A METHODOLOGY TO PROMOTE DELETERIOUS ORAL HABIT CHANGE THROUGH AN EDUCATIONAL AND FUN GAME

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Abstract

Babies develop several reflexes to help them adjust to life outside the womb, and one of them is sucking. However, if persisting for more than three years after birth, deleterious oral habits can cause consequences such as inadequacy in positioning the jaws, lips, tongue and palate, among other health issues. This work presents a methodology to promote deleterious oral habit change through an educational game that encourages the child to abandon this habit in a conscious and consenting way. We created the narrative and developed the game to be played for seven consecutive days. It contemplates four phases of a learning player's journey. Moreover, this learning journey is enriched with four fun and challenging minigames. Each day, the player can experience new adventures and awareness activities to stimulate behaviour change spontaneously through positive reinforcement. Furthermore, we implemented a points-based rewards system to generate an impact on player satisfaction. Finally, our methodology also offers the opportunity to bring together the child's family and dental professional to act collaboratively in favour of health, offering the child confidence and the chance to explore the deleterious oral habit, learn, and change.

Keywords: methodology; educational and transformational game; minigames; health

promotion; deleterious oral habit.

Resumo

Bebês desenvolvem vários reflexos para ajudá-los a se ajustar à vida fora do útero, e um deles é a sucção. No entanto, se este hábito persistir, por mais de três anos após o nascimento, pode trazer consequências como inadequação no posicionamento dos maxilares, lábios, língua e palato, entre outros problemas de saúde. Este trabalho apresenta uma metodologia para promover a mudança de hábito oral deletério por meio de um jogo educativo que estimula a criança a abandoná-lo de forma consciente e consentida. Criamos a narrativa e desenvolvemos o jogo para ser jogado por sete dias consecutivos. Contempla quatro fases da jornada de um jogador em aprendizagem. Essa jornada é enriquecida com quatro minijogos divertidos e desafiadores. A cada dia, o jogador pode experimentar novas aventuras e atividades de conscientização para estimular a mudança de comportamento de forma espontânea, por meio de reforço positivo. Além disso, implementamos um sistema de recompensas baseado em pontos para gerar um impacto na satisfação do jogador. Por fim, nossa metodologia também oferece a oportunidade de reunir a família da criança e o profissional de odontologia para atuar de forma colaborativa em prol da saúde, oferecendo à criança confiança e a chance de explorar o hábito oral deletério, aprender e mudar.

Palavras-chave: metodologia; jogo educativo e transformacional; mini-jogos; promoção de saúde; hábito oral deletério.

Introduction

The newborn sucking reflex begins in the uterus from the 29th gestational week (Goncalves, 2016). It is essential for the newborn in which there is the first contact with what will be breastfeeding. Normally, from the third month of extrauterine life, this reflex should gradually disappear. When it persists after three years of age, it is considered a deleterious oral habit (Goncalves, 2016; Macho, 2012).

Deleterious oral habits can cause severe physical and psychological problems in children, including inadequate positioning of the jaws, lips, tongue and palate; changes in the development and position of teeth (malocclusions); and changes in phonetic,

breathing and movements of chewing and swallowing food, affecting the growth and development of muscles and jawbones (Fernandes, 2019; Muzulan & Gonçalves, 2011).

Among the most well-known deleterious oral habits one can mention finger sucking (commonly thumb sucking), oral breathing, pacifier and bottle use, lower lip interposition/sucking, tongue sucking and onychophagia or nail-biting (Fernandes, 2019; Garde, 2014; Silva, 2019). According to professionals dedicated to oral health, this problem can be overcome in several ways. In particular, starting with a bit of attention, care and support from the school and guardians, mainly if this habit is associated with using an external object, such as a pacifier (rather than sucking one's own thumb) (Muzulan & Gonçalves, 2011). Awareness of those responsible for the children can encourage them to stop the habit and avoid harming their health. In a conscious and consenting way, for the child to succeed in the challenge of abandoning this harmful habit, oral health professionals have sought alternative forms of intervention and awareness without coercion but instead using positive reinforcement (Aguiar, 2005). For the success of this task, it is essential to work together, involving the child and their guardians, so that everyone understands that deleterious oral habits are no longer healthy after a certain age.

Previous works for promoting children's health reinforce the need for educational-preventive actions to control deleterious oral habits, emphasizing the importance of innovative initiatives to conquer this target audience and, consequently, contribute to playful, gradually and continuously solving the problem (Fernandes, 2019; Gonella et al., 2012; Muzulan & Gonçalves, 2011). In this context, an instructional method incorporating educational content or learning principles into digital games to engage learners is an essential ally as modern education resources, stimulating initiatives and positive actions to develop constructive skills for preserving health. Moreover, as an educational instrument, digital games can also generate transformational and permanent behaviour (Cullyba, 2018), mainly when the player can absorb the context of the problem and its consequences in a conscious, non-impositional and clarified way (Kalmpourtzis, 2018).

Through play, children can develop thinking skills and abilities that help them succeed in many life aspects. This work extends our previous work (De Oliveira et al., 2021) by presenting a new methodology to promote deleterious oral habit change through an educational and fun game named ``Duda: The Little Tooth's Guardian'' (in Portuguese, "Duda: A Pequena Guardiã do Dente*"*), aimed at children aged four to seven. It has attractive gameplay, clear messages with purposes, and minigames we

designed in tune with the oral health game's subject to provide more entertainment and promote that deleterious oral habit is no longer a healthy activity after a certain age. We created the narrative and developed the game to be played for seven consecutive days. It contemplates four phases of a learning player's journey. Moreover, this learning journey is enriched with four minigames (Memory, Crossroads, and Facing the Enemies, parts 1 and 2). Each day, the player can experience new adventures and awareness activities to stimulate behaviour change spontaneously. In addition, we used animation cameras to capture the movement of the 3D characters using a mechanism from different perspectives and follow-through actions to generate more engaging game scenes. Moreover, we added animations celebrating the player's achievements performed by some characters during gameplay and a points-based rewards system (stars points) to impact player's engagement and satisfaction, respectively. Finally, the youngest players need help to play. Thus, our game also offers the opportunity to bring together the child's family and dental professional to act collaboratively in favour of health through positive reinforcement, giving the child confidence and the chance to explore the deleterious oral habit, learn and change.

Related Work

This section presents related work on deleterious oral habits, storytelling and interactive narratives, and educational and transformational digital games. It ends with a brief contextualization.

Deleterious oral habits

Pagel (Pagel, 1987), based on research done at the Children's Hospital in Denver, USA, describes that rhythmic sucking optimizes the baby's breathing and heartbeat, providing calm in moments of hunger, fatigue and stress. In addition, the author reports that any discomfort is more bearable with a deleterious oral habit. However, after three years of age, Pagel suggests that parents should consider initiatives in the health area to solve this problem.

Another study presents a cross-sectional quantitative analysis in which parents and teachers from a school were invited to fill out a form about oral habits (Fernandes, 2019). As a result, they report that children who received unsatisfactory breastfeeding in the first six months of life manifested such habits (bottle, pacifier, onychophagia and finger sucking) earlier and for longer. Also, with 199 school-age children aged six to

fourteen years, a questionnaire-based study focused on analysing correlations between deleterious oral habits and anxiety and malocclusion symptoms (Silva, 2019). According to the authors, children stop sucking their thumbs or pacifiers over the years, usually, replacing this habit with nail-biting and lips habits.

Gonella et al. (2012) report that deleterious (non-nutritive) oral habits stimulate the incorporation of customs and, after so often practice, they become unconscious to the point of being integrated into the personality of the individual. Muzulan and Gonçalves (2011) describe that oral sucking habits can interfere with the growth and development pattern of the facial bones and the balance of the stomatognathic system's structures. Moreover, they present playful awareness strategies for the spontaneous removal of the habit of thumb or pacifier sucking using stories, music with choreography, puppet theatre, memory game and a calendar for the children to mark the periods when they did not practice the deleterious oral habit. Finally, they affirm that, with the monitoring and attention of parents and health professionals, the great majority of the children wholly abandoned this harmful habit during a maximum of twelve sessions applying these awareness strategies.

Storytelling and interactive narratives

Storytelling and interactive narratives are not only successful remote methods of creating empathy but have been engines of social/cultural liberalization and change (Manney, 2008), (Lebowitz & Klug, 2011). They can be a powerful way in games to connect with players and better understand their behaviours and their feelings, personal decisions, and consequences. The success resides in the intersection of meaningful stories and situations with game design and how the balance between them is weighted.

Cutler et al. (2019) address the importance of reducing the distance between the story's characters and the spectator. Regarding this, digital games have a plus allowing the player to interact with the synthetic world (Barbosa & Rodrigues, 2006) and its characters. However, few works in the literature have explored the generation of empathy between the player and the game characters using interactive resources (Junior Luz & Rodrigues, 2021; Rodrigues et al., 2022).

Interactivity is a crucial part of the narrative material. Moreover, the communication travels bidirectionally; it is taught and learned. However, bringing interactivity to digital narratives is still a challenge in a growing exploration phase (Schell, 2008). Video games, content designed for the Internet, mobile applications, social media, interactive cinema,

etc., present various forms of narratives with diverse possibilities of interactivity (Miller, 2019).

Educational, serious, and transformational digital games

Digital games designed for purposes other than entertainment have gained many users' interest over the past two decades (Wilkinson, 2016). Notoriously, in the educational and health areas, serious games (Rodrigues et al, 2014; Rodrigues et al., 2015; Rodrigues et al., 2018; Rodrigues et al., 2021), transformational games (Culyba, 2018) and simulation-based games (Serpa et al., 2020; Fonteles et al., 2018) have a significant potential impact on the target audience. More specifically, these categories of games focus on educating while entertaining, commonly used to gain experience in practical life situations (Kato, 2010; Prensky, 2003). In this context, the design and modelling of real-world problems require a strong knowledge of learning domain, pedagogy, and game design components, which are paramount to creating successful games with a better user experience, and making them more attractive, engaging and effective. In general, this category of games includes dynamics involving trial and error, repetition, and design elements customized for the target audience.

Many games can transform the individual, stimulating reflections and, sometimes, a behaviour change. Educational games are part of this group, particularly those that follow the transformational framework model (Culyba, 2018; Rodrigues et al, 2014; Rodrigues et al., 2018). In this context, Bai et al. (2019) use a framework called Interactive-Constructive-Active-Passive to encourage people to reflect on social issues and behavioural changes. They consider that while a game can effectively stimulate learning skills or shape attitudes, the game design and environment most strongly affect outcomes. In addition, the art design is also powerful and persuasive. Thus, it can also impact social change, challenging understanding of the world and its relationship. Like other works related to behavioural change on deleterious oral habits, this work bets on awareness, reflection and art as ways to transform the human being.

Final discussion

Our game had as the main inspiration the work of Muzulan and Gonçalves (2011). Despite not having developed a digital game, those authors present a case study on a successful methodology used in a group of children to abandon deleterious oral habits, mainly using a calendar to track the child's progress. In our work, the calendar resource

served as motivation for modelling the functionality we named *Daily Agenda*, in which the child, with the help of a guardian, reports its progress (or failure) daily during the challenging journey of stopping deleterious oral habits. Furthermore, the cited works (Muzulan & Gonçalves, 2011; Aguiar et al., 2005) are substantial evidences that children can change behaviour just in a few sessions for the better regarding deleterious oral habits. They prove that children can understand that such action is harmful, choosing in an informed and consented way to abandon it, based only on playful awareness and positive reinforcement.

Finally, as far as our knowledge, so far there is no methodology to promote deleterious oral habit change through an educational and transformational digital game similar to ours, neither in academia nor in the industry.

A New Methodology Based on an Interactive Gameplay

Few methodological proposals for educational digital game development have been published in scientific literature. This section presents the methodology proposed in this paper that focuses on an educational and transformational game with a narrative based on the Hero's Journey (Campbell, 2008). According to Campbell, many stories, games and film narratives follow a fundamental structure and common base, named monomyth in his book The Hero with a Thousand Faces (Campbell, 2008). He reports there is an awareness that human beings share stories and sagas told over millennia, being these very similar, regardless of the century or continent. Over the years, the monomyth has been the target of more contemporary interpretations, one of the best known being the interpretation of Christopher Vogler (Vogler, 2017). Some works are based on studies by Campbell and Vogler regarding heroic sagas in which the main character leaves a state of ``ignorance'' and goes through stages of growth and renewal, portraying the Hero's Journey.

Thus, this work refers to the possibility of the player's renewal and evolution; for that, it resorts to the role of the child's mentor character as fundamental to helping the player overcome the challenges presented in the gameplay. In addition, we sought to add elements of entertainment, empathy and educational values to the game design process. Therefore, the characters, objects and scene elements are progressively added to the game through interactive narratives having this particular character, a little fox, acting as the player's mentor.

The game narrative structure directs the challenges presented to the child and the strategies for reinforcing the player's achievements and the game's dynamics and level of interaction. We created and developed the game to be played for seven consecutive days. Like the work by Muzulan and Gonçalves (2011) and Aguiar et al. (2005) present a methodology for removing the deleterious oral habit in children. For example, Aguiar et al. (2005) proposed a method which included some recreational activities and the use of a Motivational Notebook for seven days in which each child should make drawings, collages and daily notes to avoid the deleterious habit, in the presence of a responsible adult. Thus, our specific inspiration for applying our game for seven consecutive days came from three inspirational experiences: the pediatric dentist's testimony and those studies reported in (Aguiar et al., 2005; Muzulan & Gonçalves, 2011).

Our game also contemplates four phases of a learning player's journey, including a Daily agenda functionality. Moreover, this learning journey is enriched with four minigames (Memory, Crossroads, and Facing the Enemies, parts 1 and 2) designed and implemented with the deleterious oral habit as a guiding theme for design and gameplay. Minigames are activities designed to entertain the child while they assimilate the concepts learned in the main game on that specific day. In addition, the minigames reinforce the importance of protecting oral health friends and fighting oral health enemies. Each day, the player can experience new adventures and awareness activities to stimulate behaviour change spontaneously. Figure 1 illustrates the Hero's Journey in the game and Figure 2 synthesizes all the relationships among the game phases (DAYS 1 to 4) and their respective minigames and how all these components can work together to benefit the player's oral health.

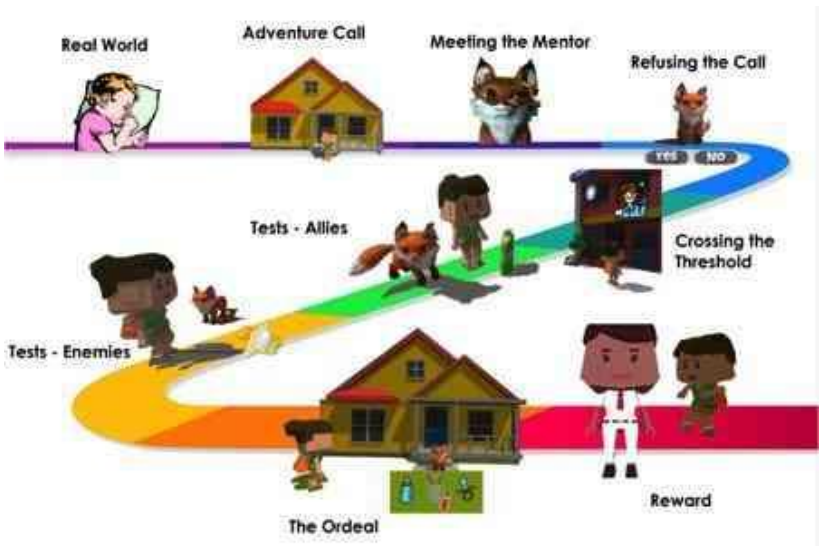

Figure 1 – A synthetic representation of the Hero's Journey in the game.

The four minigames will be available for another three days (from DAYS 5 to 7) as a bonus to the player.

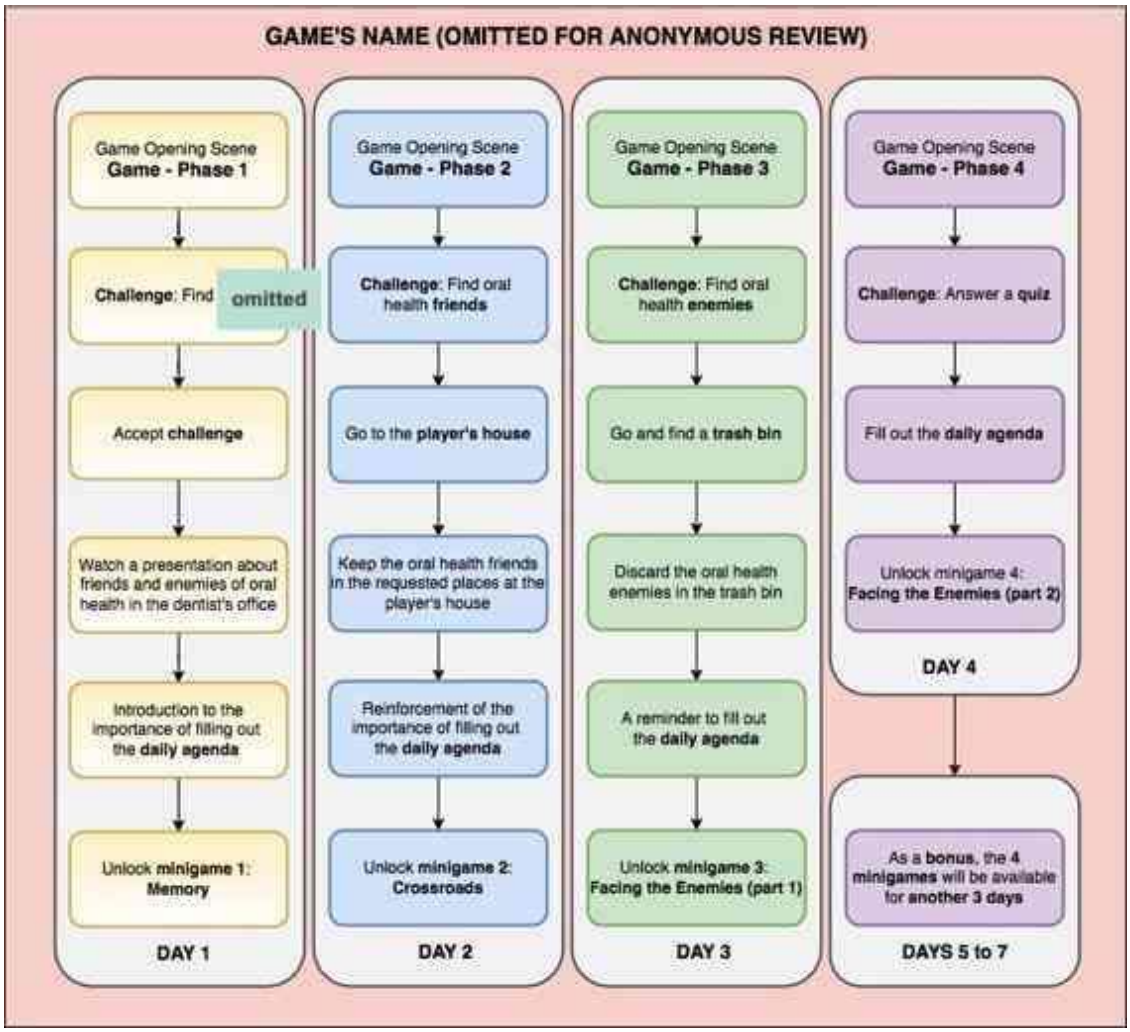

Figure 2 - Game overview.

Game design, graphics and mechanics

We designed the game to help solve a problem experienced by parents and children at a stage of childhood in which they live with sucking habits, such as thumb sucking, pacifier, and bottle feeding, starting in their first months of life.

The project had the collaboration of an interdisciplinary team composed of three educators (all mothers, including the youngest of them, the mother of a child who was inspirational for the game development). Two are game designers and developers, and one is a pediatric dentist. The game designers created the narrative that powers the

game. The pediatric dentist presented the problem of deleterious habits, the importance of creating actions to combat them, and the evidence reported by practice, as described in (Muzulan & Gonçalves, 2011), that it is possible to abandon the deleterious habit in a few days by applying an appropriate methodology.

We created a 3D game motivated by the fact that 3D characters are simple to manipulate since, unlike 2D objects, they do not need to be redrawn in different poses to create new animations. In addition, since the world surrounding us is three-dimensional, 3D characters look much more realistic, vibrant and full of life. Moreover, we can view them from varied points of view and angles in the game scene, enriching the spatial perception and, thus, the child's experience. Finally, 3D characters allow great freedom to generate animations through virtual skeletons with unlimited detail and precision.

In the role of a little girl or boy, the player has a little fox character as a counsellor and mentor named Duda, in honour of the daughter of one of the co-authors of this work. We idealized the child's mentor character as empathetic, intelligent, responsible, lively, and with a pet-like appearance, similar to a puppy, with big eyes and a trusting, friendly countenance. The mentor character was inspired by Jiminy Cricket, from the book *The Adventures of Pinocchio*, by Carlo Collodi, written in 1881. Duda is a small and apparently helpless character who acts as an anchor in the game's story, accompanying the player and stimulating learning moments—on oral health and good practices, reinforcing the negative aspects of deleterious oral habits and the positive aspects of abandoning them. The mentor guides the player through educational activities focused on oral health and the consequences of deleterious oral habits.

We designed the game's mechanics to run on smartphones and tablets through touch screen commands. However, players can also play the game using personal computers with a mouse and keyboard. Players can control the characters' movements through interaction commands and collect important game objects spread in the game scene. For the game, we created a 3D environment that metaphorically represents the city where the child lives and customised it according to the game's theme. The player can explore the whole scenario, walking through it using the game control mechanics. However, the primary interaction points occur indoors in the child's home and the dentist's office and outdoors, on the seafront avenue, in the pizzeria and in front of child's home.

Gameplay

In the beginning, the adult responsible for the child enters the child's data– name, age, gender, type(s) of deleterious habit(s) and frequency of oral habit(s), and personal information–name, email, and phone number. Then, the game starts with a 3D character who represents the player, according to the gender information typed in by the adult. However, the adult must first enter the validation code sent by email to unlock the game. Following that, DAY 1 of the game is unlocked. We created an opening scene trigged by animation with the main two characters: the child's mentor (the little fox) and the player (Figure 3).

Figure 3 - DAY 1, Game phase 1: Finding the child's mentor character and accepting the game challenge.

After introducing itself to the child, the child's mentor proposes the next mission to the player, a treasure hunt. The "treasure'' is finding the *Omitted for blind review* hidden in the game scenario and accepting the challenge. For this, the child has to explore the 3D city environment, interact with passers-by, look for tips spread out and follow the clues. Then the main character moves out of this player's home scenario. After this take, we developed a slow-motion camera switch to a camera that follows the main character in a second-person view. Two sequential clicks on the 3D environment allow the player to run, which is useful when one wants to save time and already knows where an object is hidden. In particular, textual and visual clues (arrows pointing out the correct directions) are released to help discover the "treasure'' (Figure 4). Finally, when it is found, the child's mentor character celebrates with jumps and somersaults and then

challenges the player to stop sucking the thumb, pacifier, or bottle. If the player does not accept this new challenge, the child's mentor character insists, saying it's fun until the player takes it. Thus, the game will continue only after this first agreement between the child's mentor and the player characters. After that, the player follows the child's mentor character to the dentist's office through a cut scene animation (Figure 5).

Figure 4 - Treasure hunting.

Figure 5 - Dentist's office moments.

To make more smooth the scene transition, we designed a fade-in when going into the dentist's office and a fade-out when leaving it. Next, the fox and the dentist characters will describe the “friends’’ and “enemies’’ of the mouth, all present in the game and in the player's real life. We show this educational content using animations, illustrations, and texts to detail how mouth friends help maintain oral health and why mouth enemies are bad for health. Therefore, we should fight them. Following all these explanations, the player leaves the dentist's office. At this point, a closing animation of DAY 1 is made by the child's mentor character, asking the child to fill out an in-game Daily Agenda (Figure 6) with the help of a family member. In addition, the adult must also register personal daily impressions about the experiences lived by the child.

Figure 6 - Daily agenda to be used for seven consecutive days.

For example, the child's level of engagement, ease of use and level of satisfaction with the game, if the child is reacting positively to the idea of abandoning the deleterious oral habits and understanding the importance of doing so, and if any changes are taking place consensually. Gradually, in a playful and fun way, the child's mentor character perseveres, showing the child how harmful these oral habits are to health, particularly the mouth, teeth and fingers. As a reward, the child's mentor character unlocks the Memory minigame, also in tune with the oral health theme (Figure 7).

Minigame 1: Memory

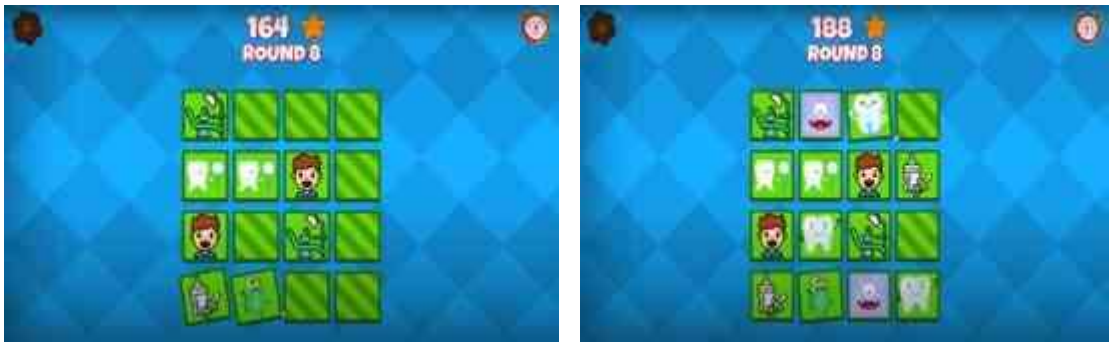

Figure 7 - Minigame 1: Memory.

Memory (Figure 7) is a minigame using cards with images related to the oral health theme. We created a game control class to choose the card pairs within that image sprite randomly. The game starts in round 1 with one pair of cards and gradually increases with one new couple of cards in the next round. The cards initially appear flipped and are flipped again to reveal the images the moment the player clicks on them. When the player clicks on any two cards that form an image matching, we activate a “success’’ sound effect to celebrate the child's achievement. At the same time, we trigger an animation on the pair of cards. On the other hand, we implemented a special visual vibration effect through animation with those clicked pairs of cards that do not match. To make the minigame more challenging, we turn those face cards down again. Each game round ends when the player finds out all the pairs of cards with matching images or when the round reaches a time limit, defined as 50 seconds. After that, the match ends with a game over message. Any round has 50 seconds time limit to discover all pairs of cards whose images match. To compensate for the repetitive work of finding identical images in pairs of cards to advance to the next game rounds, we implemented a reward scheme: the player earns points proportionally to the number of correct card pairs identified.

In the scoring system, we transformed the player's achievements in the Memory minigame into star points in the main game. To create greater dynamism, we also developed a scheme in which the points that each correct card pair is worth changes during the game rounds: in round 1, the number of correct card pairs is worth 1 star; in round two, two stars, and so on. There are a maximum of 8 card pairs displayed in the Memory minigame. However, this value can be configured and updated as needed.

On the next day, DAY 2, phase 2 of the game is unlocked. The goal is to find the primary five oral health friends (game objects) spread out in the city and keep them safe

at home, as indicated by the fox character. More specifically, the player must keep four objects in the bathroom closet (dental floss, tooth brush, tooth paste and mouthwash) and pin the fifth (dentist's poster) on an existing panel in the player's room (Figure 8). The game dynamics of DAY 2 are similar to the previous day. The player character walks around the 3D city and receives instructions about the importance of oral health "friends''. When meeting these game objects, the control mechanic is to click on the "use'' icon that appears when hovering over the object.

The child's mentor character celebrates each achievement to stimulate engagement and fun. The player scores point converted into stars in the game (Figure 8). We display the collected objects at the top of the game screen in an inventory list. When counting five friends gathered in the game, it is time to return home and correctly position them. The child's mentor character follows the player character behind. Through a camera fade-out followed by a fade-in, the scene changes inward from the player's house. The fox character instructs the player to drag each object from the inventory list and drop it in the correct position as indicated.

Figure 8 – DAY 2, Game Phase 2: Finding oral health friends and keeping them at a safe place at player's home.

After keeping safe the oral health friends at home, the game features an animation for closing the activities of this day, with the child's mentor character remembering the child character about the important task of filling out the Daily Agenda. After the player does it, the fox character releases Minigame 2, Crossroads (Figure 9).

Minigame 2: Crossroads

In the Crossroads (Figure 9), a character jumps across streets and lakes, some of them with obstacles related to oral health, where the player can collect star points. The complete set consists of a collection of sequential lanes. There are three types of lanes in this minigame: safe, unsafe and sections. Safe lanes have only physical obstacles (giant teeth and pacifiers) that prevent the character from passing at some points. There are also safe boxes along the way to collect star points. Unsafe lanes have several dangerous obstacles (halitosis, germs and bacteria, and milk jets coming out of baby bottles) that move toward the player. In addition, there are different types of terrain: lawns, lakes and strips of land. To cross the lakes, the player must wait for a water lily leaf to pass and jump over it to avoid falling into the lake and be game over.

Figure 9 – Minigame 2: Crossroads.

Moreover, some “magic” game elements appear during gameplay, floating on the strips of land: sparklers, double stars, slow motion clock, and extra lives. Such elements are perking that the player can capture while crossing the roads. There is also an object with a fog cloud effect that causes damage to the player if standing still for a long time. Finally, we release three players' lives, and whenever one of these is lost, we trigger an animation of the character flattened on the ground, falling into the water or getting lost in the cloud of smoke. The visual effect associated with this is angel wings beating to symbolize losing lives. The game's controller class is responsible for storing the configuration of the different types of lanes loaded in each match and the objects that

appear as rewards and other settings such as victory canvas or game over, cloud fog speed, number of lives, etc. Currently, Crossroads is running with twenty types of lanes and six reward objects. The finish line is reached after five hundred roads are covered, being it more common for the character to die before reaching the finish line. However, the player can keep all the stars conquered until that moment. The goal of this minigame is to entertain and illustrate the enemies of oral health in action.

Next day, DAY 3, phase 3 (Figure 10) of the game is unlocked. The goal is to find the enemies of oral health in the game scene, discarding them in the trash bin. Phase 3 begins again in front of player's “home”. The mission will be to assimilate and understand that there are enemies of oral health. Therefore, the task will be to find in the game scenario five of these enemies (bottle, pacifier, germs and bacteria, halitosis, and crooked and sad teeth). Upon finding them out, the player's character must perform the critical action of discarding them in the trash bin. Each time the player agrees to discard an object in the trash bin, the child's mentor character, who accompanies the player character throughout this vital journey of conscious and consented decision-making, celebrates. In the end, the child's mentor character releases a new minigame, Facing the Enemies (part 1), an endless running minigame within a city setting (Figure 11).

Minigame 3: Facing the Enemies (part 1)

Figure 10 – DAY 3, Game phase 3: Finding the enemies of the oral health and discarding them in the trash bin.

Again, as a positive reinforcement against the deleterious habit, the player must face the oral health enemies by controlling the child's mentor character riding a motorcycle through a 3D city environment (Figure 11). The motorcycle animations trigger acceleration or braking sound effects, simulating the tire's friction with the ground when turning and starting. In this adventure, the child must identify and avoid collision with fixed obstacles, such as buildings, tooth-shaped blocks that delimit the city, trees, and the teeth's friends (toothpaste and toothbrush), the latter, which randomly spawn in the scene. On the contrary, the child must chase and collide with the dynamic game objects which spawn with different velocities, in this case, the teeth's enemies (germs, bacteria, and halitosis) to destroy them and, consequently, earn points. Another way of scoring points is by collecting rewards (stars, double stars and damage repair). A regressive timer controls the player's time in each match and can be reduced if there is any collision with fixed obstacles that are not oral health enemies, such as buildings, trees, etc. Pacifiers and milk bottles are static distractors that can also be eliminated from the scene by colliding with them. As with the other minigames, the intention is to help the child identify the oral health enemies and fight against them. As before, the child has to fill out the Daily Agenda.

Figure 11 – Minigame 3: Facing the Enemies (part 1).

Finally, we unlock phase 4 of the game (Figure 12) on DAY 4. The player's task is to answer a simple Quiz (Figure 13) we created with five multiple-choice questions related to the oral health subject previously shared in the game. The first four questions are worth 10 points and the fifth one, 50. We prepared these questions for kids to test their knowledge and boost their memory regarding what they learned during the game playtime. Right after the player answers the Quiz, the last minigame released is Facing the Enemies (part 2), shown in Figure 14.

Figure 12 – Quiz answer.

Question 1: In the game, you threw me in the trash bin because I can harm your tooth health. Who am I?
Options: ( ) Dental Floss ( ) Pacifier and Baby bottle ( ) Toothbrush
Answer: Pacifier and Baby bottle

Question 2: I'm a part of your body that you shouldn't put in your mouth because it takes germs and bacteria into it, which is harmful to your health. Who am I?
Options: ( ) Finger ( ) Pacifier ( ) Mouthwash
Answer: Finger

Question 3: I also calm down, but my function is feeding. I can keep delicious milkshakes or juices, but you can use cups and straws in my place. Who am I?
Options: ( ) Toothpaste ( ) Germs and bacteria ( ) Baby bottle
Answer: Baby bottle

Question 4: Enemies of the mouth always appear when we don't brush our teeth and put dirty things in our mouths. I'm terrible for your health. Who am I?
Options: ( ) Germs and Bacteria ( ) Pacifier ( ) Toothbrush
Answer: Germs and Bacteria

Question 5: I also show up when you don't brush your teeth or suck your thumb or pacifier. But there's one thing about me that's disgusting: I stink! Who am I?
Options: ( ) Germs and bacteria ( ) Halitosis ( ) Mouthwash

Figure 13 – Quiz.

Minigame 4: Facing the Enemies (part 2)

This minigame is a continuation of Facing the Enemies (part 1), with a higher level of complexity (Figure 14). On a motorcycle, the fox character must explore an outdoor scenario modelled as a 3D vast desert environment. Similar to Minigame 3, the oral health enemies spawn with different velocities around the child's mentor, and the more the player chases and destroys these objects, the more star points earn. Another way to score is to collect star points that appear randomly in the game scene. Game objects also spawn close to the child's mentor, rewards (star, double star and damage repair) can be collected, and oral health enemies must be chased and destroyed (germs, bacteria, and halitosis). Another way to score points is to collide and, thus, destroy static objects representing the teeth's enemies (pacifiers and milk bottles). The player has three game lives (if necessary, this parameter can be easily configurable and calibrated by the developer). The player's health bar decreases every time the player collides with

stationary teeth friends (toothpaste and toothbrush). If the player finds the damage repair reward in the scenario, the health damage can be reversed. There is a game countdown timer (also configurable) to eliminate as many enemies as possible. At the end of each match, the accumulated points are converted into star points in the main game.

It is worth mentioning that during the design process of Minigames 3 and 4, we even thought about having the protagonist (the child) riding the motorcycle. However, it seemed unnatural to us, the figure of a child, performing such action. In addition, the manoeuvres through the scenarios are fast and challenging, reinforcing the mentor (the little fox) as a wise and problem-solver character in our game design perspective.

Figure 14 – Minigame 4: Facing the Enemies (part 2).

From DAYS 5 to 7, we release the four minigames as a bonus for the child to play. In the game interface (Figure 15), the four buttons on the left give access to the four minigames, and the button on the right-side pop-ups the Daily Agenda, which should be filled out until DAY 7. The final player score is displayed on the top right, inside the star object.

Figure 15 – Game Interface with the final player score (on the top right) and buttons to access all Minigames (on the left) and the Daily Agenda (on the right).

Game programming and functionality testing

The game was developed with the Unity game engine (Unity, 2020), using C# to build the scripts and the integrated *Adventure Creator* tool (Burton, 2022). For the game, we selected, used, built on top and customized a collection of free online 2D sprites, 3D characters and assets (Ashraf, 2017; AurynSky, 2017; AurynSky, 2018; Bestgamekits, 2020; Cabble Games, 2019; Catalyststuff, 2022; Clipartmax, 2022; Felicities, 2022; Freedesignfile, 2022; Freepik, 2022; Hovl, 2020; JonahH, 2019; Mason, 2020; PCH-vector, 2022; P. E. Limited, 2017; Piablood, 2016; Pixel-perfect, 2022; Polygon-Park, 2019; Puppeteer, 2017; Puppeteer, 2018a; Puppeteer, 2018b; Pxltiger, 2020; Rawpixel-com, 2022; Rizwan Studiogstock, 2022; Stockgiu, 2022; Synty, 2015; Synty, 2017; 9t5, 2021; 3 White Lines, 2018).

We used the Adventure Creator mainly to implement the character animations, for the configuration and control of camera movements, and for the construction of hotspots, triggers, action lists, cutscenes, inventories, conversations, and markers, among others. We configured the adjustments of the animation's continuity parameters via code and added them to the animated game objects. We performed functionally testing exhaustively to identify any errors and issues that might affect the player experience, including those related to performance, gameplay, control mechanics, visual graphics, textual information of the narratives and game instructions, and audio-to-video synchronizations. We fixed all these issues and revised the entire game, many times, after re-testing it.

Points-based rewards system

Although the game's main objective is to educate while having fun, we have also implemented a points-based rewards system to impact the player's satisfaction, which is cumulative for each challenge experienced and resolved. We represent these achievements visually in the game interface as “stars” with number values inside, symbolizing the points earned, visible during the seven consecutive days of play. We use these star points to generate analytics sent along with the Daily Agenda to the child's guardians and the dentist (the latter, if the child has access to this professional's service). We developed the points-based rewards system by implementing an *Adventure Creator* script. Thus, the star points obtained in the game and minigames are continuously summed up, updated, and saved in the main game interface.

Expert Evaluation

This section presents an expert evaluation. The goal was to possibly identify potential issues in the methodology through the digital game that might impact actual players. Following a basic strategy for usability in serious games, three main elements were the focus of the evaluation: usability, playability, and effectiveness (Procci et al., 2012).

The reviewer is an expert both in usability and in the subject domain of the project (Pediatric Dentistry and Orthodontics), having more than twenty years of practice. According to the expert, the game is easy to understand, even by children in early childhood, as long as an adult helps them with the translation of written passages. However, understanding can also occur visually, regardless of reading the texts, which is a positive design aspect. One of the significant advantages of this game is that it can be interrupted and resumed at any phase without generating anxiety in the child. The data entry requested in the game does not present difficulties for an older child due to the extensive experience with digital games to which they are already currently exposed. Still, there is a need for the monitoring of a guardian.

The game environment depicting a 3D city with its dynamism allows the educator to involve the child beyond the objectives of the deleterious habit, creating constructive playful situations with other interesting elements such as cars, cafeterias, colorful houses, vegetation and the seafront. Evaluating from the social side, one has the idea of a well-organized place, with beautiful houses and many cars along the streets and avenues. Even the player's residence in the game is spacious and comfortable. This

aspect may provoke a feeling of inferiority in those who do not have this apparent social condition.

The game promises to be very effective with the child's education since there is a mediator, the little fox character, who helps in a subtle and non-authoritarian way, to define what is good and bad for oral health, always with arguments of positive reinforcement. Furthermore, the methodology of a seven-day game, including minigames with visual elements related to oral health and well-defined and fun actions on each game day, offers many possibilities for a better understanding of the problem throughout the days. It takes patience, attention and affection during the behaviour change process. Additionally, the daily task of filling out a Daily Agenda is an essential resource of positive reinforcement, as it always encourages the child, even in the face of the difficulty of fulfilling the mission. The dentist is the main character in health education and, therefore, in the scientific validation of the arguments used by the little fox character. In addition, the dentist plays the delicate role of the judge in the child's recovery process. It is worth mentioning that a lot of sensitivity is necessary for the moments of awarding, mainly always offering a vote of confidence to those who were not able to reach the objective. The game's control mechanics match the understanding of the target age group and the ease of use. The playful animations and soundtrack refer to the idea of walking, which induces fun and engagement in the hunt for those oral health harmful elements, applying the lesson to the players' daily lives, and transforming their behaviour.

Finally, an important conclusion is that the child, using this methodology through an important transformative playful instrument, will allow itself to incorporate new educational concepts and even discontinue habits considered deleterious in a smooth, solid and consented way. Regarding parents or guardians, positive feedback is expected for having a digital ally that will facilitate the solution of such recurrent problems in childhood. Furthermore, from the perspective of the dentist (who preaches the need to stop harmful oral habits for the benefit of health and does not always has the cooperation of the child's parents), this game offers a significant, contemporary and innovative contribution, capable of promoting a link between parents, child and dentist in solving the problem.

Conclusions and Future Work

This work presented a methodology to promote deleterious oral habit change

through an educational game that encourages the child to abandon this habit in a conscious and consenting way through positive reinforcement. We created an original narrative and developed a game to be played for seven consecutive days. It contemplates four phases of a learning player's journey, enriched with four minigames aligned with the main theme game. The minigames add value to entertain the player while reinforcing concepts learned in the main game. In addition, we implemented a points-based rewards system to generate an impact on player satisfaction. According to the expert evaluation, the methodology through a game was appropriate and it promises to be very effective with the child's education, always with arguments of positive reinforcement. Furthermore, it presents support features for the child and their guardians and dentist through the Daily Agenda. Finally, our methodology also offers the opportunity to bring together the child's family and dental professional to act collaboratively in favor of health using a contemporary digital resource, giving the child confidence and the chance to explore the deleterious habit and learn and change.

In future work, we foresee the inclusion of other avatars to contemplate a greater diversity of players. In addition, we plan to conduct user experience tests with the target audience, that is, children aged four to seven to receive feedback on the game. However, prior to starting this usability study, we need to obtain ethical approval for all protocols from the appropriate ethics committee to confirm the study meets national and international guidelines for research on humans. Following that, other possibilities are to compare our game structure against the Procedural Rhetoric Theory proposed by Bogost (2007), who suggests that games can be more effective than other media in persuading people about the merit or flaws of beliefs and attitudes, and to extend our game by producing a children's book inspired by it with interactive features using immersive technologies, such as Augmented Reality and Virtual Reality.

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