Brush-E Bot: Your Toothbrushing Companion Bot

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Figure 1: Brush-E Bot Logo

ABSTRACT

Cavities is a common disease children experience and consistent brushing has been found to reduce the chances of cavities developing. Despite the importance of brushing many caretakers face resistance when trying to instill consistent brushing habits in children. By making brushing time more fun, children can create positive associations with brushing, establishing habits that can last a lifetime. Enter Brush-E Bot! Our robot is designed to make brushing engaging and educational, teaching children how to brush correctly while making the experience as fun as possible. In this paper we discuss the importance, design, implementation, and contribution of our robot.

CCS CONCEPTS

• **Human-centered computing** → **Interaction devices**; *Systems and tools for interaction design*; • **Hardware** → Analysis and design of emerging devices and systems; • **Social and professional topics** → **Children**.

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KEYWORDS

Human-Robotic Interaction, Social Robotics, Educational Robots, Children-Robot Interaction

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1 INTRODUCTION

The aversion to brushing teeth among children is a well-documented phenomenon that often poses considerable challenges to parents and caregivers trying to instill effective oral hygiene practices. The reluctance of children to brush their teeth is a significant concern, as maintaining proper oral hygiene is crucial to overall health. Additionally, conveying this importance to children can be a very difficult task on its own. It is imperative to develop methods that effectively communicate the long-term health benefits of regular tooth brushing to this young demographic, and research indicates that strategies aimed at making tooth brushing a more enjoyable activity can significantly reduce resistance in children [8].

The prevalence of dental cavities, exacerbated by inadequate brushing habits and high sugar consumption, poses a substantial public health challenge [14]. Data from the US Centers for Disease Control and Prevention (CDC) reveal that dental cavities is the most prevalent chronic disease among children in the United States, with 52% experiencing at least one cavity by the age of 8 [6, 7]. This issue persists into adulthood, as evidenced by the statistic that 25% of adults aged 20 to 64 years are affected by untreated dental cavities. Preventive strategies, such as eating foods beneficial for dental health, maintaining a rigorous brushing routine twice a day, and regular dental visits, are effective in reducing the risk of dental cavities [1].

The impacts of poor oral health extend beyond individual well-being, impacting societal productivity and educational outcomes. Annually, an estimated 34 million school hours are lost, and the economic productivity of the United States suffers a loss of approximately $45 billion due to dental health problems [7, 11, 13]. These statistics underscore the critical nature of addressing oral health problems. Consequently, any intervention or strategy that effectively mitigates the impact of oral health issues has significant importance in both public health and economic contexts.

In the search for areas of impactful intervention, we identified the household environment as a critical domain. Economic constraints often make dental care unaffordable for many families, leading to a higher prevalence of cavities among children from lower-income backgrounds [6, 7]. Consequently, effective cavity prevention often relies on regular and proper tooth brushing at home [1]. However, children frequently resist brushing due to various negative associations, which pose challenges to parents and caregivers in establishing positive brushing habits [8, 10].

Within this context, the introduction of an interactive robotic system emerges as a viable solution. A robot, specifically designed for in-home use, could significantly contribute to improving oral hygiene practices, especially among children. This approach takes advantage of the potential of robotics in daily life settings to improve health outcomes and prevent dental diseases.

Addressing the challenges in children's dental hygiene involves understanding key factors: the lack of awareness by children about the importance of brushing, short attention spans, and the need for routine and independence in their hygiene practices. Overcoming these issues requires a blend of education, patience, and creativity from parents and caregivers. Strategies include choosing appropriate dental tools, establishing engaging routines, and age-appropriate dental education. In this context, the introduction of social robots can offer an innovative approach to make brushing more appealing and educational for children, thereby facilitating the development of effective oral hygiene habits.

2 RELATED WORK

Social robots have become increasingly researched as tools for children's education [5, 15, 16]. Although Brush-E Bot does not teach students in a traditional education setting, we believe that we can draw on research in education to better understand how we can effectively teach better brushing habits. For example, a study found that social robots were able to teach concepts to children in a "playful and intuitive manner", resulting in children showing a significant interest in interacting with the robots [15]. Teaching concepts such as tooth brushing habits which children may be resistant to can be difficult, and we postulate that a more "playful and intuitive" approach could be effective in engaging children in brushing their teeth.

Although not specifically for dental care, social robots have previously been used to instill better hygiene habits in children. For example, an interactive robot was successfully developed and deployed to promote hand washing behaviors in young children in India [3]. In their experiments, the researchers found that the robot was able to increase the amount of hand washing by 40%. In further experiments with the same robot, it was found that children who interacted with the robot liked the robot very much and were strongly drawn to the robot [17]. This shows the effectiveness of social robots in instituting good hygiene behaviors in children. Based on this initial work, the robot has been further equipped with autonomous capabilities to make it even more engaging for users [12]. This robot and research served as inspiration to create Brush-E Bot. Applying these findings of social robotics research and extending them in the context of dental care, it has suggested that "increasing use of visual training may be useful to disseminate oral health information" [4]. We believe that using a social robot to achieve this visual dissemination of information will be effective in developing consistent oral hygiene behaviors in children.

3 DESIGN AND INTERACTION

When creating our design for Brush-E Bot, we set several design goals. The robot had to be engaging, safe, fun, intuitive, and inexpensive to produce. Given the application of Brush-E Bot, we planned from the start to use a robot body shaped like a tooth. In our initial design plans, we wanted to use a molar shape, since it had four distinct sections. We planned to use these sections to represent the different quadrants of the mouth that should be brushed. We also planned to include a hole in the top of the tooth to hold the user's toothbrush. After 3D printing an initial prototype of this design, which can be seen in Figure 3a, we quickly began to feel that the more realistically shaped tooth seemed somewhat off-putting and that it may not create the fun experience that we intended. These feelings were exacerbated when one of our team members pointed out that the hole in the top of the robot for the toothbrush looked somewhat like a cavity or another tooth problem (it should be noted that the robot was always intended to be white, like a tooth, however, our initial test print was done in black filament due to availability). Additionally, we found it difficult to create space in the molar-shaped robot body for our electronics because of the shape. These issues led us to discard this initial design.

After discarding the molar-shaped tooth, we found a more cartoon-style tooth model [1]. We considered this shape to be more appropriate for our application. This model had the additional benefit of being constructed as a box, with a lid and base, which we could use to place our electronic components. Enclosing our electronic components in this way worked towards our goal of making the robot safer (e.g., containing cables and providing some water resistance). After 3D printing a prototype of this model, we decided that it fit our design goals much better than our initial model, so we decided to proceed with the model as shown in Figure 3b. This model did not have a place to hold the user's toothbrush, so we created a simple cylindrical stand for this purpose, which could also hold the sensor we planned to use to activate the robot. We decided that this sensor would be the main physical point of interaction with the

[1] https://www.thingiverse.com/thing:3652713

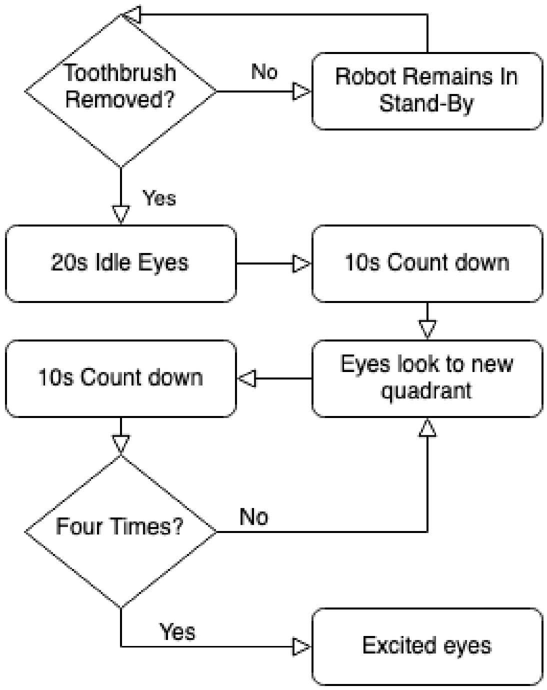


Figure 2: Interaction flow of Brush-E Bot.

robot. By allowing users to simply pick up their toothbrush to start up the robot, we hoped to make the user experience as intuitive as possible, especially for children who may not have previously interacted with a robot.

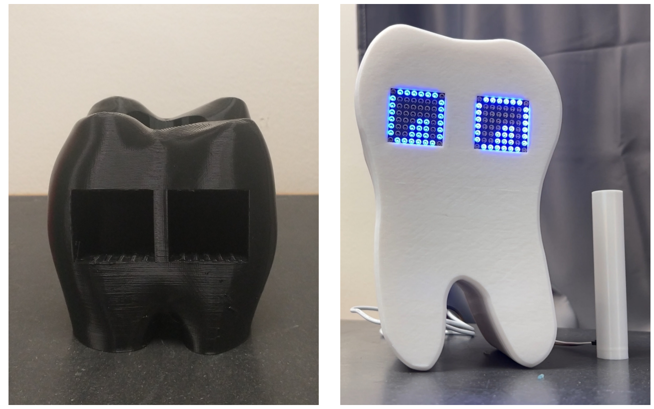
As part of meeting our design goal of making the robot engaging for users, we planned to implement animated eyes. We were inspired by an Amazon Astro robot [9] in our lab, as we found the Astro robot's eyes to be extremely engaging. We decided to use simple LED matrices with pixel-style animations for the eyes, as this would meet our goal of making the robot inexpensive. To further increase the engagement with Brush-E Bot, we also planned for the robot to be able to play music, which we selected to go with the rhythm of bushing to keep users engaged until completion.

With these design elements, we developed the interaction sequence shown in Figure 2. This sequence consists of four stages: Begin, Preparation, Brushing, and Finish.

4 IMPLEMENTATION

4.1 3D-Printed Robot Body

We used a 3D printer with PLA filament to create several prototype iterations of the robot body for Brush-E Bot. We initially started with a design shaped like a molar with four "quadrants" (see Figure 3a). After pivoting to our final design, we modified the 3D model we were using, adding cutouts for the two eyes and scaling it to a more appropriate size of approximately $20cm \times 10cm \times 10cm$ ($Height \times Width \times Depth$). After 3D printing this model, we drilled two holes in the back to run wires to the sensor and to power the electronics. The final 3D printed body can be seen in Figure 3b.



(a) Initial robot design. (b) Final robot design.

Figure 3: Two instances of our 3D printed design prototypes. The image on the left shows our first iteration, and the image on the right shows our final iteration.

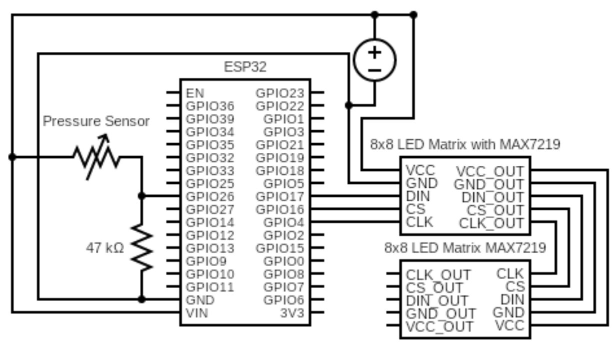


Figure 4: Circuit diagram for Brush-E Bot.

The STL files are open-source and available at https://github.com/bendossett/brush-e-bot.

4.2 Electronic Components

A small selection of electronic components were used to achieve our design goals. Each component was purchased individually and the total cost was approximately $20.00. The Brush-E Bot circuit is simple and can be seen in Figure 4.

Microcontroller: Brush-E Bot uses an ESP32 microcontroller to control the other electronic components. The code for the microcontroller is written in C++, and can be found at https://github.com/bendossett/brush-e-bot.

LED Matrix: Brush-E Bot's eyes were implemented using two 8x8 blue LED Matrices with attached MAX7219 modules. The modules were controlled using the LedControl library [18]. The animations were created using the Piskel online sprite creation tool [2].

Pressure Sensor: We used a pressure sensor to detect when the user has removed their toothbrush from the holder. When they do so, the reading of the pressure sensor changes, which triggers the microcontroller to begin the animation cycle.

5 DISCUSSION & FUTURE DIRECTION

Our design approach aligns well with our objectives, particularly in terms of cost-effectiveness. By selecting affordable components and a simplistic design, we have managed to minimize the overall cost of the robot. Although the current prototype utilizes 3D printing, which may not be universally accessible, the design is adaptable for more cost-efficient manufacturing methods in future large-scale productions.

In the initial demonstrations of Brush-E Bot, due to constraints in time and available components, we temporarily outsourced the robot's sound effects. Future iterations will incorporate an integrated audio component (e.g., jingle-style music, voice), facilitating the complete implementation of interactive audio features with minimal additional development and as part of the robot system.

This prototype represents the initial phase of the Brush-E Bot project. Our team is committed to ongoing refinement and enhancement of the design. Future developments will include the integration of voice features in different languages and action recognition capabilities, drawing inspiration from [12].

Including voice features will allow our robot to provide more direct and clear instructions to the user, building towards the objective of being educational and engaging. For example, a voice saying, "Now brush your front teeth!" might be less ambiguous than the robot looking in a particular direction. The current music and sound effect sequence would include encouraging speech as well. To implement this, we will need to test several different computerized voice options in the context of the robot. Selecting a voice that does not seem to fit the robot, or one that might be frightening or off-putting to users would likely result in disuse of the robot.

Further, for action recognition, we envisage a simplified system similar to [12], which focuses primarily on detecting brushing activity. This feature will require careful consideration of privacy concerns. We anticipate that these enhancements will significantly enhance both the engagement and effectiveness of the robot in promoting good brushing habits.

Concurrent with these new features, we plan to refine the existing hardware and software. Software optimizations will focus on power efficiency, enabling the microcontroller to enter a low-power state when inactive. Hardware improvements will address the current limitations of the 3D printed chassis, particularly the latch mechanism, and aim to reduce the number of external cables.

6 CONCLUSION

In conclusion, the Brush-E Bot project represents a significant advance in the treatment of a prevalent and crucial health concern, the regular and adequate brushing of teeth, by incorporating social robotics into daily routines. The prospective trajectory of this initiative involves the continuous improvement and evolution of the Brush-E Bot, with the aim of substantially influencing pediatric oral health. This endeavor exemplifies the potential of technological integration in cultivating beneficial health practices from a young age, demonstrating the instrumental role of innovative technological solutions in public health domains.

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REFERENCES

[1] 2023. *Cavities and tooth decay.* Retrieved December 5, 2023 from https://www.mayoclinic.org/diseases-conditions/cavities/symptoms-causes/syc-20352892
[2] Piskel App. 2023. Piskel, free online sprite editor. https://www.piskelapp.com/
[3] Amol Deshmukh, Sooraj K Babu, Unnikrishnan R, Shanker Ramesh, Parameswari Anitha, and Rao R. Bhavani. 2019. Influencing Hand-washing Behaviour With a Social Robot: HRI Study With School Children in Rural India. In *2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. 1–6. https://doi.org/10.1109/RO-MAN46459.2019.8956367
[4] Canan Duman. 2020. YouTube quality as a source for parent education about the oral hygiene of children. *International Journal of Dental Hygiene* 18 (2020), 261–267. https://doi.org/10.1111/idh.12445
[5] Camino Fernández-Llamas, Miguel A. Conde, Francisco J. Rodríguez-Lera, Francisco J. Rodríguez-Sedano, and Francisco García. 2018. May I teach you? Students' behavior when lectured by robotic vs. human teachers. *Computers in Human Behavior* 80 (March 2018), 460–469. https://doi.org/10.1016/j.chb.2017.09.028
[6] US Centers for Disease Control and Prevention (CDC). 2021. Oral Health Surveillance Report 2019-2021. https://www.cdc.gov/oralhealth/publications/OHSR-2019-index.html
[7] US Centers for Disease Control and Prevention (CDC). 2022. Oral Health Fast Facts. https://www.cdc.gov/oralhealth/fast-facts/index.html
[8] Colleen E Huebner and Christine A Riedy. 2016. Behavioral determinants of brushing young children's teeth: implications for anticipatory guidance. *JDR Clinical & Translational Research* 1 (2016), 122–130. Issue 2. https://doi.org/10.1177/2380084416647727
[9] Jin Joo Lee, Amin Atrash, Dylan F Glas, and Hanxiao Fu. 2023. Developing autonomous behaviors for a consumer robot to hang out near people in the home. (2023).
[10] Z. Marshman, S.M. Ahern, R.R.C. McEachan, H.J. Rogers, K.A. Gray-Burrows, and P.F. Day. 2010. BParents' Experiences of Toothbrushing with Children: A Qualitative Study. *Pediatric dentistry* 32 (2010), 48–55. Issue 1. https://doi.org/10.1111/idj.12171
[11] Shillpa Naavaal and Uma Kelekar. 2018. School hours lost due to acute/unplanned dental care. *Health Behavior and Policy Review* 5, 2 (2018), 66–73.
[12] Pranav Prabha. [n. d.]. Haksh-E: AI-Powered Social Robot to Promote Good Hand Hygiene Practices in Children. https://Indiaai.gov.in/article/haksh-e-ai-powered-social-robot-to-promote-good-hand-hygiene-practices-in-children
[13] AJ Righolt, M Jevdjevic, W Marcenes, and S Listl. 2018. Global-, regional-, and country-level economic impacts of dental diseases in 2015. *Journal of dental research* 97, 5 (2018), 501–507.
[14] S. Skafida and S. Chambers. 2018. Positive association between sugar consumption and dental decay prevalence independent of oral hygiene in pre-school children: a longitudinal prospective study. *Journal of Public Health* 40 (September 2018), 275–283. Issue 3. https://doi.org/10.1093/pubmed/fdx184
[15] Marta I. Tarrés-Puertas, Vicent Costa, Montserrat Pedreira Alvarez, Gabriel Lemkow-Tovias, Josep M. Rossell, and Antonio D. Dorado. 2023. Child–Robot Interactions Using Educational Robots: An Ethical and Inclusive Perspective. *Sensors (14248220)* 23 (Feb. 2023), 1–29. Issue 3. https://doi.org/10.3390/s23031675
[16] Lai Poh Emily Toh, Albert Causo, Pei-Wen Tzuo, I-Ming Chen, and Song Huat Yeo. 2016. A Review on the Use of Robots in Education and Young Children. *Journal of Educational Technology & Society* 19 (April 2016), 148–163. Issue 2. https://www.jstor.org/stable/jeductechsoci.19.2.148
[17] R Unnikrishnan, Amol Deshmukh, Shanker Ramesh, Sooraj K Babu, Parameswari Anitha, and Rao R. Bhavani. 2019. Design and Perception of a Social Robot to Promote Hand Washing among Children in a Rural Indian School. In *2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. 1–6. https://doi.org/10.1109/RO-MAN46459.2019.8956450
[18] Wayoda. 2023. LedControl. https://github.com/wayoda/LedControl.