Brushee: A "magic mirror" tooth-brushing interface to build hygienic habits in pre-linguistic children

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ABSTRACT
In the following study we explore how to induce positive behavior change in pre-linguistic children vis-à-vis the teaching of a single fundamental learned task: brushing teeth. Learning how to brush one's teeth regularly and for a certain duration can prove challenging for children and their parents alike, resulting in strained relationships and under-developed hygiene habits. Our study aims to confront these risks by improving the experience of brushing for very young children. By introducing "joy" into the obligatory task of brushing teeth we can reduce the total amount of anxiety and stress produced by the twice-daily experience for all parties involved. In targeting this activity we have elected to focus on themes of reluctance, duration, habit, and pleasure, and present a prototype which uses an interactive two-way mirror and a Bluetooth-enabled toothbrush to capture and maintain a child's interest in brushing, reinforcing healthful routines for their future.

Author Keywords
Tangible user interfaces; routine formation; two-way mirror; pre linguistic learning; toothbrush; Bluetooth-enabled device; entertainment

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous; See http://acm.org/about/class/1998 for the full list of ACM classifiers.

INTRODUCTION
Our habits make us who we are and enable what we do in our everyday lives. Organizations understand this paradigm and try to imbue their products with habit-forming qualities so they can alter our behavior and maximize engagement with the products they sell us. This mechanism works well for adults and even for children above a certain age. However, infants and toddlers are an exception to this rule. Owing to their limited cognitive and linguistic abilities, it can be especially difficult to encourage persistent changes in the behavior of very small children. One essential activity parents try to teach their children is the habit of brushing one's teeth at least once or twice a day. Since brushing is inherently a learned behavior, children resist it in the same way they resist any other unintuitive and unpleasant activities. In order to familiarize children with useful habits, parents resort to different methods of incentivizing their children to perform activities towards which they remain reluctant. Gradually, even these rewards are stripped away until the child internalizes each particular behavior and begins to exhibit it on her own accord.

In this paper, we present a prototype of a product which encourages children to brush their teeth without demanding excess cognitive effort. We have taken inspiration from popular animated characters to whom children tend to grow attached, and attempt to leverage them to elevate children's' excitement about picking up the toothbrush. Our goal is to increase engagement by making the experience of brushing interactive, as opposed to offering temporary rewards with which children cannot usually interact, and with which they may grow bored in the long run.

Figure 1. Mirror in the making

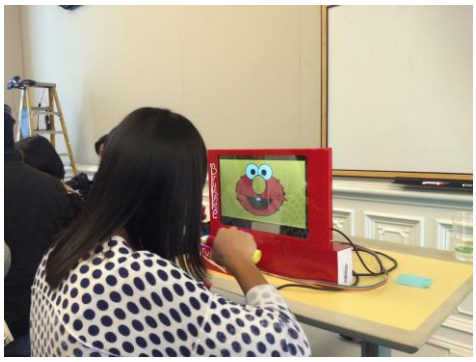


Figure 2. The final prototype in action

RELATED WORK

Two-way mirrors are typically used to observe subjects on one side of the mirror from the other side. Our inspiration for using one came from the unlikeliest of places [1] considering that this is a product meant for children: a *Conjuring 2*-themed "haunted mirror" prank put on by Roadshow Entertainment for its YouTube channel. In our ensuing research, we found the use of two-way mirrors for constructive educational purposes highly limited, and endeavored to expand the field in this direction.

While we found few examples of two-way mirrors being used for educational purposes related to early childhood development, we did find extensive evidence in support of Elmo's effect on children and their learning [2], including with the task of brushing teeth. Children find such characters relatable and friendly, and remain open to taking 'advice' coming from Elmo-like characters. This phenomenon is observed not only on children's shows and associated YouTube videos, but also on packs of toothpaste which are branded to carry colorful pictures of animated characters.

Our project aims to leverage Elmo's emotional draw scaffolded in a two-way mirror with a Bluetooth-enabled toothbrush as a novel human-computer interaction.

DESIGN

Be it games likes hide and seek, magic shows, or even digital interactive games, children find a lot of delight in being pleasantly surprised, and are far more likely to engage in something that seems both delightful and friendly. Incorporating a delightful first touchpoint was a goal that was important to us. We wanted the child to experience something that they may never have experienced before. The two-way mirror became a very important part of our interaction design since it enables us to accomplish this elegantly. In our prototype, we housed a consumer laptop inside a laser-cut box. The laptop, folded up like a tablet, works as the screen but is visible only after it becomes activated. During all other occasions--i.e. when turned off--our prototype resembles a regular bathroom mirror.

As the next step in our user journey, we wanted the child to brush along with the character appearing on the screen. There were several interactions we discussed: having a timer on screen to have the child race along with a brushing Elmo; having Elmo instruct the child how to brush; having Elmo imitate the motion of the child's toothbrush. While the first two interactions seemed like promising opportunities for development, we were concerned that they might make the experience exaggerated or stressful, or may come across as overly pedantic. The third option's affordance of imitation is understood easily by the child as soon as a couple strokes of the brush are complete. We also found that children like to follow along if people or characters they understand and trust perform the same activity as them.

Another major component of our interaction design involves the toothbrush which the child picks up. Since we planned on imitating its path on the screen, we decided to set about mapping its coordinates while it moves. We considered using the laptop's front camera to capture the motion of the brush, but scrapped the idea soon since cameras in bathrooms may come across as overly invasive. Instead, we decided to build a brush which transmits coordinates using a Bluetooth connected Arduino module inside of it. It fetches the location data from an accelerometer housed in the same casing and transmits the packets back to the Arduino connected to the computer, and which are in turn then visualized on the screen

IMPLEMENTATION

Implementation of our design involved a considerable amount of pre-planning. We first found a toothbrush that we suspected would have enough internal capacity to contain a Bluetooth module, an Arduino Mini microprocessor, and an accelerometer, along with batteries and a switch by which to complete the circuit. The brush in question turned out to be exactly suitable for our purposes, and we set about disassembling it and removing its motor.

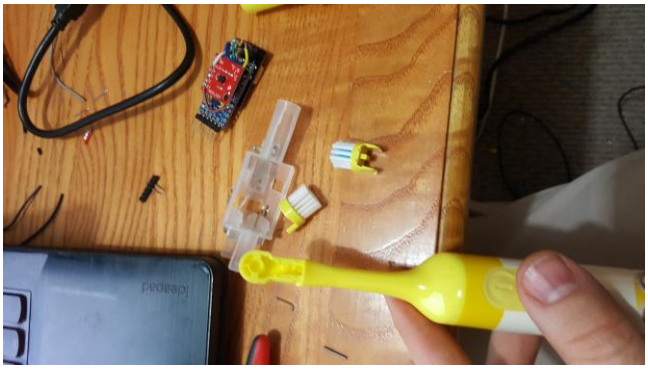
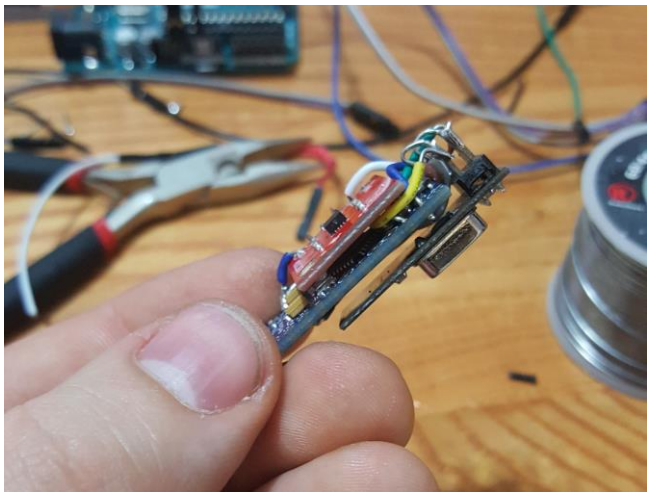


Figure 3. Disassembling the original brush.

We then planned out the schematic of the new internal components of the brush, and carefully soldered together all of our electronic elements:



.**Figure 4. The brush's internals combined**

Once the internals were included in the brush's shell, we set about developing the technology of the mirror, which we accomplished using two-way mirror film with a 5% concentration of silver, adhered to a laser-cut piece of transparent acrylic. We laser cut the first version of our mirror from plywood and spray painted the result red; the second and final version we cut straight out of acrylic to allay fears of spray-paint fumes harming any of our potential users. We also slimmed down the mirror's profile.

Figure 5. Mirror V2 (left); V1 (Right)

We finally designed an additional point of interaction with three light-up buttons. We modeled the buttons using CAD software and printed them using an *Ultimaker 2* 3D-printer, and went about wiring together the buttons and LEDs present in the interactive display with rainbow ribbon wire.

We then used a vinyl cutter to give the device some appropriate branding.

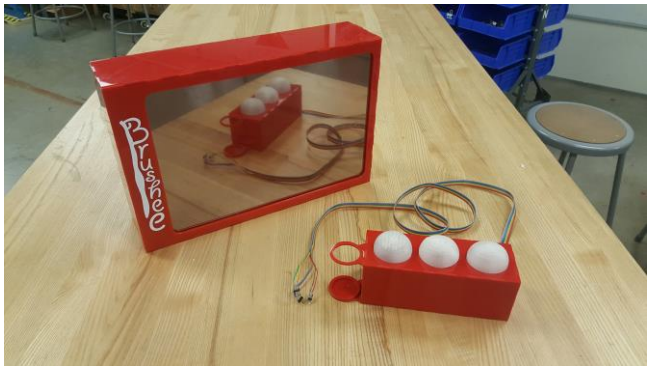


Figure 6. 3D-printed light-up buttons (Right). "Brushee" branding on Mirror V2 (Left).

PILOT EVALUATION METHOD

For the design showcase we placed our prototype on a raised lectern. Since our two-way mirror forms the centerpiece of our interaction, placing the mirror on a raised lectern helped us instantly communicate the first touchpoint in our interaction. When people walked up to our prototype, they noticed Brushee's branding, and examined themselves in the mirror. The setup–the mirror, the progress indicator and the toothbrush–piqued people's curiosity. As they approached our prototype, we encouraged them to pick up the toothbrush, while one of our team members pressed a button behind the exhibit to bring the mirror to life. Up popped a bright colored, cheerful Elmo, with music in the background and the opening lines: "Okay everybody, it's time to brush your teeth. Go get your toothbrush." We configured the demo to last 30 seconds, with the progress indicator offering signifiers for the same.

Once the demo started, we observed how people interacted with the prototype, occasionally nudging them to brush faster since that's when Elmo mirrors the user's motion most closely. We documented all of this and took pictures of people involved in the demo.

PILOT EVALUATION FINDINGS

Several things began happening when people interacted with our prototype, some expected, some unexpected. People were delighted at how colorful and peppy the red housing of our prototype looked. They really liked the Brushee logo and became even more excited when Elmo popped up on the screen. Not everyone immediately understood that they were supposed to start brushing, however. We avoided semantic prompts since our product is aimed at a demographic that is incapable of reading. As an alternative, we attempted to create aural cues as mentioned above. Unfortunately, the volume of our

soundtrack had some trouble overcoming the din of the other demos happening simultaneously in the room, leading to some users looking visibly lost and undirected before we had them lean in to register the accompanying song.

A majority of our users had a hard time understanding the purpose of the progress indicator. On day one, we had the LED lights on the indicator programmed to change from green to amber to red in sequence, with different colors indicating different levels of progress through the 30 second window. Most users did not notice the progress bar and when they did, they either thought of the lights as buttons meant to be pressed, or thought the light display was meant to judge the quality of their brushing. The next day, we tweaked the way the lights worked: we had one consistent color for the three LEDs and each stayed lit when the next activated. The display still failed to be intuitive enough to be self-explanatory for most users, but for some the change seemed sufficient. Some of the confusion can be attributed to the fact that the indicator was in fact designed to be character-selection buttons, alternating between Elmo, Bob the Train, and Mickey Mouse–which explains the indicators suggesting the affordance of buttons.

Broadly speaking, people appeared delighted and amazed at how the nearby interaction took place in what they said looked like an elegant piece of hardware. Very few users were able to guess that we had used a laptop for our screen inside the plastic housing, and on telling them about this, they expressed awe and appreciation. Some people also requested alternating characters as a feature, which validated our early assumption that a brush with more than one character might appeal to a broader selection of users.

DISCUSSION

From designing and demoing our prototype, we gained many useful insights. We learned that despite the prevalence of touchscreens, there is still something about tangible artifacts which makes people eager to explore their uses. That the screen was able to receive data wirelessly from what appeared to be just simple toothbrush struck at least a few users as charming or impressive; the screen, and the progress indicator–all colored race-car red–registered as friendly and personable. People interacting with our prototype were able to relate with these qualities, enriching the quality of their interaction. The emotional connection also meant that people started expecting things from the product for which we had not designed. For instance, in expecting Elmo to mirror all of their movement, people tried to hold the brush in different positions including above their head and below their chin. However, the on-screen brush remained steady in Elmo's mouth and people found this underwhelming.

Moving forward, we would try to enrich this interaction through a more expressive character which reacts more closely to the movement of the brush. Possible signifiers include gradually filling the screen up with bubbles during the timeframe that the child is brushing, or having advanced animation to have Elmo frown or smile depending on the quality of the user's brushing. The ideal interaction for children who are old enough to brush on their own would also include a way to let the child know what areas of the mouth have been cleansed well and which need more cleansing, but we felt the level of interactivity about right for our age group, and did not want to risk overwhelming children using the device.

CONCLUSION

In designing for children, we learn that having well thought-out affordances and signifiers is cardinal in creating lasting experiences for users. Since children typically have shorter attention spans than adults, the human computer interface needs to be intuitive without feeling didactic; it needs to appear friendly without a learning curve. Since toddlers can be fickle, we risk losing their attention if the first few moments of the interaction fail to engage them.

For TUI's Design Showcase we presented a product that our team brainstormed, visualized, developed, and expanded beginning only a few months ago. In creating this product we managed to overcome several technical and design challenges to build a user journey that we think best accomplishes our goal for this project. We have received favorable feedback from user testers, with parents of toddlers going as far as to say that this product has all the makings of a device that solves a valid real-world pain point that parents and their children experience daily. Testimony suggests that ours is a product some would consider introducing into their child's tooth-brushing routine.

REFERENCES

1. https://youtu.be/I5bd29uys0o
2. https://youtu.be/wxMrtK-kYnE