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Ubiquitous Computing
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Final Project Proposal

Problem

In today's society, where we consume excessive amounts of caffeine and sugar to keep us motivated to work, college students are prone to cavities. College students especially should be aware of their oral care, since they are away at school and most likely do not have access to their primary dentist. Cavities are a critical issue that should be targeted because if left untreated, cavities can destroy teeth and require major procedures to treat infections. Currently, there are no technologies that allow students to check up on their oral health. Normally, they will go to the dentist for an annual check-up or if their tooth is hurting. With the technology my team will create, there will be a significant impact on oral health - where college students will be able to detect whether or not they have a cavity and must visit the dentist. Students will no longer have to wait until they experience tooth pain to understand that they have a cavity. The technology will allow for early detection and oral health awareness. The device would also shorten dentist appointments by allowing students to explain why they are coming in for a visit, rather than waiting for dentists to run multiple exams and x-rays to see what issues they are having with their oral health.

How

Our team is proposing a ubiquitous computing solution to the problem of detecting and managing one's oral hygiene - specifically, we want to create a system in which users would be alerted to the presence of a cavity.

Current exploration by other researchers into the oral hygiene space in ubicomp has focused on persuasive computing and tracking behaviors as part of the quantified-self movement. For instance, Chang et al. (2008) built a "playful toothbrush" which would encourage improved brushing habits among kindergarteners by creating a vision-based motion tracker that recognizes different toothbrush strokes and gamifies the experience. Their toothbrush is intended to enhance the quality of brushstrokes to promote oral hygiene. Similarly, work was done by Kimura et al. (2009) in the captology space has affixed accelerometers into toothbrushes as part of a larger IoT implementation to ultimately persuade users to change their behavior (e.g. towards more prosocial outcomes such as brushing more frequently). Even Google has as a patent (US8337213B2) for an intelligent toothbrush monitoring device to detect brushing patterns. To note, common contemporary methods to detect cavities include a visual examination as well as the use of medical X-Rays.

Our current proposal diverges from current scholarship in ubicomp in that our goal is not only to monitor users behavior, highlighting habits related to brushing patterns and frequency, but also identifying oral cavities at home. What makes our solution unique is that we embed this detection technology into the toothbrush itself, which, presumably, an individual would use twice

a day already. Of course, the detection of oral cavities generates data which can also be used for persuasive computing mechanisms, which would allow us to prod users towards better preventative oral hygiene as well (Cf. Kimura et al., 2009, and Chen-Yu et al., 2008).

Technical Details

Though the specific technical details haven't been set-in-stone yet, our current design is based on an ultrasonic sensor (Cf. Ojaghi et al., 2016). We intend to build a micro-sized ultrasound sensor under the bristles at the head of an electric toothbrush. When the brush is turned on, information from the sensors will be sent to the phone via Bluetooth. The information will then be fed into a trained Machine Learning classifier which will have the ability to detect cavities in the mouth. We anticipate that the vibrations from the toothbrush will create a significant amount of noise in our data, however, we hope to account for this noise in our machine learning model. Furthermore, the system will utilize the data of when the brush is activated to log when the user is brushing and for how long which will be tracked by a proprietary app. Thus, users will not only be able to detect cavities, but the brush will also give users feedback on their brushing habits more-generally.

Notes on technical:

- Embed ultrasound sensor under the bristle of an electric toothbrush → running a proprietary ML algorithm against ground truth cavity data.
- Data based on the density of each tooth - more density is good, less density (tooth dependent) might indicate whether there is a cavity.

User Study Design and Evaluation

To test for the effectiveness of our cavity-detecting toothbrush we will be testing the presence of cavities via a physical examination, "ground truth," vs. our proprietary algorithm which seeks to classify a given tooth as either having a cavity or not. We intend to use a plastic sheath or a "silicon finger" to allow multiple users to test our working prototype. To note, due to the sheer scope of this project, it is unlikely that users will be able to test our toothbrush longitudinally, such that we can test the persuasive computing elements built-in.

Our current plan is to recruit college-aged participants between the ages of 18-22, to effectively test out our working prototype. The data we intend to collect is sensitive in-nature, given its medical nature so participants will need to be de-identified using an ID system. Participants will be asked to move the toothbrush to various teeth so then the system can register the bone density using the ultrasonic sensors, then a visual examination will be performed on the tooth to determine whether there is a cavity (we hope to consult a dentist to help with this step). Then comparing the data generated by our algorithm to the ground truth we hope to find that our system works as intended. Because the system cannot be tested in long-term settings we will

have a post-interview survey which will ask participants about whether they would use this technology if it were built into their current toothbrush.

Project Plan

Given the scope of building, designing, and testing a working prototype of a physical toothbrush apparatus our group wanted to petition for allowing three group members. Chris would be in charge of developing the Android application and proprietary algorithm, Grace would serve as our design lead with a focus on constructing the physical apparatus, and Colton would serve as a co-design lead as well as running the user-testing, literature reviews, and various logistical hurdles in accomplishing this project. We are open to project modifications to support a three-person team.

Our current timeline involves solving 80% of the technical challenge of developing the toothbrush by the mid-semester check-in point. This would allow us sufficient time to finish the project as well as complete the user-testing phase. By this point, we also hope to have a working draft of our paper which will include a completed literature review, the proposed experiment design, the human subjects application (which Colton is IRB approved), and an updated project plan which will lay-out the rest of the semester.

References

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