TEACHING COMPLEX BEHAVIORS: PERSUASIVE TECHNOLOGY AND SUSTAINABILITY

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INTRODUCTION

Environmental sustainability is a crisis of our time, yet changing our individual behaviors in attempts to address the problem is a complex challenge. Addressing environmental sustainability on an individual level is what will create high enough levels of public participation to allow for a more sustainable future (McKenzie-Mohr, 2000). Many barriers exist to adopting sustainable of green actions; from understanding the complexity of what these actions are, to the many physical and perceived barriers to a wide variety of lifestyle decisions. Issues of water and energy conservation, decreasing waste, transportation and understanding our decisions and their lifecycle within a local, regional and global level are all issues people must face.

In an article introducing community based social marketing, Doug McKenzie-Mohr suggests that psychological approaches must be addressed in creating any type of environmental sustainability program in which a behavior change is the goal. The current methods tend to rely on mass advertising and marketing, but this strategy has shown little to no success (McKenzie-Mohr, 2000). McKenzie-Mohr argues that this is because teaching new information alone does not decrease any barriers to behaving sustainably, and most sustainable behavior has multiple barriers in our current society.

As interaction designers, we create tools with the potential to decrease such barriers and support people in their move towards a more sustainable lifestyle. Interactive technologies can also be used to teach such behavior starting at a young age, with the goal of encouraging a lifetime of sustainable choices. But while teaching children about the environment and the conceptual framework to connect ecological, social and economic spheres is a largely growing field, how to design the technologies to support this goal is little explored. Interactive technologies offer much potential for supporting in both the education of and sustainable behaviors of children. Three fields offer interaction design tools and recommendations that help to form a foundation in designing technologies to support sustainable behavior for children: persuasive design, the design of tangible technology for children, and studies on an analogous behavior – fitness.

While this paper does not address the physical hardware and the challenges they present, design and design analysis focused on learning and motivation is crucial to field of sustainable interaction design. Eli Blevis proposes a perspective of sustainability and a "rubric for understanding and assessing the material effects induced by particular interaction design cases in terms of forms of use, reuse, and disposal from the perspective of sustainability" (Blevis, 2007, p. 503). The material effects must include how humans choose and act within the system. An understanding of the needs, goals, context, cognitive abilities and psychology of an audience for a system or technology will enhance the success of the design.

TWO DESIGN FRAMEWORKS: PERSUASIVE DESIGN AND THE CHILD TANGIBLE INTERACTION (CTI) FRAMEWORK

CTI FRAMEWORK

A tangible interface decreases the barrier between digital information (and cyberspace) and people. Our primary model today is a device with a flat, visual screen (the graphical user interface) and audio, with an input device such as a keyboard. Tangible interfaces offer more direct manipulation of digital data, through the use of objects, surfaces, and spaces, a more sophisticated use of touch and gesture and ambient sensory data. Tangible user interfaces are a move from the flat screen of the GUI to a more environmental approach, attempting to take advantage of the full spectrum of human senses and skills. One of the most mainstream examples we have today is the Nintendo Wii, in which a game player can use a full range of upper body movement to interact with a video game. A tangible interface such as the Wii assists people in learning and understanding their environment while directly acting within it.

Another current example is the Jabberstamp, a project of the MIT tangible media group (Raffle, Vaucelle, Wang, & Ishii, 2007). With the Jabberstamp, a child can draw on a normal sheet of paper. Using a rubber stamp, they can stamp any part of their image to record their own voice. Recorded audio plays back to the child when they touch a small trumpet to the stamp. The Jabberstamp allows children to create complex narratives with their own images and verbal stories before they are capable of writing. In *The CTI Framework: Informing the Design of Tangible Systems for Children*, Alissa Antle cites research that "provides support for tangible, physically-based forms of child computer interaction...body movements, the ability to touch, feel, manipulate and build sensory awareness of relationships in the world are crucial to children's cognitive development" (Antle, 2007, p. 195).

Antle feels that the field of tangible technologies is missing a design framework based on appropriate developmental theories for children about "how children develop intelligence through their physical, social and spatial interactions with the world" (p. 196). Her paper attempts to create a conceptual framework to influence and analyze the design of tangible technologies for children. Named the CTI framework, it is divided into five areas "based on attributes specific to tangible and spatial styles of interaction," and characterizes children as "active learners embedded in a physical and social environment" (p. 195). Its focus is children ages four to twelve and developmentally appropriate theories related to children's cognition. In the design of tangibles for children, Antle aims to support abstract thinking, and she pulls from both the embodied cognition and cognitive science field. Despite noting that she considers the two fields to be opposed, she feels that using both helps to address "the strengths of action-based cognition and the limitations of children's mental representational abilities" (p. 196). What the framework does not explore are affective and motivational factors (or engagement), which is explored in both persuasive design and teaching fitness.

The first area of the CTI framework is entitled "space for action," and advocates two design concepts: embodied cognition and pragmatic and epistemic action. The tradition of embodied cognition shows that reason grows out of bodily experience. One example the author cites is how children use their fingers to learn to count, and how several progressive teaching methods (such as Montessori and Frobel) are based in theories that show that interaction within their environment is a crucial part of a child's cognitive development (p. 197). Antle puts forth that designers should consider body-based interaction and control, an age appropriate repertoire of physical actions, and existing performative knowledge (p. 197). The other side to designing space for action includes both pragmatic and epistemic action. Pragmatic action involves interacting directly with physical objects in order to accomplish a task. Epistemic action is when the nature of the task is changed in order to assist in accomplishing a task. This is often because the mental processes involved in accomplishing the task are challenging, and children will often attempt to use external objects to change or assist the nature of the mental processes needed to complete the task. Children use this to understand the various ways things work in the world, often using external aids (interactions with people or aspects of the environment) to "offload cognitive processes" they find difficult (p. 197).

For the second theme, "perceptual mapping," Antle lays ground for why designers of tangible user interfaces should consider the relationship between how children perceive objects in their environment and digital representations in relationship to their own bodies. This includes consideration for both perceived and designed affordances. A perceptual affordance lies in the relationship between the perceived potential for action and the nature of an object. How children map between the perceived properties of a tangible user interface and the physical or digital properties of a system should be designed as age appropriate. On-screen and adult-centric perceptual affordances are not appropriate, for what is designed for adults may not trigger the same action in children. However age appropriate perceptual affordances are important for "designs which rely on perceptual affordances will allow even very young children to activate the system and subsequently explore the mappings between physical and digital aspects of the system" (p. 197). Also important is how children perceive more abstract concepts in relation to the physical world. Antle recommends designing with the child-body scale as reference in mind. Children learn to understand the world in terms of their own bodies, and often find it challenging to learn abstract representations of scale. Antle feels that combining digital representations with physical interaction can help children explore the complexity of scale by "represent[ing] children's bodies at a variety of scales to enhance understandings of scale" (p. 197).

How children understand the behavior of objects in the world is another consideration explored in the third theme, behavioral mapping - especially in the relation between how information is inputted into and then outputted within a system. Cognitive mode switching refers to moving between experiential and reflective cognition. Reflective cognition develops slowly in children, and supporting both solo and group reflective activities are important, and a design recommendation. Antle also recommends that designers consider the philosophical concept of ready-to-hand vs. present-at-hand. As with tools in physical world, Antle cites research that shows "uncertainty and unexpectedness in system events can...promote a switch to a reflective mode of cognition" (p. 198), meaning an unexpected event can often lead to reflective thought about the actions taken. Designers must consider both because "children need significant support to ensure that they move from an active, experiential mode to a reflective mode where they can acquire new understandings" (p. 198).

How children perceive the rules of cause and effect also relates to understanding behavioral mapping in designing a tangible system. If a child does not understand the relationship of cause and effect within a system it may trigger reflective thought, however it may also cause confusion. There are three principles in which children understand cause and effect, and the accuracy of how they use them develops as they grow. The principles are temporal precedence, covariation and contiguity. Temporal precedence explains how a cause either precedes or occurs at the same time as the effect. At the age of three, children can begin to identify temporal order in relation to effects (p. 198). Covariation says that "causes and their effects must systematically covary...a causal relation describes an invariable connection between events," and the older children become, the "more tightly [they hold] to this principle when attributing causes to effects" (p. 198). Contiguity says that a cause and effect "must be contiguous in time and place or at least linked to each other by an intervening chain of contiguous events" (p. 198). If too much time occurs between a cause and effect without any linking events, only children eight or older can reliably identify the covariation (p. 198). Both the order of importance of these three principles and variables that influence causal judgments can affect design. According to

Antle, the three cause and effect principles can be both supported or broken to help them learn new conceptual structures.

The fourth theme, semantic mappings, refers to the various ways representations of information can occur within the physical and digital aspects of the system (p. 198). Young children have difficulties relating objects to their representation across contexts and understanding that a single object can be represented in more than one way (p. 198). Because of this, Antle recommends exposing such representations and exploring the relationship between objects and their representation in the design of tangible user interfaces. Antle describes research that shows as children learn to read maps, their development of spatial cognition is reciprocal (p. 199), that is, both the developing conception of one's environment and the ability to understand a representation of it improves each skill. Such reciprocal mapping is another design recommendation under semantic mapping. Another design concept revolves around children understanding abstract concepts as rooted in their bodily understanding, which can be leveraged to teach abstract concepts. Working with how children organize spatial concepts can serve as a cognitive aid for memory, communication and reasoning (p. 199) and can help teach abstract concepts.

The final theme of the CTI framework calls to make space for friends through collaboration, imitation and intentional affordances. According to Antle, collaboration and imitation "are typical and important ways that children develop schemata" (p. 199). Collaboration has been shown to provide both learning and motivational benefits in interacting in computer environments (p. 199). To support collaboration in tangible interfaces, Antle recommends designing so that interaction supports rather than requires collaboration, using multiple input units or modes, and setting in place a protocol for changing mode or transfer of control. Observing and imitating is one of the primary ways in which children learn (p. 199). In observing other people perform activities with tools, children begin to understand the intentional affordances of objects or tools (p. 200). Therefore it is important to give clues to intentional affordances, provide visual access to performative actions, and allow turn-taking of physical or spatial controls.

Tangible technologies support children in learning in the real world. In learning and engaging in sustainable activities, tangible offer new and unique ways to teach by doing, rather than simply teaching information. More abstract concepts, such as the lifecycle of physical objects or energy conservation, can be taught in interactive ways that support embodied learning and children’s cognitive abilities. For example, Antle’s recommendation of embodied cognition could be used in creative ways to support a body based understanding of the lifecycle of objects from creation, use to waste. Children can also create an understanding in reference to their own bodies the scales of how things move throughout ecology and within our society through playing with tangible toys and tools they can hold and move and manipulate. Without any tangible controls, using the flat computer screen works against such learning, for it ignores the more physical and sensory ways in which children learn.

With tangibles, interaction designers with the intent to teach sustainable behavior can also explore the cause and effects of actions in the world to carefully encourage reflective thought about the material origins and wastes of objects around them (or within nature). The multiple meanings of objects, and how they fit into systems, can be explored in simple ways with interactive technology aiming to teach sustainability. In nature everything works in multiple ways within its habitat, and so do our own made objects, but not always intentionally. These meaning must be explored carefully as the CTI framework explains, but it is an important conceptual understanding for sustainable behavior. And as the other studies described in this paper also point out, designing in social activity and collaboration is crucial. Antle speaks of collaboration in terms of the physical tangible interface, for considering the various ways inputs and outputs work, access to aspects of the technology and turn taking, which are important considerations outside of actually designing a socially oriented game.

PERSUASIVE DESIGN AND THE FUNCTIONAL TRIAD FRAMEWORK

B.J. Fogg has run the Stanford Persuasive Technology Lab since 1993. He's created the space for a new field of 'persuasive technology' for which he has coined the term captology, and acronym for "computers as persuasive technologies" (Fogg, 2003, p. 5). Hi 2003 book, *Persuasive Technology: Using Computers to Change What We Think and Do*, lays down principles for both studying and creating persuasive interactive technologies. The intention of persuasion, to make certain decisions or change behaviors, is the most important element of Fogg's argument. Three additional elements that make up captology are motivating people as they are interacting with technology (rather than through the medium), an emphasis on intention to persuade (vs. a side effect) and the design of persuasive elements into technologies (rather than someone choosing to use a technology to change a behavior outside of the designers intent, what he calls "endogenous intent") (pp. 16-17). The overall intent in the design for persuasion is what he calls the "macrosuasion, while individual persuasive elements within a larger system or design are called "microsuasion" (p. 18). An example might be a large website with the intent to sell a product or idea as the macrosuasion, and a unique call to action on an individual page as one of several microsuasions. An example Fogg uses is the rating system within the online auction website eBay. The ability to rate the seller in a public forum motivates sellers to be honest and responsive, and is a microsuasion within the overall macrosuasion of encouraging a profitable online auction community (p. 19). Ethics are a primary concern to Fogg and a recurring theme throughout the book. Coercion and deception, amongst other deceitful tactics, are often a danger which he considers outside of the realm of captology though a risk designers must be wary of.

As a means to understand the various ways in which persuasion can be designed into technology and the theories that support it, Fogg describes a functional triad framework. A conceptual framework, the triad looks at persuasive technology through the point of view of a user. Within the triad, interactive technologies function as tools, as media, or as social actors (p. 23). Tools function for ease and efficiency. Technology as media is symbolic and sensory, as well as interactive. As a social actor we form a relationship with our technologies or through them.

Within the framework, each of the three primary functions of computers as persuasive technology has associated principles. Persuasive tools function in many ways applicable to encouraging more sustainable choices. The principle of reduction, or breaking down complex tasks into simpler ones and there for reducing the cost of acting and increasing the persuasiveness of the action is one. By making the choice easier, it is more likely that people will follow that path. Tailoring involves adapting technology to an individual's needs and/or context, which can become especially important when considering sustainable behaviors on a regional or local level. Suggestion is a principle related to time and context - seizing the opportune moment. For some activities, awareness in the moment can be most persuasive in choosing a behavior, and technology can support in the moment decisions, for example, knowing a bus will arrive in 5 minutes. Self-monitoring serves as a cognitive aid by tracking and analyzing performance or status of a set goal. When closely aligned with a goal or outcome that people (individuals or groups) care about, self monitoring can be a powerful tool. Finally, conditioning is the principle of using positive reinforcement to support learning new or transforming existing complex behaviors. People respond positively to praise, and it's recommended to emphasize positive messages within computing tools.

Using computers as persuasive media primarily focuses on experience, and Fogg sees computer based simulation as one of the most effective aspects of persuasive media. Simulation can model the relation between cause and effect in a safe environment, and can show outcomes almost immediately. Users can also rehearse behaviors in a safe, simulated environment, for example, in a game environment. Virtual rewards can be effective at influencing and motivating users for activities in the real world.

Fogg views computers as social actors because he has observed people responding to their machines socially throughout his research. He notes that we instinctually respond to cues in our environment that seem alive, and when a social presence is perceived, various emotions and cultural conventions become part of the experience of interacting with the machine. Physical cues, especially attractiveness, are one way in which a designer can take advantage of technology as a social actor. Whether the technological object or a character represented, attractiveness increases the persuasiveness of technology. Similarity is also an important aspect to using technology as a social actor. People we think are similar to us can more easily persuade us compared to those we feel are not (p. 95), and similarly, people prefer computers with a personality similar to their own (p. 97). Convincing a user to feel an affiliation with their computer, like being on the same side, is another way to use the principle of similarity, as well as attempting to mimic the cultural environment of the user. Praise, whether perceived as sincere or not, positively affects users. Reciprocity is a kind of social rule to reciprocate a favor, and Fogg has found people respond to computers in a similar way when they feel it has done them a favor. People also respond to authority, and Fogg feels that computers can act as an expert or advisor, adopting a position of authority. Overall, one of Fogg's recommended uses for using social cues with computers is for teaching children and educational games. This is in part because designers can use this to teach social dynamics.

To Fogg, mobile devices offer some of the greatest potential for the design of persuasive technology. There are constraints to current mobile devices, like the small screen and means of inputting information, however Fogg feels that such constraints can be overcome through awareness of input limitations and simplicity. He also cautions that when designing for mobile, the goal should always be to help people accomplish their own goals. This is because people often see their phones as an extension of themselves and disrupting this can feel like a betrayal (pp. 192-3). The reason Fogg is such an advocate for persuasive mobile devices is that they are networked to both the internet and each other, meaning they can use social influence, better information, and intrinsic group level motivators that are social (competition, cooperation and recognition) (p. 205).

Better information is "current, contingent and coordinated" (p. 188). Fogg writes that up to date information is the most persuasive. An example he describes is the online auction eBay texting a bidder that their item has been outbid. Tactics such as this maintain interest, act as a reminder, and cut out the step of checking on a bid to stay current. Such currency is "seductive" (pp. 195-6). The opportune moment, what he refers to as "kairos," (p. 188) factors in location, routine, time of day, goals for day, and current task. Mobile devices can best harness kairos because people often carry them wherever they go. As mobile devices begin to incorporate more intentional persuasive design, Fogg warns that experience design must also be factored in, so that interactions "weather well" like a "comfortable friendship" (p. 194). However the "information quality" advantage of mobile devices over non-connected devices is rich grounds for persuasion.

Connected mobile devices can also leverage social influence, and Fogg notes that "attitude and behavior change" are more likely achieved in a group than on one's own (p. 197). Fogg explores some prominent social theories he feels are relevant to persuasive design with mobile devices: social facilitation, social comparison, conformity, social learning theory.

Sports psychologists have concluded that people "exercise more effectively when they are with other people" [197]. Social facilitation theory supports this, for it suggests that people are more likely to perform or behave better when other people are present, whether participating or watching (p. 197). Fogg argues that the same can be accomplished with a virtual presence or virtual social group. The virtual presence need not be a "real" person, for simply the perception of social facilitation is motivating enough for most people (p. 198).

How people act around us shape our own behavior and decisions. People look to others to learn about and compare what they should be thinking or doing, and social comparison theory suggests that "people seek to know the attitudes and behaviors of others in forming their own attitudes and behaviors" (p. 198). Social comparison theory shows how the influence of those around us is "so powerful it sometimes can change physiological responses," and Fogg notes that studies have shown that when people compare their feelings of pain to others, it can decrease those feelings of pain. Such influence is strengthened when we find those we compare ourselves to be similar to ourselves.

Those around us can also have a "normative influence," similar to peer pressure or the pressure to conform (p. 199). While it is not the same as social comparison theory, conformity can result in people "changing their attitudes and behaviors to match the expectations, attitudes, and behaviors of classmates, a team, a family, a work group, or other groups" otherwise referred to as "in-groups" (p. 199). Fogg imagines an example in which technology would expose one's recycling habits to their in-group, however if this were the only approach it might fail over time.

One of the most prominent and effective ways to change attitudes and behaviors, social learning theory, was developed by the psychologist Albert Bandura (p. 201). Social learning theory advocates modeling behavior, and shows that we learn new behaviors by "observing other actions and then noting the consequences of those actions" (p. 201). People are more likely to perform desired behaviors if they see someone else rewarded for it, especially if those whom they see are similar to themselves, yet slightly older or more experienced (p. 201).

In any design with the intention to promote or support sustainable behavior, persuasion will play an important role. Most sustainable behavior does not currently offer the easiest solution, and an understanding of motivation and persuasion can help to increase the chances of success for any project. All of Fogg's principles can play a role in the design and analysis of interactive technologies meant to teach or support sustainable behaviors, but especially the connectedness and social aspects of networked technologies. Collaboration with peers not only supports learning, but according to Fogg, is persuasive in itself. Modeling sustainable behavior or concepts, whether through trusted virtual characters or connected peers can also be explored by designers. Social learning theory can be utilized by designers to teach the consequences of behavior of individuals or groups. If using any physical or virtual characters, both the similarity and attractiveness of those characters can help to create a bond between the child and the technology. And, as studies into fitness point out, a positive environment, virtual rewards and praise are all important is reinforcing the value of sustainable behavior from a young age.

FITNESS AS AN ANALOGOUS BEHAVIOR IN CHILDREN & ADULTS

Acting sustainable can often mean making a decision with the future in mind over momentary convenience. In post-industrial times physical fitness is similar, for choosing to be physically active today is not always the easiest choice to make for your health in the future, especially if under stress or in bad weather conditions. Many people struggle with fitting activity into our sedentary society, whether with finding time or motivation, and this environment has led to high numbers of obesity and diseases like diabetes. Making daily choices for environmental sustainability can be equally challenging or confusing. It is easy to make the choice to walk to a supermarket a block away from one's home, and even bring a reusable bag and choose produce not grown with harmful pesticides. However where the produce is shipped from, packaging materials and even the energy use of the supermarket all play a role in the scheme of things. While many of these choices may be out of an individual's hands, technology can be used to decrease confusion and support sustainable decision making, as well as behavior. Supporting more positive decisions, like with physical fitness, is much about awareness and the opportune moment.

In their 2008 article *Research on Effective Teaching in Elementary School Physical Education*, Judith Rink and Tina Hall compile current research in fostering a physically active lifestyle, which offers clues to how to do the same with sustainable behavior. They explore the correct balance and emphasis among the US national content standards for physical education, for which there are six target areas: motor skills, education on what is needed for a physically active lifestyle, encouraging regular participation, facilitating the development and maintenance of fitness, responsible personal and social behaviors, and value participation (p. 208).

As adults we engage in a range of complex physical activities. It's been found that to effectively prepare children for such a range of activities a foundation of motor skills must be learned at a young age. Basic skills such as rolling, hopping and balancing can be "developed into activity-specific patterns" considered necessary for a lifetime of activity (p. 209). Programs that rely too heavily on either specialized skills or fun (without a focus on skills) are both found to not perform well (p. 209). Basic skills, developmentally appropriate and either too specialized or unstructured, build confidence in children, which is what the authors point out as important to laying the grounds to a lifetime of activity. It is "the belief that skills can be successfully performed, and, when needed, that new skills can be acquired" (p. 209).

Beyond teaching developmentally appropriate and foundational motor skills, those skills must be practiced and the quality of that practice is just as important as quantity of practice (p. 213). High quality practice and seeing a progression of tasks over time supports the development of those skills in long term memory. A focus on self progress and praise also feeds into the value of practice, for praise combined with repeated and similar yet varied tasks reinforces basic skills. Praise and quality practice relate to students current and past perceptions of success, which helps to motivate children to engage in motor tasks (p. 213). Rink and Hall also emphasize the importance of individualizing tasks and adapting them to individual learning styles. Current research shows greater success with a focus on task orientation (or self progress) over ego-orientation (self vs. others). Emphasizing self progress can help to "personalize [a child's] notion of success and avoid external comparisons that are not relevant to their own achievement" (p. 213).

Rink and Hall note that teaching the personal value of physical activity is the greatest challenge, and similarly, many people understand the value of sustainable behavior, translating that value into action in the real world is equally challenging. For physical education, one reason for this is the individual nature of human perception and motivation - a fun and positive experience for one may not be so for another (p. 211). Over time, most people do not participate in physical activities because of health benefits; instead, they enjoy the social interaction, challenge, self expression and joy of play and movement (p. 211). So while there is no certain pedagogy for making activity a habit, Rink and Hall conclude that a positive class atmosphere, individual development (versus comparison performance), and a variety of movement forms can all help to develop a personal value of physical activity (p. 211). Positive reinforcement, as well as an individualized approach to teaching the value of sustainability, may also be important for teaching the many behavior and concepts of environmental sustainability as well.

While educating children about sustainability involves teaching more abstract concepts, children are engaged by learning in an active, physical manner as Antle shows through theories such as embodied cognition and children's understanding of bodily-based concepts. Teaching sustainable behaviors, especially some of the more physical aspects, using interactive technologies should look to lessons learned in physical education for some clues. Positive reinforcement and individualizing goals are two design elements that can be used, as starters.

Encouraging physical activity through interactive technology for adults is a topic that is currently being explored in various ways, and also offers clues to guide in designing similar applications for children. Houston and Ubifit are two case studies, one drawing on the other, that exemplify mobile health tracking devices tested on an adult population. Both resulted in design recommendations for motivating adults to consistently engage in physical activity.

Described in a 2006 paper, Consolvo, Everitt, Smith, and Landay designed and tested Houston, a mobile application used to track "opportunistic" physical activity, that is, physical activity that can easily be incorporated into daily life such as walking and climbing stairs, and more strenuous cardiovascular exercise like jogging (p. 457). The authors chose mobile technology because they feel its portability allows it to be there in hand when the right moment pops up for the user, and more likely to encourage physical activity in that moment. Houston includes a Nokia phone with the Houston software installed and a pedometer. The software uses step counting and a mobile phone fitness journal, and a refined prototype of the software was tested on three groups of women over a three week pilot study, all of them being motivated to either maintain or lose weight. The broader question they pose in their study is if technology can "encourage physical activity by providing personal awareness of activity level and mediating physical activity-related social interaction among friends" (p. 457).

The authors summarized their analysis of the resulting qualitative data into for major design requirements to encourage physical activity: give users proper credit for activities, provide personal awareness of activity level, support social influence, and consider the practical constraints of users' lifestyles (pp. 457-8). Personal awareness and social influence were considered to be the two primary motivators for physical activity (p. 464).

A pedometer cannot account for all forms of physical activity, nor can it distinguish the level of activity, which made it difficult for Houston to meet the first design goal, giving users proper credit for activities. Participants found this frustrating, some even discouraged from increasing their level of activity while using Houston. Because of this, the authors warn of "deceptive measurements" (p. 462) in a technology that aims to motivate people. Some participants spoke of the desire to edit or supplement the data in the pedometer, like noting activity level or mood, which led the authors to recommend that when using technology that deals with similar tangible activities to provide some function that can help to supplement or edit the limitations of a device like a pedometer (p. 462).

Participants were intrigued by the data reporting on the activity they had actually performed. Comparing the memory (or perception) of an activity to the reality often motivated participants. In this Houston was a valuable cognitive tool, by recording actual data out in the world (vs. a person sitting down and having to remember and input the data in), users can get a true gauge of how they act, and, if motivated, work to increase or decrease their behavior. The authors found three types of personal awareness important to provide to users; history, current status and activity level performance (p. 462). Current status was found to be motivating in the moment, so it should be available to users at all time, and history was a reflective tool for participants to find patterns and plan for future activities (p. 462).

Positive feedback on top of the participants' activity level in reference to their goal was also motivating to participants (p. 463).

A limited amount of quantitative data was collected and analyzed by the authors, and it showed that groups of participants that shared activity data performed better (p. 461). When using the Houston software in groups, it was found to both motivate by competition (or social pressure) in a public format, and motivate through the support of message passing and seeing other group members success (p. 463). In this example, with adults, the combination of competition and empathy was successful, as was the motivation of seeing successful behavior modeled by a peer.

The lifestyle and context of the user was found to be of primary importance. If the user does not want to wear the device, then it won't be used in the first place. How a tool meant to motivate physical activity works within a person's environment and how the device is worn must be considered. Goals for users must also take in context, and in the case of Houston, it became important to find ways to encourage sustainable individual goals for step-count (p. 464). The authors noted that participants tended to be frustrated by the goals they set if too high, but individual goals worked well if they were in reason (p. 464). Goals also helped to motivate participants in a maintenance stage because it encouraged competition (p. 464).

Several of the designers of Houston used the resulting design recommendations from the case study in the design of the Ubifit software two years later. Consolvo, et al., describe Ubifit, in their 2008 paper *Flowers or a Robot Army? Encouraging Awareness & Activity with Personal, Mobile Displays*. Ubifit was designed as a persuasive technology to "encourage individuals to self-monitor their physical activity and incorporate regular and varied activity into everyday life" using a stylized representation of behavior and mobile phones (Consolvo, et al., 2008, pp. 55-6). The designers tested an additional method to encourage awareness in participants with use of the background screens and screen savers on mobile display. The authors point out that "these always-available displays could be used to increase an individual's awareness about various elements of daily life. For example, these personal, mobile displays could provide awareness of one's own behavior (e.g., how physically active one is) or of the activities of friends and family. Awareness about one's own behavior is particularly useful if one is trying to change behaviors or habits (e.g., lead a healthy lifestyle)" (p. 54).

The Ubifit software includes a desktop display on a mobile phone that uses an abstraction of people's weekly physical activities. The metaphor chosen is a garden - different color flowers represent different activities, and they grow and sprout leaves as those activities are performed. As goals are met, butterflies are added to the garden. Ubifit does not use punishment - if activities don't happen, you simply see green grass and a blue sky, and if no goals are met, no butterfly will appear. The combination of the Ubifit software, its abstract display representing activities and a health monitoring device encourage participants to self monitor their own activities while providing only positive reinforcement and simple rewards for meeting personal goals or carrying out encouraged activities. Unlike Houston, Ubifit accounts for a greater range of activities that can be captured by a pedometer, and in fact encourages more diverse activity (including strength and stretching) by considering it part of weekly goals. The stylized mobile display encourages self reflection through its abstraction of the participants' weekly activities, but can also be ignored for a period of time without affecting the user in a negative way.

The authors tested Ubifit with 28 participants over three months. The months chosen were the winter holiday season, to see how behavior might be affected at a time typically known as one where people lose interest in maintaining a healthy lifestyle. Overall the authors found that the stylized display increased awareness for participants. Both quantitative and qualitative data collected "indicate that such displays can indeed be effective at raising awareness and potentially influencing behavior" (p. 61). The activity level of those who did not have the glanceable display decreased over the holidays, while those who used the display maintained their average activity level (p. 59). Both the Houston and Ubifit case studies show the importance of principles noted in both the CTI and functional triad frameworks: praise and a positive environment, social connectedness and collaboration, individualizing goals and de-emphasizing competition unless users choose to engage in it, an awareness of the user's cultural and physical context, and using awareness for seizing on opportune moments.

DESIGNING FOR SUSTAINABLE BEHAVIOR

All three areas ; principles for designing tangible interface for children, designing for persuasion and best practices in teaching and designing for motivating fitness offer clues to how we might design interactive technologies to teach and support sustainable behavior. Some design conclusions are as follows.

Teach basic, developmentally appropriate skills in a structured manner. Consider basic concepts that make up more complex theories of sustainability as building blocks towards a more sophisticated understanding, and design with children's cognitive abilities in mind, such as their understandings of representation in relation to themselves and of the workings of cause and effect.

Create technologies that adapt to personal skill level and personal preference. Store information about the child user, and adapt the speed or nature of what is being used or played to mimic their preferences. Also focus on personal task orientation and support self progress towards personal goals over a competitive environment with peers.

Whether virtual or real, design for social interaction and collaboration. Children learn socially and through imitation, so design carefully with this in mind. If designing a tool (or anything that functions like a tool), in the moment awareness can be used to remind children of various activities. Make sure to also give proper credit to individuals if any games involve connecting with peers or collaboration.

Whether through the design of a collaborative environment or through the technology, create a positive environment that offers praise and virtual rewards. Virtual rewards need not be over the top, but simply a tangible toy dog wagging its tail, or a smile on a virtual character. If possible, make praise adaptive over time and with memory. As the child learns the device, develop the challenge or reflect upon the past in creative ways.

When designing a game or a tool for children, model behavior and the consequence or effects of actions to teach positive sustainable behavior. Do this through designing it into collaboration with social peers or modeling it in a virtual world. Clearly show cause and effect, and if using disruptions or surprises be sure to work with children's understandings of causation.

Create real world interaction with tangible interfaces. Sustainability is an abstract concept that must be acted out in many ways in the real world. Games or technologies that are physically passive only reinforce inactivity. Attempt to connect teachings to real things around children. Similarly, ground any abstract concepts taught in bodily understanding. If teaching about the various functions of an object (or person) within a system, tie it to a simple, physical activity a child can carry out or relate to.

Consider the context of the target audience, such as where the device will be (physically) used and the culture in which it is used. For example, if designed for a classroom, consider collaboration in a small, crowded space, noise level, storage, multiple access to inputs and outputs. Use observation and ethnography to guide design. Also, design for feelings of similarity and attractiveness to a chosen audience.

To effectively work towards environmental sustainability a human centered approach must be considered, for without taking the needs, motivations and contexts of actors within or society into account very few tools or programs will be effective. Sustainable behavior and concepts can be introduced at a young age, however an understanding of motivation and their unique cognitive abilities needs to be accounted for in design. Design for physical fitness, tangible interfaces and persuasion all offer clues into creating a framework to teach and support the complexities of sustainability.

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