Social Toothbrush: Fostering Family Nudging around Tooth Brushing Habits

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Abstract
The earlier in life an individual adopts healthy practices the more impact those practices have on the long term. In this paper we present Social Toothbrush, a hardware plugin for electric toothbrushes that aims to induce proper tooth brushing behaviors on young children and adults. Social Toothbrush does so by taking advantage of family communication and coordination practices to encourage healthy practices. We first describe the theoretical grounding of our design process, *Social Translucence*, followed by the design and development of Social Toothbrush.

Author Keywords
Persuasive technology; tooth brushing; family; behavior change; ubiquitous computing.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
Establishing proper tooth brushing habits from an early age has been shown to reduce chance of experiencing serious health conditions, such as heart disease, diabetes complications and respiratory infections, in later life [9]. Yet, despite being a relatively inexpensive behavior that does not require much effort and which can be easily taught [1], individuals often fail to adopt

Figure 1- The led light placed on the bottom of the toothbrush attachment light up to convey user's last activity.

a healthy tooth brushing habit, often due to missing a routine, lacking the motivation, or experiencing time constrains, and parents often struggle to educate their children regarding gaining proper tooth brushing habits [5].

Motivated by this, numerous research efforts have emerged to support and reinforce tooth-brushing behaviors. For instance, Nakajima et al. [10] developed the *Virtual Aquarium*, a system that attempts to motivate individuals to adhere to a 3-minute tooth brushing practice by representing tooth brushing actions in aquarium elements displayed in the bathroom mirror (e.g. if the child brushes properly her teeth, fish living in the aquarium grow and reproduce). With the same reasoning, Chang et al. [6] developed *Playful Toothbrush,* an interactive game where children are tasked with cleaning virtual teeth through their toothbrush strokes. Bozgeyikli et al. [4] proposed *Cravy Brush,* a system that supports children in developing a daily tooth brushing habit by providing virtual rewards in a mobile game, based on their tooth brushing activity. Lastly, commercial solutions such as *Tooth Tunes* try to increase children's interest in the activity by playing a two-minute music clip while the child is brushing her teeth [12].

While representing a significance advance, all these efforts focus on the individual, assuming the technology as the single agent for behavior change. In our line of work we attempt to create technologies that become embedded into families' communication and coordination processes. This implies two changes in perspective: a) that technology is not the sole agent for behavior change, and b) that technology's role is not only to persuade an user to adopt healthy practices but also to raise the visibility of behaviors within the family and support them in communicating around their behaviors.

Strong social ties, such as those within families, have been known for long to exert strong influence on individuals' behaviors. For instance, Bauch [3] found that parents' actions led to noticeable improvements in children's performance at school, in 86% of the cases, when parents became aware of children's misconducts. Different from weak social ties, family members are committed over the long term to supporting each other, they entail reduced privacy concerns and maintain strong awareness about each other's behaviors (such as tooth brushing habits), and often resort to advanced social strategies, such as playful nudging and the creation of common routines and social norms, in an attempt to affect each other's behaviors.

In our line of research we build upon the Theory of *Social Translucence* [8] to design behavior change technologies that achieve behavior change through support families' communication and coordination practices. Rather than thinking of technologies as persuasive, we think of them as *socially translucent*, whose goal is to raise awareness about each other's habits and support them in establishing norms around their behaviors.

In this paper we introduce Social Toothbrush, a socially translucent technology that encourages families to reflect and nudge around tooth brushing habits. We present the design and implementation of Social Toothbrush's two components: a hardware component that senses the frequency, duration and performance of tooth brushing, and a mobile application that visualizes individuals' tooth brushing behaviors and aims at

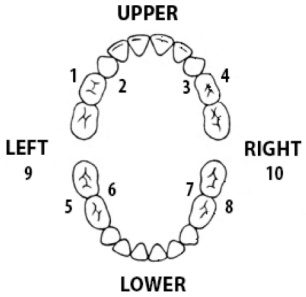

Figure 2 - In total, we are able to detect ten mouth areas, based on an experimental analysis with eight users.

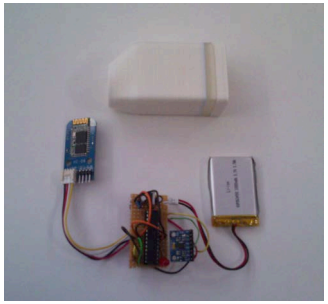

Figure 3 - The hardware plugin is enclosed in a 3D printed case and contains an Arduino, inertia sensors (accelerometer, gyroscope and magnetometer), a Bluetooth communication module, an SD card module and electronics for the inductive charging of the hardware plugin and the electric toothbrush.

increasing intra-family awareness around tooth brushing habits.

Social Translucence

Social Translucence [7] prescribes how individuals' actions are influenced when they become aware that their behaviors are shared with and evaluated by others. It proposes three vital properties for the design of a social translucent technology: *visibility*, *awareness* and *accountability*. *Visibility* refers to making socially significant information visible to others. In our context, this might be whether or not a child brushed her teeth after having breakfast. *Awareness*, or better-called mutual awareness, refers to one's realizations that her actions are being shared and that others are aware of her behaviors ("I know that you know"). Through these two first steps, Social Translucence theory assumes the emergence of *accountability,* that individuals feel accountable about their behaviors and they will act in a manner so that they gain or maintain others' approval [2,8].

Social Toothbrush

Social Toothbrush consists of two components: a hardware plugin to an electric toothbrush, and a mobile application. The hardware plugin comprises of a number of sensors (see figure 3) that enable the unobtrusive monitoring of users' tooth brushing practices (i.e., frequency, duration and performance) through the recognition of user's toothbrush motions. The mobile app collects sensed data and visualizes one's and other family members' tooth brushing practices.

Sensing

We perform automatic recognition of user's behaviors trough a motion-based tracking of the toothbrush extension. Thus, the detection of user's tooth brushing behaviors is accomplished when it involves: (1) lifting the toothbrush from the charging station, (2) detecting toothbrush movements for at least 20 seconds – 10 of them are stipulated as an average time to lie toothpaste and (3) placing the toothbrush back to the charging station. If the system detects further motion after a minute after placing the toothbrush in the charging station, the system considers it is a new activity.

Tooth brushing motions are detectable by tracking the values of two sensors, an accelerometer and a gyroscope. The sensing method is implemented to recognize ten different brushing motions, each of it resembling to a different teeth area (see Figure 2). In order to distinguish the brushing motions, a motion sensor is strategically positioned in the toothbrush extension, aligned with the bristles of the toothbrush. This way we detect the top, down, left and right, inner and outer mouth areas locations by analyzing the angle in which the toothbrush bristles are against the fixed coordinate frame.

To interpret the relation between values in different axes, we analyze and group them in specifics range of values. We displayed the waveforms of sensor readings using Processing (during a simulated tooth brushing) and based on given thresholds, we obtained and identified position patterns. Furthermore, we employed a *Kalman* filter [11] to reduce sensor errors and better estimate the angular position of the toothbrush by

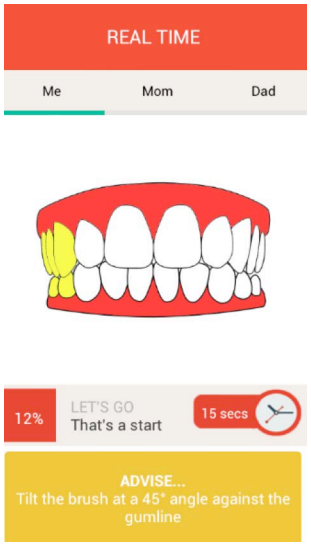

Figure 4 – The User Interface of the Playful Toothbrush mobile app.

assessing neglected measures that occurs while data is being read.

Evaluation of tooth brushing motion sensing
An experimental analysis verified the accuracy of the thresholds, which were recalibrated to reflect real use. To validate the approach, we asked eight individuals to perform two tooth brushing activities during a week, using the sensing platform, in a laboratory environment. Recognition accuracy was computed through the comparison of the patterns recognized by the system with user's actual behaviors as recorded through video capture, with a 1-sec sampling rate. While the activity was conducted, we video recorded user's motions, we saved a picture of user's motions each second and simultaneously, we logged the recognized pattern in a text file.

Preliminary results revealed high accuracy for the detection of six brushing areas (upper vs lower and side/front-side/front), yet, certain ambiguity was present in the disambiguation of the inner regions of the mouth and some false-positive detections occurred when users were brushing those areas.

Classifying user behaviors
The assessment of user's tooth brushing behaviors is executed while the tooth brushing practice is being performed. User's performance is classified into one of three categories - good, medium and poor - based on the time the he or she spent brushing each mouth area. A good performance is accomplished when the user brushed each area for at least the minimal recommended time - thirty seconds. If the user brushes for at least thirty seconds all four areas, we considered that she achieved a good performance. Less than twenty seconds correspond to a medium performance and less than ten is considered a bad performance for each respective region. Through this measurement, we additionally calculate the total time spent of the practice – duration- as the amount of times the user brushed a day - frequency.

In this system, the ideal behavior is defined as follows: a. users should brush their teeth at least three times per day; b. user's should brush their teeth at least for 2 minutes; c. brushing should involve all four mouth areas and user should brush each one for at least 30 seconds.

Feedback
To deliver information into families' daily living environment, we resort to the extension's light feedback. We represent user's behavior through a set of colors codes, which is displayed in the bottom of the extension (see Figure 1) within 24 hours and updated every five hours if there is no user action. When the user achieves a good performance by brushing properly all areas, the extension is lit in green. Otherwise, the extension is lit in yellow. Finally, in case the user did not brush her teeth during the past five hours, the extension lights up red. Due to the high-energy consumption, we make use of the toothbrush charging station to charge the embedded battery through inductive charging.

Additionally, *Social Toothbrush* encompasses an android application to support user's interactions with the extension and incite reflection base on their inferred behaviors (see Figures 4 and 5). Through the application, users can:

a. Visualize their daily tooth brushing activity - all activities are displayed and identified by the time they were performed. When the user selects one specific activity, related information is updated. Otherwise, the app displays user's last tooth brushing data.
b. Monitor family member's weekly progress and setbacks - each toothbrush extension communicates wirelessly through Bluetooth and thus allows the collection and comparison among all family members' behaviors.
c. Visualize messages and hints that point users towards strategies for achievement of appropriate health practices.

Conclusion and future work

In this paper we presented *Social Toothbrush* an ambient sensed prototype that infers individuals tooth brushing behaviors with the goal of raising awareness among family members. Our future work aims at conducting a longitudinal field study to understand how social interactions affect individuals' tooth brushing practices and how this approach affects family communication and coordination around their behaviors. Next, we want to understand the impact of the approach on the long term, when the novelty effect fades away [13,14].

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