the success of the mural and the momentum from the previous field trial, but as participants highlighted, there was a strong social component they felt was beneficial. Marvin enjoyed the public nature of the mural and commented how not as many people would see his creation at home. The best friends, Lisa and Macey, simply enjoyed working together on the mural. Their social bond gave Lisa the necessary confidence to craft the chirping
sound module, a task she considered challenging.

The public display of artifacts is reminiscent of Seymour Papert’s constructionist philosophy which places particular emphasis on the presentation and sharing of tangible objects. He argues that:

> the construction that takes place ‘in the head’ often happens especially felicitously when it is supported by construction of a more public sort ‘in the world—a sand castle or a cake, a Lego house or a corporation, a computer program, a poem, or a theory of the universe. Part of what I mean by ‘in the world’ is that the product can be shown, discussed, examined, probed, and admired. It is out there [72](p. 142)

In our study, the public display of health visualizations happened naturally, prompted in part by the already existing mural and by the need of participants to create a “public entity.” The mural essentially served as a low-risk canvas for their creative health expressions.

### 8.5.3 Binary Measures

Another interesting aspect of our results was how children used our health crafting toolkit. The button was by far the most popular method for measuring self-selected habits. This is somewhat understandable considering that habits such as knitting or reading do not readily lend themselves to automated measurement. However, and perhaps more importantly, the button has a hidden cognitive benefit; it is completely transparent. Children know exactly what is happening when they press it. When Marvin transitioned to the accelerometer for tracking physical activity, he was not exactly sure how it worked. He remarked how the button was a lot easier.

Moreover, when the button was placed contextually, it was useful for gathering activity data. Spencer, for example, placed the button along with the lantern next to the book he was reading. Similarly, Lisa placed her tracker next to her knitting bag. We received useful data from both participants. In light of this result, future trackers may simply be small buttons contextually placed on artifacts associated with various habits. For children this may be a simple way to support tracking of self-selected behaviors without too much of a cognitive burden.
Chapter 9

Discussion

It is interesting to note how the health crafting idea has evolved over the tenure of our research. When we first started our endeavor, we envisioned a purely wearable system with the visualizations built as part of the wearable. We imagined children would craft electronic brooches that changed color based on outdoor exposure, and vibro-tactile bracelets that responded to heart rate. However, we quickly discovered that children were hesitant to have on-the-body displays citing the need to “fit in” (Chapter 6, Section 6.4.2) and instead preferred to have ambient visualizations. As a result, our system changed to include both ambient and wearable modules. When we probed a little deeper, we also discovered that children’s ideas of health did not coincide with the traditional adult notions of physical activity and diet. They favored self-selected behaviors (e.g., reading, sketching, playing a musical instrument) that were important to them. At this point, we could have certainly asked children to consider adult health metrics, however, we felt it was important to continue exploring health from a child’s perspective even if it meant our research was not all that successful. This marks a shift in our own thinking, from adult views to hearing children’s voices. After all, adult health implements are not being naturally taken up by children anyway [94]. We believe our approach has provided some compelling results and speaks to a more holistic idea of health. In this section, we discuss some of the broader implications of our work from working with children to the role of technology for health awareness.
9.1 Self-selected Behaviors

The phenomenon of self-selected behaviors is perhaps one of the more interesting aspects of our work. While there were some participants that chose traditional dietary (e.g., fruit and water consumption) and physical activity (e.g., spending time outdoors) metrics, we found that the majority of children chose habits that they considered valuable to their well being. These personal indicators of wellness were manually tracked with a button. One of our initial concerns with self-selected behaviors was with negative habits such as watching television or playing video games. We feared that children would use our system to track these types of negative behaviors. However, we found it compelling that all the children chose positive behaviors without much prompting or guidance; children already had a general idea of what was good for them. In a sense, the button was used as a “do good” button to manage their worries, spend time with friends, improve their hobbies, or connect with their family. At the same time, the ambient modules served as a way to reflect that “goodness.” To some extent, it was not what children built with our toolkit but that they were willing to build with it. As alluded to earlier (Section 8.5.1), we believe that giving children the ability to track activities relevant to them was part of why they were so engaged.

Although, some of the habits children tracked such as coloring, sketching or playing a musical instrument are not traditional measures of health, we argue that these activities are important aspects of mental health. We also highlight the World Health Organization’s (WHO) definition of health established over half a century ago. It states, “Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity [71].” The metrics that children chose certainly fall within this definition of health.

9.2 Building Blocks for Healthful Thinking

In one sense, our work has not been very successful in promoting the critical habits (e.g., improved eating habits and increased physical activity) necessary for improving children’s health. Even the participant, who decided to monitor physical activity (Marvin in study 4) did not use
the wearable tracker regularly. However, as a consequence of giving children the freedom to choose self-selected habits, we observed them taking small steps towards self-regulation. We observed them setting goals, succeeding and failing, and reflecting on the results. These types of metacognitive activities are the building blocks of healthful thinking [89, 86].

We had a brief glimpse of a participant (Spencer) reflecting on his reading goals in the third study. However, it was really in the last study that we discovered more prominent hints of self-regulation. This was because the four children in the last study were also participants in the previous field trial. These children had essentially worked with us for over 14-weeks. As a consequence, we were able to notice subtle changes in their thinking over the duration of the two studies. Between the third and fourth studies many of the participants transitioned from reflecting daily to weekly activity in their mural modules. Marvin for example, even commented on the unsatisfactory binary nature of the mural module when reflecting the current day’s data (Section 8.4.1). Instead, he wanted the dragon fire to get brighter as he played guitar throughout the week. Similarly, Lisa wanted to track her weekly knitting habits using the chirping bird module. Participants essentially graduated to setting long-term goals.

We also documented instances of children reflecting on their goals. Spencer, who initially set a goal to read three times a day in the third study, commented at the end how it was too ambitious. He switched his goal in the last study to reading once a day and tracking the habit weekly. He further refined his goal to reading five times a week by the end of the study. Similarly, Lisa reflected how “4 times” a week was “kind of a lot” for her knitting habit. Marvin was one of the few participants who was satisfied with his guitar playing habits and transitioned to an “adult” health metric, physical activity. These cases are examples of children learning what it means to set reasonable and realistic goals. No doubt this process involves time and effort to get right. However, learning goal setting strategies are important for when children decide to track habits critical to their health.

Admittedly, the small steps that children took towards self-regulation was not purely due to health crafting alone. While the ambient modules did require goals in order to function (e.g.,
how many times do you want to read/knit/sketch per week?), adults were required to mediate the interaction and facilitate reflection. We feel this social element that requires a teacher or researcher to facilitate discoveries, guide problem solving, mediate attention and reflection is as much a part of health crafting as the system. Essentially, what we advocate is a form of “guided health crafting.” This practice is not unlike the concept of “guided discovery” in education [11]. In this style of teaching, students are encouraged to think independently to discover new and different approaches to a particular problem or skill. It is an inductive process that leads the student towards insights and generalizations rather than providing the answers. Thus, every learner will take out of the process something unique and personal.

9.3 A Trojan Horse Approach to Health Technology Design

As noted, many of the children in our study proved to be less interested in traditional issues of “health maintenance” and more interested in tracking self-selected behaviors. We received the impression that since participants perceived themselves as already healthy, they could easily justify behaving unhealthy. In some respects, this is not terribly surprising since it is well known to both researchers [53, 25] and policy makers that young people are more prone to risky health behaviors (e.g., taking up cigarette smoking) than adults. Therefore an alternative approach might be create technological artifacts that can link healthy behavior in an understated way to other “child attractive” activities. In our own work, craft served as an implicit entry point towards wellness habits. Lisa’s initial interest in the fourth study, for example, was focused around the mural. She was attracted to the sound module used by her friend Macey in the previous field trial.

Therefore, it may be valuable to explore Trojan horse-like artifacts that “sneak in” the healthful elements while linking these elements to less “preachy” activities. Simply giving children health technologies for tracking exercise or diet, based on the assumption they care about these activities, is less likely to succeed. Traditionally, activities such as outdoor play, sports, or (for adolescents) dancing might serve as fun healthful Trojan horse activities in this sense. However, there are significant factors such as time spent alone, the increase in “screen time” that dilute the
effectiveness of these healthy pursuits [65]. In this sense, health crafting is an attempt to “swing back the pendulum” somewhat toward a richer set of healthful, but culturally meaningful, options for children’s time. By blending, in a natural way, individually expressive craft representations with healthful habits, our framework can provide a model of how designers can expand the space of health-promoting artifacts for the young. This Trojan horse approach to design has also been discussed by other researchers in the context of learning. In their book on serious games, Michael and Chen talk about learning games where the serious (learning) content may be like a Trojan horse, hidden in context with fun gameplay [62]. The use of comics in classrooms to improve literacy and linguistic performance in another similar example [67]. It may be, that with children, we need to employ these types of methods to counteract harmful health trends.

9.4 Designing for Flexible Usage

Broadly speaking, we see health crafting as an approach toward allowing health information to blend with personal expression. Although we created specific wearable and ambient craft modules for this purpose, we never envisioned the health crafting concept to be associated with any one specific device. Rather, we see our devices as the core of a larger developing “technological ecosystem” of health-oriented wearables and craft technology. This idea of “technological ecosystem” is largely inspired by the work of W. Brian Arthur. This concept is well-expressed in his book, The Nature of Technology: “Novel technologies arise from the combination of existing technologies...Some of these in turn go on to become possible building blocks for the creation of yet newer technologies. In this way, slowly over time, many technologies form from an initial few, and more complex ones from using simple ones as components [3].” The essential point here is that we need not think in terms of designing a single stand-alone “health measuring” device. Rather we can think, more productively, in terms of designing multipurpose artifacts that can be composed, modified, and combined with still other (external) artifacts in the service of an unbounded range of projects. Moreover, our approach takes advantage of the already existing ecosystem of devices and techniques: a growing collection of wearable sensors, of lightweight microprocessors that can
be adapted to textiles and accessories, of child friendly programming systems for those microprocessors, of websites (such as instructables.com) where young people can post descriptions of their projects, and so forth. In this light, we see our own work as the starting point for a highly flexible, varied set of basic devices with which children can create their own idiosyncratic representations of health.

9.5 Supporting Creativity in Health Maintenance

First, the health crafting style, unlike most efforts in wearable health electronics, emphasizes the creative input of the user. The children’s projects shown here are not exemplars of “convenient” or “invisible” health maintenance, nor are they intended to be. Instead, they are intended to tap into an impulse for creative play that supports a high level of individual decision making. In this constructionist vision, the child appropriates the possibilities of craft technologies for the purposes of understanding and maintaining her own physical well-being.

There is something of a distinct emotional tone in our work relative to that suggested by many commercial wearable devices. Commercial devices are often advertised as a “product for everyone” (fitbit.com) where the underlying image is one of “control” or “mastery.” A certain urgency is implied in the statements: “Every moment matters”, “Because fitness is the sum of your life”, “How far will you go?”, and “Live healthier and be more productive” (quotes from fitbit.com, jawbone.com/up, microsoft.com/microsoft-band). Contrast this with the health crafting approach which emphasizes informality, play, and a sense of whimsy about health maintenance; the task of maintaining one’s body is thus considerably more expressive and considerably less demanding. We witnessed this informal, playful attitude in the language children used during our evaluations. Words such as “cute,” “cool,” and “awesome” were common when discussing the mural or the individual trackers.

Essentially, we view health crafting as a form of creative play that has the potential to introduce serious health concepts in addition to promoting social and emotional development in children [64]. Moreover, since the child has taken the initiative to design his own challenging visual
representations of health or wellness, it is at least plausible that the health crafting approach will evoke meaningful participation and “buy-in” for health maintenance. Our field trial and subsequent case studies were promising in this aspect considering that we were working with early adolescent children, a challenging group for any research study.

9.6 “Pleasantly Frustrating” Experiences

In many ways, our work in health crafting is at a very early stage. Even though the wearable and ambient modules have undergone multiple revisions, in our view, the wearable can still be made smaller, the connectors to the sensors can be more robust, and the programming environment can be made friendlier (to name a few). Needless to say, running studies with early-stage, non-production systems can be challenging, especially with children. However, we discovered that the hassles children faced, as a consequence of our less-robust system, often lead to satisfying experiences. The difficulty in figuring out Arduino programming, or finding the right power and ground points, exposed the inner workings of the system, and children in turn struggled and learned. The satisfaction of struggling and making the artifact was ultimately the reward for some of the participants. Macey, who used the sound module to play the Little Mermaid theme song in the field trial, found the programming aspect confusing and frustrating. However, when she finished, she exclaimed, “I can’t believe I made that.” In the last study, her best friend Lisa also had a similar experience with the chirping bird.

This is not to say our system is perfect the way it is. It can certainly be improved, but there is a trade-off here between making things too easy, too obvious and exposing all the details. As Gross and Eisenberg argue, there is a indeed a “fine balance between eliminating needless complexity to make a more elegant design environment, and hiding important detail in the name of ease-of-use [31].” In essence, the technological environment must encourage curiosity and mastery, and mastery almost always implies a struggle or a challenge. As Csikszentmihalyi, a well-known research psychologist, points out “a challenging activity that requires skill” is one of the components of an “optimal experience [22].” However, if the experience is too challenging then children may
get frustrated. On the other hand, if it is too easy, children may lose interest and value. What is needed is a kind of “pleasant frustration” [30], where challenges feel hard but doable. This balance is indeed hard to strike.
Chapter 10

Future Work

As noted earlier, we never envisioned health crafting to be associated with one particular implementation. We view our own work as part of a much larger ecosystem of health-oriented craft technology where components are fungible. This ability to substitute individual units within the system allows us to have a vast space of potential health artifacts with just a little variability. As such, we see many potential directions for our work.

10.1 Hardware Platform

First, it is worth exploring how the hardware platform can be extended to support a variety of sensors. Currently, each sensor maps to a specific set of pins on the wearable base. For example, a button uses two pins and an accelerometer uses five pins. The interface for each sensor is different and not all sensors can be connected in the same way. One approach to this problem is to add a small microcontroller to each sensor. Much like how the ambient modules only need three connections (power, ground, data) to operate, the sensors could also function as part of a small network. Each sensor-microcontroller module could record data and transmit that information to the wearable base periodically. This would standardize the interface to all sensors and we would only need a single 3-wire connector. While this would increase power consumption and add complexity, it would also open up the platform to a host of new sensors. The wearable tracker would essentially become a distributed network with a common communication protocol.
10.2 Programming Environment

An area where we can considerably improve our system is the programming environment associated with the wearable and ambient modules. We chose the Arduino IDE to keep the system accessible to as wide an audience as possible. However, the environment was often challenging for children. They were only comfortable modifying variables or cutting and pasting code snippets. A promising future direction in this area is Ardublock (blog.ardublock.com), a graphical programming environment for the Arduino platform. Much like Scratch [80], a popular visual programming language for children, Ardublock provides drag-and-drop color coded blocks and operators for programming hardware (Figure 10.1). Although it removes the annoyances of syntax (e.g., misplacing semicolons, brackets) and provides a colorful welcoming environment, users still need to know aspects of hardware such as the difference between digital and analog pins. Regardless, Ardublock is a good starting point for future integration with our system, especially since our devices are already part of the Arduino platform.

Figure 10.1: Ardublock graphical programming environment for Arduino
10.3 Health Education

In many ways, our work would be a useful complement to a health education curriculum. Much like how Lilypad Arduino has been used to teach kids about computation and programming [47, 40, 79], our devices could be used to teach children about health. In this constructionist approach to health education, children could learn about why physical activity is important and concurrently craft wearable and ambient artifacts for tracking the metric. A variety of health topics such as diet, exercise, and stress management could be explored this way. The practical and tangible exploration of such topics could help children internalize much of the information they receive in a classroom environment. This could help children take these “adult notions” of health more seriously.
Chapter 11

Conclusion

Since beginning work on the first wearable and ambient prototypes, our thoughts about health crafting have slowly evolved. Over the course of three user studies, we gained valuable insight into how young people think about health, the activities they consider important, the kinds of health artifacts they want to craft, and how they use crafted health systems.

Our original health crafting kit was a simple wearable device that tracked UV exposure and reflected the sensor data in a built-in LED display. Based on this prototype, we envisioned a set of plug-and-play sensors and feedback modules as part of the wearable toolkit. However, in our first needs assessment study with early adolescent children (11-14 years old), we discovered that kids preferred ambient visualizations to accompany their wearable. As a result, we created four ambient feedback modules to reflect sensor data. We also noticed that children seemed less responsive to adult notions of health.

In the second study, a 6-week field trial with 9 children, participants used our ambient modules to create a large health mural. Each module reacted only to the respective owner’s wearable device. Children mostly tracked personal wellness metrics as opposed to traditional adult measures of diet and physical activity. For tracking these “feel good” habits a simple button contextually crafted often sufficed. We also observed that participants who crafted their wearable for longer than 90 minutes generally used it to a greater extent.

In the last study, we conducted a 2-month evaluation of our toolkit with 4 children. Three of the four participants continued working on the mural from the previous field trial and added new
ambient modules to reflect their self-selected behaviors. Only one participant crafted a personal ambient visualization to take home. Although children failed to hit their predefined goals, many of them reflected on how they were too optimistic in their original aspirations.

While our work was not very successful in promoting the critical habits necessary for improving children’s physical health, we found participants taking incremental steps towards self-regulation through goal-setting and reflection. These skills form the basis for health behavior change. Fundamentally, children are learning new habits that require time and effort. By providing them the ability to create their own health technologies, we account for individual differences and support progress at different paces. Perhaps, more importantly, health crafting is a great way to engage children towards healthful thinking in a manner that is expressive and personally meaningful.
Bibliography


[34] J.C. Hertz. Wearables are totally failing the people who need them most. *Wired*, November 2014.


[61] David A. Mellis, Sam Jacoby, Leah Buechley, Hannah Perner-Wilson, and Jie Qi. 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, pages 83–90, New York, NY, USA, 2013. ACM.


Appendix A

Wearable Base Schematic and Board

Figure A.1: Schematic view of wearable base
Figure A.2: Board view of wearable base (Top layer)

Figure A.3: Board view of wearable base (Bottom layer)
Appendix B

Ambient Modules Schematics and Boards

Figure B.1: Schematic of motor module
Figure B.2: Board view of motor module (top and bottom layers)

Figure B.3: Schematic of sound (piezo) module
Figure B.4: Board view of sound (piezo) module (top layer)

Figure B.5: Schematic of RGB LED module
Figure B.6: Board view of RGB LED module (top layer)

Figure B.7: Schematic of vibration motor module
Figure B.8: Board view of vibration motor module (top and bottom layers)
Researchers and makers have typically used expensive desktop vinyl cutters, such as the Roland GX-24 ($1500) to cut out copper circuits from adhesive backed copper foil. This details how similar results can be achieved using a less expensive ($200) desktop craft cutter, the Silhouette SD. This is a somewhat older craft cutter and has been superseded by the Silhouette Cameo. However, the methods detailed here should work with the newer Silhouette models as well. Rather than cut out each copper trace separately and transfer it by hand, we focused on cutting the entire circuit and transferring it as one piece to a card stock substrate. This maintains pitch, or the relative distance between pins in electronic components.

The materials used in this process include:

- Silhouette SD or Silhouette Cameo craft cutter
- 8”x12” Portrait Cutting Mat with sticky adhesive
- Silhouette Ratchet Blade
- VentureTape self adhesive copper foil sheet 12”x12”

A few notes on the materials: it is fairly important that a sticky cutting mat is used; without this, the copper sheet will bunch up. The default blades with the Silhouette SD do not perform well. The ratchet blade in our experience produced the best results. The copper sheets can be found on Ebay in packs of 4.
We used Eagle PCB Design to model a simple microcontroller circuit that actuates a RGB LED. This paper circuit block employs circular magnetic connectors to interface with other circuitry. We used a through-hole package for the microcontroller, 1206 SMD packages for the resistors, and 6x5mm SMD package for the RGB LED. These are slightly larger SMD package sizes and provide some distance between the copper traces. If the packages are too small, there is a tendency for the copper traces to lift up while being cut by the craft cutter. Additionally, a 1mm trace width was used for all the connections. The traces, pads and dimension layers were exported to an EPS file format using the CAM processor in Eagle. The EPS file was then converted to JPG using Photoshop. The resulting circuit image for our example is shown in Figure C.1.

![Circuit image for RGB module](image)

Figure C.1: Circuit image for RGB module

The circuit image can then be imported into the free version of Silhouette Studio. In order to cut the traces in copper, we need to trace the outline of the black connections. Fortunately, Silhouette Studio has a trace function (top right icon toolbar, also selected in Figure C.2).
To use this feature, we have to first click the button, “Select Trace Area,” then draw a selection bounding box around the image as shown in Figure C.3.
With the bounding box drawn, we then set the high pass filter value to 12 and press the “Trace” function under the “Apply Trace Method” heading. This produces a red outline around the electronic traces as shown in Figure C.4.

Figure C.4: Outline of traced circuit

We then need to remove the original image by selecting and deleting it from the workspace. Once this is accomplished only the red outlines will remain as shown in Figure C.5.
Next, we firmly attach a piece or sheet of copper foil to the sticky cutting mat and load it into the machine (Figure C.6). Make sure the copper sheet is secure on the cutting mat.

Next under “Cut Settings,” we select “Printable Foil” as the material type. We also want to
set the ratchet blade to 1. Please note that this does not automatically set the ratchet blade on the cutter to 1. That must be done manually while loading the blade into the cutter. If you find that your blade ceases to cut after cutting a few circuits then increase the blade and ratchet setting to 2 or 3. The relevant settings for cutting copper foil are shown in Figure C.7.

![CUT SETTINGS](image)

**Figure C.7:** Silhouette Studio cut settings

Once we adjust the settings, we can then send it to the cutter. In the first image in Figure C.8, we can see the resulting cuts for the circuit presented earlier. To transfer the copper from the sheet
to the substrate, masking tape can be used to peel off the circuit (Figure C.8, 2nd panel). If some of the traces are not lifting then push the masking tape back down and rub over the area. We can then cut the masking tape to the exact shape of the substrate and paste it on. In this case, the circuit is mounted on thick card stock that is cut into the corresponding octagonal shape. When we peel off the masking tape, we are left with the full copper circuit on the substrate. All that remains is to remove the excess copper around the traces with a pair of tweezers.

Figure C.8: Copper trace transfer process
Appendix D

Background Questionnaire

The purpose of this questionnaire is to provide us with some background information about yourself and your experience with technology.

Instructions: The answers you give here and anywhere else in this online study are completely confidential. We only publish aggregate results or de-identified responses from this study, so no one but the researchers in charge of this study will know what answers you put for each question.

About You

Age: ____________

Gender: (Circle all that apply) Male / Female /Other: ____________

Ethnicity: Hispanic or Latino

Not Hispanic or Latino

Race (Circle all that apply):

American Indian or Alaska Native

Asian

Black or African American

White

Unknown or Not Reported

Current Grade: ____________
**Technology**

1. Do you have a computer at home? Yes No

   If so, how often do you use it?
   - Everyday
   - A few times a month
   - A few times a year
   - Not at all

2. Have you ever made an online profile page that others can see, like on MySpace, Facebook, or Pinterest?
   - Yes
   - No
   - Not sure

3. One a scale of 1 to 5 with 1 being no confidence at all and 5 being complete confidence, please check how confident you are at using the computer for the following tasks (if you have never used a computer for a task, please check never used).

<table>
<thead>
<tr>
<th>Task</th>
<th>1 No Confidence</th>
<th>2 Some Confidence</th>
<th>3 Complete Confidence</th>
<th>Never Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Email</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Connect a computer to a wireless network</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Instant Messaging</td>
<td></td>
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<td></td>
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<tr>
<td>Music - Listen</td>
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<tr>
<td>Music - Upload or Download</td>
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<tr>
<td>Music - Share</td>
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<tr>
<td>Use a computer - Record a Video</td>
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<tr>
<td>Use a computer – Share a Video</td>
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</tr>
<tr>
<td>Photos - Upload or Download</td>
<td></td>
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<td></td>
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<tr>
<td>Photos – Share</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
4. Do you own a mobile phone?  Yes  No

If so, how often do you have it with you?

- All the time
- Some of the time. Please explain: ___________________________
- None of the time

5. What type of mobile phone you have? (Select all that apply)

- Basic phone (non-smart phones)
- Smart phone (Blackberry, Android, iPhone)
- N/A

6. One a scale of 1 to 5 with 1 being no confidence at all and 5 being complete confidence, please check how confident you are at using the mobile phone for the following tasks (if you have never used a computer for a task, please check never used).

<table>
<thead>
<tr>
<th>Task</th>
<th>1 No Confidence</th>
<th>2 Some Confidence</th>
<th>4 Complete Confidence</th>
<th>Never Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make / Receive phone calls</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Send / Receive text messages</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Take / Share photos</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Take / Share videos</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Download applications</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(games, etc.)</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

7. Are you interested in science or engineering?

☐ Yes  ☐ No  ☐ Maybe  ☐ Not sure
8. Classes in middle school are (check one):
   - Easy for me
   - Somewhat easy for me
   - Somewhat hard for me
   - Hard for me

9. Have you worked or played with electronics before?
   - Yes
   - No

10. Have you crafted, tinkered or made things for yourself or others?
    - Yes
    - No
    If Yes what did you make? ________________________

11. Are you part of any after school activities or clubs apart from Gold Crown?
    - Yes, What activities? ________________________
    - No
Appendix E

Study 4: Background Interview Questions

Sample semi-structured interview questions to get a holistic picture of the participant’s current life.

Background
• Age
• Gender
• Race
• Current Grade
  o How are you doing in school?
  o What are your favorite classes?
  o What do you want to be when you grow up?
• Technology use
  o Mobile phone?
  o Computer?
• Family and relationships
  o Brothers or sisters?
  o Caregivers and parents?
  o Pets?
  o Best friends?
    ▪ What do you and your friends like to do together?
• Likes and dislikes
  o Favorite books and movies?
  o Music?
  o Hobbies?
  o Do you play any musical instruments?

Health Questions
• Do you think you are healthy?
• Have you ever been to a doctor?
• From who or from where do you learn about your health?
  o School?
  o Parents?
• What does being healthy mean to you?
• What are some things you do to stay healthy?
• Favorite foods?
  o Good foods?
  o Bad foods?
• Favorite activities to do?
  o Any physical activity? Sports?
    • Activities with friends?
  o What do you do when you have free time?

Gold Crown Clubhouse
• What do you like about the clubhouse?
• How long have you been coming here?
• Do a lot of your friends come here?
• What kind of things do you like to do at GoldCrown?
  o Can you describe some things you have made here?

Study related questions
• Why do you want to participate in this study?
• What seems interesting to you?
  o Crafting?
  o Health?
  o Electronics?
• What do you want to be better at? Why is this important to you?
Appendix F

eCrafting Pre-Survey

Date: ____________  NAME: __________________________

We are interested in finding out what you think about computing. Please circle the number that best represents how true you believe the following statements are.

<table>
<thead>
<tr>
<th>STATEMENT</th>
<th>SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Computers are fun.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>2. Programming is hard.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>3. Girls can have jobs in computing.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>4. Boys can have jobs in computing.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>5. Computer jobs are boring.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>6. I am good at computing.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>7. I like computing.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>8. I know more than my friends about computers.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>9. My family encourages me to use computers.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>10. My friends like using computers.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>11. I can become good at computing.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>12. I like the challenge of computing.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>13. I think computing is useful.</td>
<td>1  2  3  4  5</td>
</tr>
</tbody>
</table>

Appendix F

eCrafting Pre-Survey

Date: ____________  NAME: __________________________

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<th>SCALE</th>
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</thead>
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<tr>
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<td>1  2  3  4  5</td>
</tr>
<tr>
<td>3. Girls can have jobs in computing.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>4. Boys can have jobs in computing.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>5. Computer jobs are boring.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>6. I am good at computing.</td>
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<td>7. I like computing.</td>
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<tr>
<td>8. I know more than my friends about computers.</td>
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<tr>
<td>9. My family encourages me to use computers.</td>
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<td>10. My friends like using computers.</td>
<td>1  2  3  4  5</td>
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<tr>
<td>11. I can become good at computing.</td>
<td>1  2  3  4  5</td>
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<tr>
<td>12. I like the challenge of computing.</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>13. I think computing is useful.</td>
<td>1  2  3  4  5</td>
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</table>
14. I want to find out more about computing.

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<thead>
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<th>2</th>
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<tr>
<td></td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>In Between</td>
<td>Agree</td>
<td>Strongly Agree</td>
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15. I am interested in a career in computing.

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<tr>
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<tbody>
<tr>
<td></td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>In Between</td>
<td>Agree</td>
<td>Strongly Agree</td>
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HOW MANY HOURS DO YOU SPEND ON A COMPUTING DEVICE LIKE AN IPAD OR COMPUTER AT HOME EACH DAY? Circle one

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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>I don’t use a computer</td>
<td>Less than 1 hour</td>
<td>Between 1 and 2 hours</td>
<td>Between 2 and 3 hours</td>
<td>More than 3 hours</td>
</tr>
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</table>

HOW MANY HOURS A DAY DO YOU SPEND ON A COMPUTER...

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<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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</tbody>
</table>

WHAT DO YOU HOPE TO LEARN FROM THIS WORKSHOP? Circle all that apply to you:

1. How technology works
2. Creative Design skills
3. If computer science is something I am interested in learning more about in school
4. If computer science would be a good career for me
5. Other: ________________________________
<table>
<thead>
<tr>
<th>PLEASE SELECT YOUR GENDER:</th>
<th>WHAT GRADE ARE YOU IN?</th>
<th>HOW OLD ARE YOU?</th>
</tr>
</thead>
<tbody>
<tr>
<td>① Female</td>
<td>A 4th</td>
<td>A 9</td>
</tr>
<tr>
<td>② Male</td>
<td>B 5th</td>
<td>B 10</td>
</tr>
<tr>
<td></td>
<td>C 6th</td>
<td>C 11</td>
</tr>
<tr>
<td></td>
<td>D 7th</td>
<td>D 12</td>
</tr>
<tr>
<td></td>
<td>E 8th</td>
<td>E 13</td>
</tr>
<tr>
<td></td>
<td>F 9th</td>
<td>F 14</td>
</tr>
<tr>
<td></td>
<td>G 10th</td>
<td>G 15</td>
</tr>
<tr>
<td></td>
<td>H 11th</td>
<td>H 16</td>
</tr>
<tr>
<td></td>
<td>I 12th</td>
<td>I 17</td>
</tr>
</tbody>
</table>

PLEASE SELECT YOUR ETHNICITY/RACE BELOW:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>① Asian</td>
<td>A</td>
</tr>
<tr>
<td>② Black</td>
<td>B</td>
</tr>
<tr>
<td>③ Hispanic</td>
<td>C</td>
</tr>
<tr>
<td>④ Native American/</td>
<td>D</td>
</tr>
<tr>
<td>Alaska Native</td>
<td>E</td>
</tr>
<tr>
<td>⑤ White</td>
<td>F</td>
</tr>
<tr>
<td>⑥ Multiracial</td>
<td>G</td>
</tr>
</tbody>
</table>

THANK YOU!
Appendix G

eCrafting Post-Survey

Date: ___________  NAME: ____________________

We are interested in finding out what you think about computing. Please circle the number that best represents how true you believe the following statements are.

<table>
<thead>
<tr>
<th>STATEMENT</th>
<th>SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Computers are fun.</td>
<td>1</td>
</tr>
<tr>
<td>2. Programming is hard.</td>
<td>1</td>
</tr>
<tr>
<td>3. Girls can have jobs in computing.</td>
<td>1</td>
</tr>
<tr>
<td>4. Boys can have jobs in computing.</td>
<td>1</td>
</tr>
<tr>
<td>5. Computer jobs are boring.</td>
<td>1</td>
</tr>
<tr>
<td>6. I am good at computing.</td>
<td>1</td>
</tr>
<tr>
<td>7. I like computing.</td>
<td>1</td>
</tr>
<tr>
<td>8. I know more than my friends about computers.</td>
<td>1</td>
</tr>
<tr>
<td>9. My family encourages me to use computers.</td>
<td>1</td>
</tr>
<tr>
<td>10. My friends like using computers.</td>
<td>1</td>
</tr>
<tr>
<td>11. I can become good at computing.</td>
<td>1</td>
</tr>
<tr>
<td>12. I like the challenge of computing.</td>
<td>1</td>
</tr>
<tr>
<td>13. I think computing is useful.</td>
<td>1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATEMENT</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>In Between</td>
<td>Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>1. Computers are fun.</td>
<td>①</td>
<td>②</td>
<td>③</td>
<td>④</td>
<td>⑤</td>
</tr>
<tr>
<td>2. Programming is hard.</td>
<td>①</td>
<td>②</td>
<td>③</td>
<td>④</td>
<td>⑤</td>
</tr>
<tr>
<td>3. Girls can have jobs in computing.</td>
<td>①</td>
<td>②</td>
<td>③</td>
<td>④</td>
<td>⑤</td>
</tr>
<tr>
<td>4. Boys can have jobs in computing.</td>
<td>①</td>
<td>②</td>
<td>③</td>
<td>④</td>
<td>⑤</td>
</tr>
<tr>
<td>5. Computer jobs are boring.</td>
<td>①</td>
<td>②</td>
<td>③</td>
<td>④</td>
<td>⑤</td>
</tr>
<tr>
<td>6. I am good at computing.</td>
<td>①</td>
<td>②</td>
<td>③</td>
<td>④</td>
<td>⑤</td>
</tr>
<tr>
<td>7. I like computing.</td>
<td>①</td>
<td>②</td>
<td>③</td>
<td>④</td>
<td>⑤</td>
</tr>
<tr>
<td>8. I know more than my friends about computers.</td>
<td>①</td>
<td>②</td>
<td>③</td>
<td>④</td>
<td>⑤</td>
</tr>
<tr>
<td>9. My family encourages me to use computers.</td>
<td>①</td>
<td>②</td>
<td>③</td>
<td>④</td>
<td>⑤</td>
</tr>
<tr>
<td>10. My friends like using computers.</td>
<td>①</td>
<td>②</td>
<td>③</td>
<td>④</td>
<td>⑤</td>
</tr>
<tr>
<td>11. I can become good at computing.</td>
<td>①</td>
<td>②</td>
<td>③</td>
<td>④</td>
<td>⑤</td>
</tr>
<tr>
<td>12. I like the challenge of computing.</td>
<td>①</td>
<td>②</td>
<td>③</td>
<td>④</td>
<td>⑤</td>
</tr>
<tr>
<td>13. I think computing is useful.</td>
<td>①</td>
<td>②</td>
<td>③</td>
<td>④</td>
<td>⑤</td>
</tr>
<tr>
<td>Question</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>In Between</td>
<td>Agree</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-------------------</td>
<td>----------</td>
<td>------------</td>
<td>-------</td>
<td>----------------</td>
</tr>
<tr>
<td>14. I want to find out more about computing.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>15. I am interested in a career in computing.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>16. This workshop made me interested in computing.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>17. I learned about computing in this workshop.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>18. I now know more about computing as a job because of this workshop.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>19. I will remember what I learned in this workshop.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>20. I will use what I learned in this workshop.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>21. I learned how computing can be used in different ways in this workshop.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>22. I know more about jobs in computing because of this workshop.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>23. I would recommend this workshop to my friends.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>24. I am interested in a career in computing.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

WHAT DID YOU LIKE BEST ABOUT THIS STUDY?
WHAT DID YOU LIKE LEAST ABOUT THIS STUDY?

WHAT CHANGES WOULD YOU MAKE TO MAKE THE STUDY BETTER?

THANK YOU!
Appendix  H

Study 4: Tinker Time Interview Questions

Sample semi-structured interview questions for Tinker Time workshops in Study 4.

- Health Craft Prototype Questions
  o Could you tell me about your prototype? Why did you decide to build a UV/Button/sensor monitor?
  o Could you tell me about how you have modified it – if at all – since the last workshop?
    - If they have attended a Tinker Time workshop: Did you modify the prototype during the Tinker Time workshop? Could you tell me more about it?
    - Why did you modify it? Did it break? How did you try to fix it?

- Usage Questions
  o Could you tell me about a time when you used your prototype recently?
    - Ask if they have used it in public. Ask if people asked about their prototype and what they told them about their prototype. See if it matters if the person is a family member, friend, or stranger.
  o We see from your usage that [you use it often, haven’t used it in a while, etc.], could you tell me more about this? Do not make them feel bad about not using it – we are just trying to find out why they have not. Maybe the prototype has a bug that needs to be fixed.

- Today’s Workshop
  o What are your goals for today’s workshop?
  o How would you want to modify your prototype?
  o If you could add some other visualization to the prototype, what would it be?