SmartHolder: Sensing And Raising Families' Awareness Of Tooth Brushing Habits

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ABSTRACT
With an increasing emphasis on behavior change technologies, interest has grown over time also on the role of HCI in motivating healthy tooth brushing habits on children. In this paper we present the design and development of SmartHolder, a toothbrush holder that senses the frequency and duration of toothbrush practices and motivates healthy tooth brushing habits, through raising family members’ awareness of each other’s practices. We first present two preliminary studies about children’s and adults’ tooth brushing behaviors and how these are influenced by social interactions within the family. We conclude through a presentation of early conceptual designs as well as an initial working prototype of SmartHolder.

Categories and Subject Descriptors
Persuasive technology, children, tooth brushing.

Keywords
H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces.

INTRODUCTION
Regular brushing of teeth is essential in maintaining oral hygiene and preventing from chronic diseases [1, 2]. Tooth decay, toothache and bleeding gums stand out among the common oral problems but, poor oral hygiene can even have detrimental effects to chronic conditions such as diabetes and heart disease and has also been linked to mouth cancer and early labor [1, 2, 3].

Despite its importance, individuals often fail to adhere to healthy tooth brushing habits. This is often rooted in a lack of motivation to perform an unattractive task, or in the absence of an established routine [1]. While establishing such routines from early childhood has proven particularly important [1], parents are often struggling to educate their children about the importance of maintaining healthy tooth brushing habits. To help overcome this situation, different approaches have been developed to change brushing behaviors and create engagement (especially children), from colorful and musical toothbrushes to technological solutions that sense and provide feedback on individuals’ tooth brushing habits.

In our line of work we attempt to motivate healthy tooth brushing habits through tapping to the social mechanisms of families. Grounded upon the theoretical framework of Social Translucence [13], we argue that increasing the transparency of tooth brushing behaviors among family members will increase individuals’ motivation and accountability in adhering to desired behaviors. We discuss the design and development of SmartHolder, a prototype that senses the frequency and duration of tooth brushing practices and attempts to raise family members’ awareness of each others’ behaviors. In the current paper we present our early attempts towards this direction with two studies that attempted to inquire into the drivers and barriers towards adhering to healthy tooth brushing behaviors and present our early prototypes.

RELATED WORK
Engaging children in tooth brushing practices is not a new trend. Playful products such as colorful toothbrushes and tasteful tooth pastes have been some of the early solutions towards this goal. More recently, technological products have filled the market. For instance, Spinbrush1 and Squeaky Clean Teeth2 are tooth brushes that play a song while tooth brushing for the minimum recommended time (i.e., 2 minutes) with the goal of sustaining children’s interest in the activity. Beam Brush3 also logs users’ behaviors and allows them to review using a mobile app. Oral-B Smart Series 50004 provides a visual display with feedback about time as well pressure control.

Recent research efforts have gone a step further. Playful Toothbrush5 is an ubicomp technology that attempts to assist parents in educating kindergarten children on proper tooth brushing practices. The prototype uses a vision-based motion tracker that recognizes different tooth brushing strokes and an interactive game that highlights the teeth that are yet to be brushed. Alonso et al. [6] developed a prototype that provides haptic feedback with the goal of learning to perform a complex tooth brushing technique. Nakajima et al. [7] proposed a virtual aquarium that motivates individuals to adhere to 3-minute tooth brushing practice. Gerling et al. [8] and Soler et al. [9] proposed serious games as educational tools in raising awareness of the importance of tooth brushing and educating children on proper tooth brushing behaviors. Finally, Hachisu and Kajimoto [10] proposed a solution that manipulates the auditory sensation of tooth brushing with the goal of augmenting the experience of progressive cleanliness.

Theoretical foundations
The vast majority of the technological solutions described earlier have relied on providing just-in-time motivational feedback with

1 http://www.spinbrush.com/toothtunes.html
2 http://neyeni.net/16051/squeaky-clean-teeth.html
3 http://www.beamtoothbrush.com/
4 http://www.oralb.com/products/professional-care-smart-series-5000/
5 http://www.oralb.com/products/professional-care-smart-series-5000/
the goal of increasing adherence to desired behaviors or performance within. In line with Fogg’s behavior model for persuasive design, they attempt to increase children’s awareness and motivation for frequent or appropriate tooth brushing, to increase children’s (perceived) ability to perform the task, or to provide the triggers that encourage behavior change during appropriate moments.

An aspect missing from these applications is the role of the family in inducing behavior change on children. An extensive body of work in behavior change applications has pointed out the strong influence that social ties have in reinforcing or changing behavior [12]. Especially close social ties, such as families, have profound influence on their members’ behaviors, through effective and advanced social strategies such as playful nudging and maintaining an awareness of each others’ behaviors. Over time, these practices enable families to develop common routines and establish social norms. As such, technological interventions may be more effective if they integrate with families’ existing social practices.

A theoretical framework that can be particularly fruitful for the design of such systems is the Social Translucence framework [13], which prescribes how individuals modify their behaviors when they become aware that these are visible by others. Social Translucence identifies three critical properties of systems acting towards this goal. The first is visibility; the system should make meaningful information about each others’ behaviors visible to others (e.g. has a child brushed her teeth this evening?). Secondly, awareness refers not only to the fact that parents become aware of the child’s behavior, but also to that the child becomes aware that her parents are aware (mutual awareness). Social Translucence argues that through this process, a critical property is established – accountability, which increases the likelihood of the child’s conformity to the desired behaviors.

One should note two things. First, a socially translucent technology should not aim to replace families’ existing means for behavior change but rather to best integrate with them. Second, a socially translucent technology should make no value judgments on the child’s behaviors – it is up to the parents to appropriate the feedback of the technology and establish norms and practices around it, such as playful nudging and positive reinforcement.

The Social Translucence framework has been extensively applied in the design of collaborative systems [13], and more recently in the design of behavior change systems. For instance, Barreto et al. [4,11] used the Social Translucence framework to study how families’ communication and coordination practices influenced energy consumption practices in a household. They found that even with aggregate information (i.e. overall household consumption), families had a rich understanding of the practices and appliances that led to an increase in consumption, and employed creative social practices to influence each other.

With SmartHolder we aim to focus on the role of social interactions in motivating proper tooth-brushing, understanding which contributions could stand out and differentiate from the previous individual behavior change work mentioned.

**PRELIMINARY STUDIES**

The following section presents two studies, a survey and a set of interviews, that tried to inquire into children’s and adults’ practices of tooth brushing (such as the perceived frequency and duration), the motives and the barriers towards adhering to desired practices, as well as how social interactions among family members affect individuals’ tooth brushing practices.

**Survey**

A survey aimed at gaining insights into individuals’ tooth brushing behaviors. A total of 61 participants completed the survey. Their mean age was 24 years old (min=7, max=59). Fourteen (23%) of the participants were children between seven and nine years old. Children completed the survey on paper and were recruited in a school with prior authorization (mean age=7, min=7, max=9).

To avoid memory biases we employed a similar procedure to the Day Reconstruction Method ([13], see [15] for an alternative). Rather than asking them to report on their typical behaviors, we asked them to recall the past day and report when and for how long they brushed their teeth, along with other information about these events.

**Findings**

**Tooth brushing practices**

Overall, individual’s self-reported habits are better than expected. In fact, 97% of participants reported brushing their teeth two or more times a day, the minimum frequency recommended by experts [3] the average number in our sample was three per day. However, while participants’ reported frequency of tooth brushing may be judged adequate by experts, the majority of the them (61%) reported that they would like to increase the frequency of tooth brushing by 1 time/day (43%) or 2 or more times/day (14%).

The median perceived duration was 2 minutes and 37 seconds; only 59% of participants reported brushing their teeth for 120 seconds or more, the duration recommended by experts [3].

We found that individuals with age lower than 18 years old (N=21, Mean=146 seconds, SD=108 seconds) spent less time brushing their teeth than adults (N=61, Mean=177.15 seconds, SD=216.19 seconds, t(79)=-6.19, p<0.01). An even stronger effect was found in the perceived frequency of tooth brushing with children and teenagers displaying less frequent behaviors (N=21, Mean= 2.05, SD=0.740) than the adult participants (N=61, Mean=2.90, t(79) = -3.61, p<0.01).

As expected, children of nine or lower were not aware of the time spent brushing their teeth, but they were conscious about their tooth brushing frequency. Only 43% of the children reported a tooth frequency of twice a day (or more), the minimum recommended practice.

**Barriers against healthy tooth brushing practices**

We identified five primary barriers against adopting healthy tooth brushing practices: individuals’ lack of motivation coupled with the unattractiveness of the task (39%), time constrains (blaming the frenetic lifestyles and rotating schedules, preventing the execution of the “task that in itself requires some time” - 21%), missing routines (17%) and the lack of information about health consequences (12%).

**Intra-family awareness and influence**

In total, 59% of survey respondents reported being aware of other family members’ tooth brushing practices. They attributed this mostly to common routines (16%), such as leaving home at the same time and taking meals together. About 9% of the respondents reported this awareness coming through discussion as they attempt to remind each other to brush their teeth, while respondents reported that subtle cues such as the sound of tooth
brushing as well as the tooth brushes being wet often raises this awareness.

Almost all of respondents (90%) reported that they often attempt to influence other family members’ tooth brushing habits, with the primary practice (in 77% of the cases) being contextual reminders, such as reminding others to join them when brushing their teeth.

All children below nine reported that they brush their teeth accompanied by a family member. The majority of them (71%) admitted being forced by their parents to brush. However, when asked about the importance of oral hygiene, we found young children to be well informed about the reasons why one should maintain good oral hygiene.

**Limitations**

While this study provided some interesting preliminary results, one may note a possible self-selection bias, especially in our adult population. This might have affected the results as individuals concerned about oral hygiene, and consequently more likely to adhere to healthy behaviors, could be more likely to respond to the survey.

**Interviews**

The interviews aimed at a deeper inquiry into children’s and adults’ practices and the social interactions among family members. We interviewed a total of 29 individuals from 11 families, from which 8 were children (ages between 3 and 14 years old). We started by inviting all family members to complete a Day Reconstruction diary [14] one day prior to the interview. This diary asked participants to reconstruct all activities an individual performed during the past day, from the moment of waking up till the moment he or she went to sleep. This provided us with a rich, situated account of one particular day of the family and served as input to the interview. Interviews took place with all family members present and lasted approximately 20 minutes. We ended by walking through a typical tooth-brushing event in the actual space.

**Findings**

Overall, the interviews corroborated the findings of the survey with lack of motivation, time constrains and missing routine being critical barriers in individuals’ adherence to healthy tooth brushing practices. While some individuals demonstrated lack of awareness on what constitutes a healthy practice (“[P22] I think I own a good oral health... I do not feel like brushing my teeth more than once a day, one is enough...”, “[P7] I brush my teeth once a day. Perhaps my oral hygiene could be better”), the majority of participants knew what a healthy practice is, but often failed to adhere to it, attributing this to lack of motivation (“[P7] People do not have patience, they can even have time to brush their teeth but have no motivation”, “[P25] Sometimes I am too lazy to brush my teeth”), time constraints (“[P6] Sometimes people are always in a rush and do not give importance to brush teeth”), or the lack of an established routine (“[P5] I do not have a good tooth brushing routine but at this time I find difficult to change it. I use to try to brush more often but after a few days I tend to forget”).

Parents reported employing a number of strategies to help them and their children engage with the task, such as listening to music (“[P6] I turn the radio on every morning and only turn it off when I am leaving home. I think it motivates me to perform my daily practices and I end up leaving home in a good mood”), providing incentives to children (“[P28] Kids do not feel achieving something when brushing their teeth so we try reward techniques like: if you brush you can choose the movie”), making the task more playful for their children through selecting fun toothbrushes and toothpastes (“[P15] I have a toothbrush with some drawings that I like”, “[P26] I like to brush my teeth because I have toothpaste that is very tasty. That toothpaste is cool to swallow” (4 years old), embedding the task in daily rituals (“[P20] “When we are almost done eating mummy asks what we should do next and then we scream brush our teeth!”), brushing their teeth at the same time with other family members (“[P26] I brush my teeth with my brother, it’s more fun”, “[P6] (...) When children are home, I brush my teeth and wait in the bathroom while they brush theirs.”), or simply nudging them (“[P10] (...) with my son, I have to remind him every day. Sometimes he forgets but in others he is too lazy! He needs to get used to it while he is young”).

**Summary of findings**

Overall, the results from the survey and the interviews revealed some interesting findings: tooth brushing is a behavior that can be accomplished more easily in the long term when grounded upon a strong, established routine. This proved to be a hard task and individuals try to incorporate means of playfulness to increase engagement, especially when children are involved. Despite the difficulty to keep supervision and being aware of others family members’ behaviors (primarily with dual-income families and rotating work schedules) individuals exhibit concerns about others behaviors, and feelings of accountability quickly manifest. As expected, this sense of responsibility showed to be stronger between families that possess a good family dynamic and feel comfortable in sharing their daily practices.

A number of interesting implications for design and concepts emerged from the studies. We believe that for effective behavior change the system should hold three main characteristics:

a) A playful, appealing system (visually and functionally) - a playful system is more likely to engage individuals in prolonged periods of time [14, 16] than one that focuses merely on information presentation, helping to create a routine and jost lack of motivation.

b) Increases transparency – Rather than merely presenting information to individuals, the system should opt to make this information available and visible to all family members through comprehensive explanation about the current behavior, helping increase awareness among them, especially when families hold different schedules. We believe that individuals are more likely to become interested and care about their behaviors if they are face often to them.

c) Enhances positive communication – Rather that inducing negative self-perceptions coupled with feelings of accountability and guilt, the system should induce positive and playful among family members.

**WORKING PROTOTYPE**

We decided to incorporate an awareness system in a common object, visible to all family members without adding external resources to their environment. We present a functional prototype of the proposed solution: a toothbrush holder that senses families’ toothbrush behavior and provides situated, just-in-time feedback through visual cues and support families to communicate and coordinate on desired practices.

The design process followed three steps. Firstly, we examined different metrics relating to the frequency, the duration and the performance of tooth brushing. Based on our survey and interview...
results, we decided to focus on frequency and duration as this was most often what individuals were concerned about, what families coordinated upon, and since we noticed that estimating the duration of tooth brushing was not an easy task for individuals.

Secondly, we developed a number of designs taking in account the bathroom space and behaviors within, based on our interviews and activity walkthroughs with the interviewed families, leading us to different forms and feedback displays that were modeled into cardboard prototypes as well as virtual 3D prototypes.

Figure 1. Two early conceptual designs

Thirdly, we developed a first working prototype of SmartHolder using 3D printing, an Arduino platform and a set of sensors and actuators. SmartHolder is a usual toothbrush holder that sends when each toothbrush is (or not) present through an infrared emitter and receptor. This allows us to log when and for how long each individual uses his toothbrush and provide feedback accordingly.

Figure 2. SmartHolder indicating the user of the right side had brushed at least twice for 2 minutes. When no activity is detected (left side), the system do not provide any feedback.

On the top of the holder, each hole is surrounded by a semi-transparent ring that provides feedback about the user tooth brushing frequency. The ring lights up green if a user has brushed her teeth at least 2 times during the last 24 hours, yellow if only once and red for none. After 32 hours the led does not light up, assuming that the respective user is not in the household. On the front side of the holder four led lights per user provide instance awareness of tooth brushing duration, with each led lighting up once 30 seconds of tooth brushing having elapsed, recommending a total duration of 2 minutes. These led lights are triggered by a motion sensor, thus providing ambient awareness as individuals enter the bathroom. Music and micro-learning audio-clips are played throughout tooth brushing, according to users’ preferences and time of the day helping increase engagement and willingness in the practice. An algorithm as well as a crowd sourcing community for the duration and evolution of audio content is currently being developed.

CONCLUSION

Data relating to oral hygiene habits have shown alarming results through time, and the importance of acquiring healthy habits early on during one’s life has been repeatedly stressed. With this work, we aimed at a socially translucent technology that aims at leveraging families existing social mechanisms rather than replace them. Using Social Translucence [13] as a theoretical framework we designed and prototyped a toothbrush holder that senses the frequency and duration of all family members’ tooth brushing practices, and makes this visible into the familial environment. Our future work aims at further iterating on the prototype and conducting a longitudinal field study.

REFERENCES