Health Sense: A Gedanken Experiment on Persuasive Wearable Technology for Health Awareness

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ABSTRACT

In this paper, we introduce a gedanken experiment for increasing health awareness in children through wearable computing. The proposed system, Health Sense, seeks to create a sixth health sense through wearable computing components that unobtrusively sense and ambiently present wellness information in intuitive and holistic ways to children. The novelty of this experiment lies in providing an ecosystem of plug-and-play wearable components that is geared towards health education and child empowerment through a "you build it" approach. Health Sense is informed by findings from prior research in wearable systems and a literature analysis of health behavior and children's education theories. We illustrate the Health Sense design by discussing some preliminary prototypes we developed.

Categories and Subject Descriptors

H.5.m [**Information interfaces and presentation**]: Miscellaneous; H.5.2 [**User Interfaces**]: User-centered design

General Terms

Design, Human Factors

Keywords

Wearable technology, Health awareness, Childhood obesity, Ubiquitous computing, Persuasive technology

1. INTRODUCTION

The obesity epidemic among children has become a widespread problem in the United States. Thirty percent of all children ages 2-19 are overweight or obese [20]. In the past 3 decades, obesity has tripled among children and adolescents (rising from 5% to 17%) [19]. In response to this issue, we propose a system, Health Sense, that improves health situational awareness through wearable technology. This new genre of augmented health sensing aims to integrate seamlessly into daily wear and unobtrusively sense and present health information in novel ways. In this gedanken experiment, we do not present results from a complete, evaluated system, instead we sufficiently motivate the system based on theoretical foundations from disparate fields, carefully researched system design, and a small prototype system as a simple experiment for potential feasibility.

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2. MOTIVATION

Since overweight children tend to become overweight or obese adults [13], they are the first access point to fight the obesity epidemic. A new sixth sense, such as the proposed Health Sense, must be with a child at all times *sensing* and providing *actionable feedback*. Based on this idea, we identified wearable technology to increase health situational awareness and persuade physical activity. We can *sense* through miniaturized sensors (e.g., pedometers, accelerometers) to obtain objective measurements of physical activity. Similar to the nervous system feedback loop, this automated sensing and presenting of data can provide a child with an awareness of their physical activity patterns and perhaps be a motivator for change - thus sensing more physical activity.

In persuading change, however, the success of a given wearable technology is often dependent on its design [4]. How information is gathered and presented is a crucial aspect of the system [14]. While existing devices have had some success in monitoring, inferring, and presenting activity, they do not always convey the value of physical activity in a holistic, organic way. The feedback design is important in designing wearable technology for children as opposed to adults because quantifiable measurements are less likely to cause a connection with health in children [7].

We approached the question of health awareness from an educational standpoint. Fundamentally, the goal of any wearable health technology is to educate the user on some aspect of their current health and wellness. We suggest a "you build it" approach to wearable technological design that emphasizes personal expressiveness, construction, and education through craft. Much like educational children's toys, we argue for a design that contains a trade-off between "ease of use" and "user empowerment." We contend that this educative style (motivated by successful results from children's educational research [11]), creates a greater investment and commitment on part of the child to the wearable technology.

3. RELATED WORK

With the advent of low power, low cost sensors and computing platforms, wearable technology has been increasingly

Table 1: Overview of Health Related Research with Wearable Technology

	Project	Technology	Target Population
Shared Activity	Fish 'n' Steps [15]	Pedometer, PC	Adults
	Houston [4]	Pedometer, mobile phone	Adults
	Chick Clique [22]	Pedometer, PDA	Teen girls (12-19)
	Remote Jogging [18]	Mini computer, GPS, mobile phone, headset	Adults
Self-monitoring	UbiFit [5]	Custom multi-sensor device, PDA	Adults
	FitBit [9]	Custom 3D motion sensor, e-health application	Adults
	AVIVA [10]	Custom fitness monitor	Women (18-35)
Gaming	TripleBeat [6]	Accelerometer, ECG, smart phone	Adults
	Djogger [2]	Accelerometer, music player	Adults
	Persuasive Audio [12]	Pedometer, music player	Children (7-12)

used in health related research towards promoting physical activity. We summarize some of the relevant research in the area in Table 1. Perhaps the most common commercial device used to detect physical activity throughout the day is the pedometer. Three recent studies, Fish 'n' Steps [15], Houston [4], and Chick Clique [22] have used pedometers to encourage individuals to take more steps. In Fish 'n' Steps, the user's step count is linked to the life of a virtual fish in a virtual fish tank. The tank includes the fish of other users and is displayed in a public kiosk. In Houston and Chick Clique, groups of users shared daily step counts with each other via mobile phones, thereby fostering a shared interest and goal. Chick Clique, which was developed for adolescent girls, allowed the girls to constantly keep track of their own and their buddies' progress towards their walking goals; it enabled them to send motivational text messages when it seemed like their friends were lagging.

A different approach to infer physical activity from devices is to couple custom hardware with off the shelf smart phones the user might already carry. The creators of UbiFit Garden used multiple connected components: a custom fitness device, and a PDA-based application with a glanceable display [5]. The UbiFit fitness device automatically detected and reported a variety of activities to the PDA application and provided users with the ability to modify and reflect on their data. In the commercial space, FitBit is a similar device that uses a 3D motion sensor to track activity [9]. When in proximity of a wireless base station, the device syncs with an online e-health application to keep track of progress towards goals.

For active users, TripleBeat coupled custom hardware with a smart phone to allow users to establish healthy cardiovascular goals [6]. The research studied 10 runners and compared their efficacy and enjoyment in achieving pre-defined cardiovascular goals through competition. DJogger, on the other hand, maintained motivation during exercise by varying the pace and selection of music dynamically depending on the workout plan [2]. Similar to DJogger, but designed for children ages 7-12, Persuasive Audio used a simple pedometer to control and vary music tempo based on activity level [12].

While many of the research studies shown in Table 1 have proven effective in motivating physical activity in adults and teens, designing to stimulate health and fitness in children requires additional effort because children lack direct control over their environment. Moreover, only one (Persuasive Audio) was designed specifically for children. Most of the designs require many manual steps for input, visualization and awareness that require a significant change in behavior (e.g., regularly viewing a display and mapping metrics with health). Additionally, many of the devices cannot integrate well into a child's lifestyle. For example, many classrooms have rules about how children are allowed to use information and communication technologies (ICT) throughout their school day. The studies presented however, do provide clues into health behavior theories that might work better in children. A recreational based design, for example, might prove to be a more responsive and persuasive wearable technology, and allowing customization might prove effective in giving children some sense of control.

4. HEALTH SENSE FOUNDATIONS

Since we wanted to design a new sixth, Health Sense, for children, we primarily explored literature in three areas - wearable technology, education, and persuasive technology. Wearable technology informed us on how to make the system a true human sense - something naturally on the child. Educational theory provided us insight into how to motivate children towards adoption and finally, persuasive technology aided us in understanding how to provide the child with feedback to empower them to make better decisions based on the data they received.

4.1 Motivating through Craft

Researchers in craft and art computing have successfully studied wearable computing with children to design educational toys and interactive clothing [3, 11]. One toy project of special note was Quilt Snaps, a fabric based construction kit where pieces of fabric have an embedded microcontroller, LED and a set of "input" and "output" snaps. By snapping together pieces of fabric, patterns of light move from patch to patch in unique ways. Quilt Snaps makes a case for old-fashioned fabric crafts augmented with conductive threads, and embedded computing in teaching simple computational models like data-flow. An interactive clothing project result of interest are the off-the-shelf electrical components in stitch-able packages [3] that allows novices to build and create their own wearable crafts. Each of these elements can be sewn into cloth with conductive thread. An example from one of their studies includes a 12 year old with no previous experience in programming or sewing decorate her handbag with an RGB LED controlled by a touch sensor.

While Einsenberg and Buechley's work focused on technology education through craft, we argue that their work and ideas of "user empowerment" can be applied to wearable health technology for children. Typically, children lack direct control of their environment, thus it would be beneficial if some part of the design gives them that ability. Persuasive audio [12] accomplished this by allowing children to control how music is played. In Health Sense, we build on this idea by creating self contained wearable components that fit together in a plug-and-play fashion; in building and customizing the device, children can learn about their own health and wellness. We argue that this creates a greater investment and commitment on part of the child to the device. This style of technological design emphasizes personal expressiveness, construction, and education through craft.

4.2 Designing a Sixth Health Sense

In designing such a system for children, it is important to gather and present data in an intuitive and holistic way. By holistic we mean gathering data unobtrusively and providing a continuous awareness of health that does not require a drastic change in behavior. A research study that illustrates this concept well - with potential applications in the Health Sense design - is LifeBelt [8]. LifeBelt implemented a vibro-tactile directional feedback system in a wearable belt to notify individuals in panic about potential exits. As opposed to a PDA or smart phone implementation that would require constantly looking at the display, with LifeBelt, the user can direct their attention on walking safely out of a harmful situation. It provides a holistic, intuitive interface for navigation during an evacuation process. Apart from vibro tactile feedback, other holistic methods include auditory and aesthetic visual representations. An example of an aesthetic visual representation would be a thermochromatic material that changes color. We argue that this idea of intuitive, holistic systems is more conducive to children's health awareness than an LCD screen that presents numerical health data. This is supported partly by prior research that suggests that in interfaces for children, text should be avoided as much as possible to reduce cognitive load [7].

In the design of effective wearable technologies, several recurring themes have appeared in research literature. From the design of Houston, Consolvo et al have identified four key requirements for health and wellness technologies [4]. They include giving users credit for their activities, providing personal awareness of activity levels, supporting social influence, and considering the practical constraints of the users. Health sense employs these requirements - from a child's perspective - in designing and evaluating the system.

4.3 Persuading Change in Children

In any system designed to assist users in changing their physical activity behavior, motivation is a key element. Persuasive technologies that motivate change however, can accomplish this task using different methods. The research overview presented in Table 1 can be grouped into 3 broad activity promotion categories, shared activity, self-monitoring and gaming [16]. Each uses different health behavior theories to motivate change.

Shared activity awareness applications take advantage of group dynamics and social influences in facilitating exercise. They often employ goal setting [10], teamwork or competition [6] to motivate members within the group. These lightweight social awareness applications encourage physical activity through experience sharing, related interaction and reflection. In research conducted by Brien and Mueller,

Figure 1: Health Sense Bracelet [1]

they found that conversation between remote jogging partners was desirable and motivating [18].

Self-monitoring applications on the other hand capture data and inform individual users on their current performance or health goals. The aim of such applications is to help the user maintain a routine by providing interactive goal setting and feedback on progress [9]. This however requires motivated individuals who are committed to well-established exercise routines.

The last method, gaming, persuades physical activity through fun and enjoyable interaction. Several studies presented above use music [12, 2] on portable players for enjoyment and motivation during workouts. The idea is to make the health related action rich in experience so that there is a higher probability of it happening again in the future. A significant advantage of promoting physical activity this way is that it couples exercise with fun and leisure instead of a predefined health related activity.

In persuading physical activity in children, a recreational activity is more likely to induce change since children are more interested in exercising for fun than for weight loss [12]. By creating a design that emphasizes "fun and enjoyment," we can change the way they perceive exercise. This moves recreation as the primary benefit and weight loss as a healthy side effect. Moreover, gaming activities tend to be more immersive and have a tendency to instigate lengthened periods of activity. Apart from recreation, a socially interactive design would also be beneficial as children desire products that they can use with others [12].

5. HEALTH SENSE ILLUSTRATION

To illustrate some of the Health Sense design considerations presented above, we introduce some preliminary work on a simple Health Sense bracelet that a child might create to keep track of movement. Figure 1 shows a leather bracelet (embeds tiny electronic components - micro-controller, sensor and LEDs) that detects movement through a tilt sensor and displays the result by lighting different color LEDS (5 shown). Which color LED is lit is directly correlated with the amount of movement detected by the tilt sensor over time. A red LED, for example, indicates a lot of activity over time, while a blue LED indicates little to no movement for the day. The reset switch on the far right resets the device for the day. All components in the design operate in a plug-and-play fashion and just need to be stitched with conductive thread to the leather backing. The bracelet unobtrusively collects and holistically presents activity information without requiring too much change in behavior. By using simple colors, it provides a clear, intelligible visual representation of movement. More importantly, with a simple component design it allows the child to be involved in the design of the bracelet. Since the LEDs are just separate stitch-able components (Figure 1, the child can customize the properties of the display by attaching different colored LEDs. While the base functionality has not changed, it allows the child to express her individuality but creating a unique wearable bracelet.

This Health Sense bracelet follows all four of Consolvo et al's design requirements [4]. It credits the user and provides personal awareness by lighting the appropriate LED based on their activity level. It supports social influence by publicly displaying data through light. An example would be the child's friend commenting on the change in color from yesterday to today, making the child aware that perhaps she didn't move as much today. Lastly, since the bracelet integrates seamlessly into daily wear, it also considers the practical constraints of the child's lifestyle.

While the bracelet is a fairly simple design, it is easy to envision a more complicated family of devices based on the Health Sense design guidelines. For example, with a communication module, we can create socially aware wearable technologies. Much like Legos, with a Health Sense construction kit, a child can create wearable devices more diverse than we can imagine.

6. HEALTH SENSE SYSTEM DESIGN

The general platform for building diverse Health Sense devices can be broken down into the following high level areas: computation, sensing, storage, networking, and container.

- Computation - This is generally accomplished through a micro-controller. It communicates with the other components based on a well defined interface via a bus. It also runs the algorithms defined by the software area.
- Sensing - This is accomplished by sensors that collect data such as pulse, skin temperature, sound, humidity, visible, infrared light, etc. The data can be passed to the storage system if present. Each sensor is independent and publishes its data on the bus.
- Storage - This is required in order to allow data to be collected and stored. Storage allows us to display patterns of user behavior collected from multiple days.
- Software - The base set of functionality that determines how the component behaves and interacts with others.
- Networking - Serves to communicate with other devices or allow a device to be part of an ecosystem of independent networked devices. Networking as allows the device to be programmed on-the-fly, untethered.
- Container/Presentation - The packaging and presentation of the device, e.g., leather bracelet, belt buckle, etc.

While the above areas do well to describe any embedded system, a key aspect of the Health Sense design is in developing each area in a modular fashion. This allows different sensors to be coupled with different containers in a unique fashion. More importantly, the software and hardware interface between all the components needs to be well defined. Figure 2 shows how the high level areas of computation, sensing and presentation can be broken down into modular electronic components. Every component has a micro-controller and

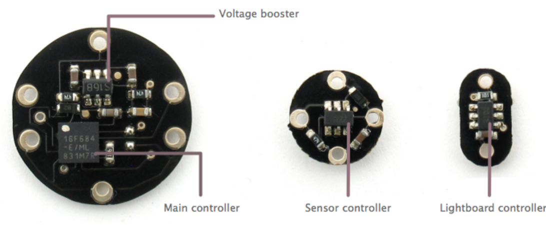

Figure 2: Computation (left), sensing (middle) and presentation (right) components [1]

is able to send and receive data on the bus. The main controller (on the left of Figure 2) connects to the other components serially via the two holes on either side. This modular design allows different sensors to be coupled with the main controller.

7. DISCUSSION

The Health Sense gedanken experiment presented in this paper raises some interesting points. In the relatively nascent area of persuasive technology, the primary focus has been to persuade behavior change. Very little attention, however has been placed on sustaining new healthy behaviors on the longer term. While we argue that empowering and motivating the child through craft would engender greater investment and commitment, it is not clear whether this behavior would be sustained. It may very well be that the Health Sense bracelet only sees a few weeks of use before it is discarded. Since there is some self investment in the device however, it may promote the cognitive process of self-referent encoding where information that is perceived to be related to the self is given cognitive priority [21].

As suggested by Maitland and other researchers [17], one of the problems of persuasive physical activity technologies lies in their failure to accommodate individual differences by providing a generic solution for a preconceived community. From this standpoint, one of Health Sense's strengths lies in its flexibility. Its craft-component approach provides the child the ability to tailor and customize wearable technology to their practical necessities and constraints. At the core of our research efforts lies the development of modular sensing and computation components that abstract away the technology associated with embedded electronics. The challenges here lie in designing components that consume little power and seamlessly integrate into daily wear. Typically, there is a trade-off here between functionality and the power requirements of the device. The second thread of research focuses on effective user experiences that engage the user in activity. The key challenge here lies in discovering the balance between user input and automation. Engaging the user in performing many tedious manual steps requires a considerable change in behavior and would likely result in discontinued use of the device. On the other hand, full automation would not require an attention on part of the user, resulting in decreased health awareness. A significant aspect of motivating physical activity and increasing health awareness is self-reflection. The frequency of opportunities for self-reflection in health technology, however, continues to be an important research question. In Chick Clique [22], researchers found that when they automated the task of gathering step counts, the teens were less aware of their activity level and the resulting counts dramatically decreased.

In some ways, we are exacerbating the last problem by providing the child ability to control the wearable devices they create using various Health Sense components, but we argue that a flexible design would only help the user in discovering the right wearable system suitable to their temperament and motives (within a given framework).

8. FUTURE WORK

Towards the future, our goals are to expand on the Health Sense design by creating new self-contained embedded sensing components, and exploring new containers and holistic presentation techniques (vibro tactile, auditory). To accomplish this, we need to create a well-defined plug-and-play interface for communication between each of the components. Furthermore, for communication between unique wearable devices we need to implement a wireless module. It would not only promote social interaction but allow us to reprogram the devices untethered. Our aim is to iteratively design and implement the Health Sense system by setting up workshops for children to gather feedback and evaluate the validity of our design periodically.

9. ACKNOWLEDGMENTS

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10. REFERENCES

[1] Aniomagic. Aniomagic schemer. http://www.aniomagic.com, 2010.

[2] J. T. Biehl, P. D. Adamczyk, and B. P. Bailey. Djogger: a mobile dynamic music device. In *CHI '06: CHI '06 extended abstracts on Human factors in comput. sys.*, pages 556–561, New York, NY, USA, 2006. ACM Press.

[3] L. Buechley and M. Eisenberg. Fabric pcbs, electronic sequins, and socket buttons: techniques for e-textile craft. *Personal Ubiquitous Comput.*, 13(2):133–150, 2009.

[4] S. Consolvo et al. Design requirements for technologies that encourage physical activity. In *CHI '06: Proceedings of the SIGCHI Conf. on Human Factors in comput. sys.*, pages 457–466, New York, NY, USA, 2006. ACM.

[5] S. Consolvo et al. Activity sensing in the wild: a field trial of ubifit garden. In *CHI '08: Proceeding of the twenty-sixth annual SIGCHI conf. on Human factors in comput. sys.*, pages 1797–1806, New York, NY, USA, 2008. ACM.

[6] R. de Oliveira and N. Oliver. Triplebeat: enhancing exercise performance with persuasion. In *MobileHCI '08: Proceedings of the 10th Intl. Conf. on Human computer interaction with mobile devices and services*, pages 255–264, New York, NY, USA, 2008. ACM.

[7] A. Druin et al. Designing a digital library for young children. In *Proceedings of the 1st ACM/IEEE-CS joint conf. on Digital libraries*, pages 398–405. ACM, 2001.

[8] A. Ferscha and K. Zia. Lifebelt: Silent directional guidance for crowd evacuation. In *ISWC '09: Proceedings of the 2009 Intl. Symposium on Wearable Computers*, pages 19–26, Washington, DC, USA, 2009. IEEE Computer Society.

[9] FitBit. Fitbit fitness tracker. http://www.fitbit.com/product, 2010. [Online; accessed 6-June-2010].

[10] R. Gockley et al. Aviva: a health and fitness monitor for young women. In *CHI '06: CHI '06 extended abstracts on Human factors in comput. sys.*, pages 1819–1824, New York, NY, USA, 2006. ACM.

[11] M. D. Gross and M. Eisenberg. Why toys shouldn't work "like magic": Children's technology and the values of construction and control. *Digital Game and Intelligent Toy Enhanced Learning, IEEE Intl. Workshop on*, 0:25–32, 2007.

[12] J. Hartnett et al. A responsive and persuasive audio device to stimulate exercise and fitness in children. In *CHI '06: CHI '06 extended abstracts on Human factors in comput. sys.*, pages 1837–1842, New York, NY, USA, 2006. ACM.

[13] A. A. Hedley et al. Prevalence of overweight and obesity among us children, adolescents, and adults, 1999-2002. *JAMA*, 291(23):2847–2850, June 2004.

[14] B. Y. Lim, A. Shick, and C. Harrison. Prevalence of overweight and obesity among us children, adolescents, and adults, 1999-2002. Technical report, April 2008. CHI 2008 Workshop on Ambient Persuasion.

[15] J. J. Lin et al. Fish 'n' steps: Encouraging physical activity with an interactive computer game. pages 261–278. 2006.

[16] J. Maitland and K. A. Siek. Technological approaches to promoting physical activity. In *OZCHI '09: Proceedings of the 21st Annual Conf. of the Australian Computer-Human Interaction Special Interest Group*, pages 277–280, New York, NY, USA, 2009. ACM.

[17] J. Maitland, K. A. Siek, and M. Chalmers. Persuasion not required: Obstacles faced by low-income caregivers to improve dietary behaviour. In *3rd Intl. Conf. on Pervasive Comput. Technologies for Healthcare 2009*, 2009.

[18] F. F. Mueller, S. O'Brien, and A. Thorogood. Jogging over a distance: supporting a "jogging together" experience although being apart. In *CHI '07: CHI '07 extended abstracts on Human factors in comput. sys.*, pages 2579–2584, New York, NY, USA, 2007. ACM.

[19] C. L. Ogden et al. Prevalence and Trends in Overweight Among US Children and Adolescents, 1999-2000. *JAMA*, 288(14):1728–1732, 2002.

[20] C. L. Ogden et al. Prevalence of high body mass index in us children and adolescents, 2007-2008. *JAMA*, 303(3):242–249, January 2010.

[21] T. B. Rogers, N. A. Kuiper, and W. S. Kirker. Self-reference and the encoding of personal information. *J Pers. Soc. Psychol.*, 35(9):677–88, 1977.

[22] T. Toscos et al. Chick clique: persuasive technology to motivate teenage girls to exercise. In *CHI '06: CHI '06 extended abstracts on Human factors in comput. sys.*, pages 1873–1878, New York, NY, USA, 2006. ACM.