Musical App in Hypersensitivity to Sounds and Neurodevelopmental Disorders: Applicable Strategies

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ABSTRACT

Sêntimus is a musical app dedicated to children diagnosed with Hypersensitivity to Sounds associated with Neurodevelopmental Disorders. The research is part of Master's Degree project in progress, conducted at the Department of Music in partnership with the Department of Computer Science at the Federal University of Minas Gerais, Brazil. The objective of this app is to stimulate expressive behaviors of pleasure or dislike, characteristic of Hypersensitivity to Sounds, through game play and music. We have proposes investigated how treatment principles and symptoms for Hypersensitivity to Sounds, Neurodevelopmental Disorders can be taken into account in the design of a game aimed at children with mild or moderate levels of both diseases. The results obtained were 12 Principles and Strategies such as "Exposure Gradually", "Attention" and "Social Interaction" and 7 Recommendations by researchers serious game.

1. INTRODUCTION

People with Hypersensitivity to Sounds complain of excessive irritation related to some sounds and noise levels considered common [1]. People with Neurodevelopmental Disorders usually present deficits that produce impairments related to personal, social, academic, or occupational functioning [2]. These symptoms hamper the daily lives of this population. Music and games can help the treatment of these pathologies. The treatment of Hypersensitivity to Sounds is based on exposing patients to sounds, which can cause discomfort to them. In this context, games can motivate patients to be exposed to its sounds and focus, rather than trying to escape from them.

This paper is part of a Master's Degree in progress at the Department of Music in partnership with Department of Computer Science at the Federal University of Minas Gerais, Belo Horizonte, Brazil. The research project "Musical App in Hypersensitivity to Sounds and Neurodevelopmental Disorders" is aimed at children with a mild or moderate level of both disorders. The goal of the research is to stimulate modifications in expressive behaviors of pleasure or dislike, associated to Hypersensitivity to Sounds, through music and gameplay. To do so, we propose an app which is a musical game for children diagnosed with Hypersensitivity to Sounds and Neurodevelopmental Disorders, based on the treatment proposed by Jüris [3] and symptoms of the Neurodevelopmental Disorders described in the Manual DSM-5 [2]. The name of the game app is Sêntimus, which came from a connection of two Latin words: Sentimentum and Musica.

The purpose of this paper is to understand the specific needs of children diagnosed with Hypersensitivity to Sounds associated with Neurodevelopmental Disorders, and how to take them into account in designing a digital game for them. To do so, we have reviewed the literature to understand symptoms and treatment associated with these conditions, as well as the literature describing musical games and software aimed at patients. Based on these findings we propose a set of strategies of how to take into account these symptoms and treatment principles in the design of a digital game. We then describe how the strategies are used in the development of Sêntimus.

Our work brings relevant contributions to the research on the use of technology to support Hypersensitivity to Sounds associated with Neurodevelopmental Disorders. It proposes we have investigated how treatment principles and symptoms for Hypersensitivity to Sounds, Neurodevelopmental Disorders can be taken into account in the design of a game aimed at children with mild or moderate levels of both diseases.

This paper is organized as follows: Section 2 describes the Theoretical Foundation of the related topics; Section 3 describes the Methodology; Section 4 describes the Results; Section 5 describes the Applied Strategies in the Game; and Section 6 describes the Conclusion.

2. THEORETICAL FOUNDATION

This research links four areas in theoretical foundation: Hypersensitivity to Sounds, Neurodevelopmental Disorders, Music and Digital Games. In this section we present the relevant topics about each one of them, necessary to the development of the game.

2.1 Hypersensitivity to Sounds

Defined as unusual intolerance of ordinary environmental sounds, Hypersensitivity to Sounds is an alteration of the sound processing in Central Nervous System. The cochlea and hearing aid are often perfectly normal although patients complain of excessive irritation related to some sounds and noise levels considered common. In the literature we can find the following terms: *Hearing Hypersensitivity, Audiosensitivity, Phonophobia, Noise Sensitivity, Hyperacusis Dolorosa, and Reduced Tolerance to Noise*, being used in the same context [4]. In this paper, we used the term *Hypersensitivity to Sounds*, which is a disorder in the sensation of everyday sound intensities [1, 3, 5, 6]. Sounds intensities that are not perceived by most people can cause great discomfort to *hyperacusis* (people with Hypersensitivity to Sounds). Also, violent noises, such as car horns or fireworks can cause disorientation on individuals with hyperacusis, reflecting in atypical reactions. A typical feature, of the condition, is *fear of sounds* based on their meaning or association [1, 7]. Hazell presented one almost universal true example of the sound created by scratching chalk on a slate. Argues that our perception of loudness is not dictated simply by the strength or intensity of the sound arriving at the ear, but also by the association that it has some threatening qualities. *"Will the sound damage the ears?"* or *"Will it disturb sleep?"* [1, p. 3]. This example can trivialize Hypersensitivity to Sounds and anyone could think: I have hyperacusis. However, we must remember that very often the over-sensitivity for sounds begins by an irrational fear which, nevertheless, becomes an absolute belief and it also involves pain. Hazel reported cases of patients who strongly believe that their lives are ruined by environmental noise from nearby factories or generators. Patients often also complain about low-frequency sounds transmitted through the ground (considered silent because other people may be unable to hear). According to Jüris in [3] the fear/avoidance beliefs were rare, but when they are presented, nevertheless, they elevate the risk of future pain feeling episodes.

Prevalence studies of hyperacusis are not trivial, since they have a subjective nature, Jüris [3, p. 15] mentions one of the very few existing. A study in the Swedish population [8] collected data using two surveys: (1) a postal version of a random sample, which involved 589 participants; (2) an internet version, in which 595 participants' self-reported hyperacusis. The results show that, excluding participants who related hearing impairment, the point prevalence of hyperacusis rate of 7.7% (39 participants) and 5.9% (28 participants) in postal and internet, respectively. The present data suggests that hyperacusis is a common problem.

In terms of diagnostic Jüris [3, p. 13] shows that there is no consensus-based standardized procedure for hyperacusis diagnosis due to the following factors: (1) there are different types of sensitivity to sounds such as: *phonophobia, misophonia, recruitment of loudness, decreased sound tolerance* and *hypersensitivity to sounds*; (2) the concept of these terms is inaccurate, thus it is complicated to distinguish between different types of sensitivity to sounds; (3) there are still diverse terms used in audiological literature making diagnostic even more complicated, as not all people who experience unfavorable effects of sound exposure really suffer from hyperacusis; (4) sound sensitivity is diagnosed in several professions, audiology, neurology and psychiatry; (5) common procedure normally is to take the medical history, followed by audiology testing (in which pure tone audiometry is performed to detect hearing deficits); and physical and laboratory examination; (6) the main source of information diagnostic evaluation is the self-report and Questionnaire.

According to Katzenell and Segal [4], studies in etiology, in clinical guidelines, and review literature describe four main groups of causes of hyperacusis: (1) in *clinical conditions involving the peripheral auditory system*, we highlight: Bell's Palsy, Stapedectomy, Ramsay Hunt Syndrome, Recruitment and Noise-induced Hearing Loss; (2) in *clinical conditions involving the nervous system*, we highlight: Minor Head Injury, Headache, Depression, Learning Disabilities and Stuttering, Williams's Syndrome, Spinal Problems, Tinnitus Hyperacusis; (3) in *hormonal and infectious diseases*, we highlight: Lyme Disease and Addison's Disease; and (4) *unknown causes*. The authors conclude that pathogenesis of hyperacusis is not clear and it probably involves a Central Nervous System. They consider that validation of the effectiveness of the treatment is still necessary.

The symptoms of Hypersensitivity to Sounds can be variable and it can go beyond fear or uncomfortableness. Previous studies [1, 3, 8, 9] indicate that Hypersensitivity to Sounds when evident can show intermittent symptoms such as *anxiety*, *migraine*, *depression* and *severe crisis* due to sensitivity to sounds. The patients often feel *isolated* and *discouraged* considering that they cannot imagine living due to their frequent sensitivity condition.

For the treatment, the authors Hazell and Jüris [1, 3] indicate that the best solution is based on desensitization through *counseling* or *retraining*. Counseling must be undertaken by trained psychological professionals since it *"is understandably difficult to accept that sound which can be uncomfortable or even painful to the hearing, can be quite harmless to the ear"* [1, p. 4]. The retraining is designed to take away the need to plugs (e.g. earplugs) or actions which can protect the ear (e.g. avoidance to sound). The treatment is a process of *sound exposure* and can take quite a long time. Sound exposure is a procedure in which ordinary environmental sound *volume is gradually* increased. Jüris states that the aim of psychological interventions is not to "cure" the patients, but rather to reduce their distress and increase their quality of life [3, p. 21].

2.2 Neurodevelopmental Disorders

Gomes [5] states that previous research has documented that sensory-perceptual abnormalities, especially when concerning the sound, is associated to *Autism*. Hypersensitivity to Sound and Neurodevelopmental Disorders can be associated with clinical conditions involving the Nervous System [4]. Hughes [10] argues that autists often demonstrate behavior such as *holding their hands over their ears to protect or hand flapping and head shaking combined with fear of environmental situations because of sounds.*

According to Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [2] the Neurodevelopmental Disorders are a *group of irregular conditions* with onset in the developmental period before the child enters grade school.

They are characterized by developmental *deficits* that produce impairments of personal, social, academic, or occupational functioning. The *limitations are very specific,* such as learning or controlling executive global functions related to social skills or intelligence impairments. The Manual (DSM-5) showed that the "Neurodevelopmental Disorders frequently co-occur in individuals with autism spectrum disorder who often have intellectual disability (intellectual developmental disorder)".

The Manual DSM-5 [2] ranked the group of conditions and classified it as Diagnostic Criteria. We next briefly present these conditions: (1) *Intellectual Disability* (Intellectual Developmental Disorder) includes both intellectual and adaptive functioning deficits in conceptual, social, and practical domains; (2) *Language Disorder* difficulties in the acquisition and use of language across modalities (i.e., spoken, written, sign language, or other); (3) *Developmental Coordination Disorder* the acquisition and execution of coordinated motor skills is substantially below the expected given the individual's chronological age and opportunity for skill learning and use; (4) *Specific Learning Disorder* presence of learning difficulties and in the use of academic skills, following deficits such as inaccurate or slow and effortful word reading (e.g., reads single words aloud incorrectly); (5) *Attention-Deficit or Hyperactivity Disorder* (ADHD) a persistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functioning or development that negatively impacts directly on social and academic/occupational activities; (6) *Autism Spectrum Disorder* (ASD) persistent deficits in social communication and social interaction across multiple contexts, including deficits in social-emotional reciprocity, nonverbal communicative behaviors used for social interaction, developing, maintaining, and understanding relationships.

2.3 Digital Games and Music

Novak [11] indicates that music, sounds, games, and entertainment are linked to communication, players and emotions, and these elements also are linked to the interaction experience. Novak argues that music role in games is very important since *music helps to set the atmosphere and feeling*. Soundtrack, sounds and sound effects can change emotions and perceptions of the players. These elements can cause a decisive impact on the player *immersive experience* [11]. As reported by Coutinho [12], a convincing atmosphere with visual elements, sounds, and screenplay can help in the immersion of the players. Fortunas [13] observed improvement in kids with Cerebral Palsy using music compositions software. The author related musicalization and experimentation progress in the users. The most interesting approach to this issue has been proposed by Cibrian [14] about music therapy and musical game (interactive surface). The results showed improvements in the autistic participants' in general experimentation. Ringland [15] developed music technology for kids with Neurodevelopmental Disorders. Ringland's studies have a theoretical foundation in therapy and argue that technology products associated with therapy can be a *complementary therapeutic tool*.

3. METHODOLOGY

Hypersensitivity Disorder patients have special needs, thus in order to better understand these needs, and propose a game that could be useful, our first step consisted of a literature review on three different topics: Hypersensitivity to Sounds [16]; Musical software and Neurodevelopmental Disorders [17]; and Musical Games for Hypersensitivity to Sounds and Neurodevelopmental Disorders [18]. The analysis of our literature review followed the methodology proposed by Laville and Dionne [19].

As a result of our review on Hypersensitivity to Sounds [16] we selected Jüris [3] as the main reference on Hypersensitivity to Sounds treatment to guide our work. In her thesis, Jüris aims to better understand the use of Cognitive Behavioural Therapy (CBT) on the clinical treatment of the condition hyperacusis. Her research focuses on *exposure to sound, psychoeducation, applied relaxation and behavior activation in patients with hyperacusis*. Thirty patients participated in the experiment. The experiment's design involved patients in a control group, as well as in a specific treatment group for 12 months. The theoretical framework in CBT is behavior, which is based on the laws of learning in both conditions: respondent and operant. Respondent conditioning applies to the establishment of a response by pairing a neutral stimulus. Operant conditioning refers to the type of learning in which an individual's behavior is modified by its consequences (e.g. positive and negative reinforcement). As a result, Jüris showed that CBT has proven to be effective for a range of psychiatric disorders and treatment for many patients with mild to moderate psychiatric problems, and specifically a promising treatment option for patients with hyperacusis.

To investigate about Neurodevelopmental Disorders we used the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [2]. The DSM is a *taxonomic and diagnostic tool for the classification of mental disorders*, perceived as a universal reference for psychiatric diagnoses. It has been used by clinicians and researchers from different orientations (biological, psychodynamic, cognitive, behavioral, interpersonal, family/systems).

Based on the analysis of our review of musical software and games for Hypersensitivity to Sounds and Neurodevelopmental Disorders, we identified a set of recommendations [17, 18] *aimed at game and software design specific to support the special needs* of patients of Neurodevelopmental Disorders.

In this paper, we propose a set of strategies that address how the treatment principles and symptoms identified in the literature could be considered in game design aimed at hyperacusis patients. We also associate existing recommendations to each strategy. In the next section we present our results.

4. RESULTS

In this section, we present *12 Principles* (P) of clinical nature care identified in the literature. For each principle, we present a *Strategy* (S) of a technical nature, that presents considerations on how to take the principle into account in the design of a game. Finally, we associated the existing *Recommendations* (R) identified in the musical game and software literature to the principles and strategies. Notice that we have identified 7 recommendations, so they do not cover all the spectrum described by the principles.

P1 - Sound Exposure Gradually. It is an upwardly technique of graded sound exposure to patients. The patient is exposed to an initial sound volume, which is then gradually increased every week. This exposure takes place with a general purpose of environmental sound enrichment. For example repeatedly dropping a spoon, in a way that the initial height is gradually increased, and so is the sound enrichment [3, p. 31]. This technique is also presented in Jastreboff [20].

S1 - a) making a background layer of the ambient sound which gradually increases in intensity during the game; b) using graphic elements and characters emitting different sounds, adding energy for sound enrichment; c) using characters random arise in different moments.

P2 - Audiological Measures. Jüris defined a hearing threshold to identify patients with hyperacusis. To do so, a pure tone audiometry was performed in the patients using the ascending technique. Hearing thresholds were measured in dB (HL) at 125 to 8000 Hz. It was defined as the average of the frequencies 500, 1000, 2000 and 3000 Hz for each ear. For loudness discomfort levels (LDL) the measured frequencies were 250, 500, 1000, 2000, 3000 and 4000 Hz. And for at least one ear, the person was considered to meet test criteria for hyperacusis level of 90 dB or less for the frequencies of 500, 1000 and 2000 Hz [3, p. 26,27]. This technique is also presented in Anari [21].

An interesting approach to this issue has been proposed by Coelho [7, p. 171]. In her experiment with hyperacusis children it was noticed that many children did not report discomfort during the audiometry examination with measured output of: 110 dB HL at 0.25 Hz; 120 dB HL from 0.5 Hz to 6.0 kHz, and 100 dB at 8.0 kHz, adding 5 dB gradually at a time.

Anari [21] made a very important recommendation for audiological measurements. The authors started at a lower level 50–60 dB HL, different from traditional recommendations that start at 70 dB HL, as the authors considered based on their experience that 70 dB HL causes discomfort for many patients including the not hypersensitive.

S2 - a) making sound intensity model based in audiology measurements frequencies; b) equalizing audio developed; c) to setting the level of start at 50–60 dB; d) applying harmonic music in the game; e) creating configuration screen for overall game elements.

P3 - Applied Relaxation. Commonly patients with Hypersensitivity to Sounds feel tense listening to their sounds that are discomfortable for them. For this reason, Jüris applies a shortened version of the CBT applied relaxation technique. This technique is best used in treatment for stress and can be applied several times a day [3, p. 31]. This technique is also presented in Hayes [22].

S3 - a) develop mobile games that can easily be played in different situations, times and contexts; b) define few difficult situations and, for these situations.

P4 - Behavior Activation. Patients often give up different activities due to hyperacusis of sound. The goal of this part of the treatment is gradually *restart activities* that patients had given up by behavior activation. Treatment is usually used for treating depression [3, p. 32]. This technique is also presented in Schaaf [23].

Klein [24] highlights that Williams Syndrome [1] is associated with Hypersensitivity to Sounds. In a study she designs parental questionnaires to determine the prevalence of hyperacusis. The questions are: (1) *"has your child ever been unusually frightened by certain sounds?"* and the parents answered "yes" or "no". The results indicate that 83% of participants answered "yes" in the Williams group and 3% in the control group; (2) *"check the following noises that had or still do repeatedly bother your child."* aand the parents check one or more characteristics of the sounds that their child found offensive. The results were "firecracker," "power saw," "electric drill," "fire engine siren," "motorcycle," "loud auto muffler," and "blender" were selected by 60% of the parents. Features of the offensive sounds asked were: "loud" and "sudden" were chosen 73% and 74% of the time; whereas "high pitched" was chosen by 52%, and "low pitched" by 6%. The sound "thunder" was the most common self-write sound by 19%. The characteristic, benign sound, was added to the list by parents were "automatic ice maker," "television test tone," "newspaper crackling," and "church bells" [24].

S4 - a) searching and defining locals can help behavior activation; b) creating a game scene illustrating the difficult circumstances for hyperacusis; c) creating sounds related to circumstances; d) creating mode benign sound and rough sounds; e) searching and defining places can help behavioral activation; f) creating customizable game screen for input music and background screen; g) creating a noise model, various noise track based on research.

P5 - Psychoeducation. The technique applied to the education the patients, considering reasons and effects of the condition in their overall health, and the structure and contents of the treatment material. The main base of the psychoeducative method was on teaching the patient how to avoid sounds that can affect the auditory system and fear/anxiety. Jüris shows explanatory material on the treatment hyperacusia with information about the treatment of hyperacusis, the CBT model utilization, sounds applied, sound levels and assessment of riskful sounds by the participating patients [3, p. 30]. This technique is presented also in Kennerley [25].

S5 - a) creating documentation about treatment applied to the end user; b) creating audiovisual material in the game about the treatment applied; c) creating help documentation of the game; d) creating explanatory material about sound levels and model utilized.

P6 - General Mental Abilities. This condition is characterized by deficits in intellectual functions that concern reasoning, planning, abstract thinking, learning from instruction and experience, problem solving, judgment, and practical understanding. It is a typical symptom of *Intel-*

[1] Williams Syndrome is characterized by cardiac defects, physical and developmental delay, stellate eye pattern, elfin/pixie facial features and hyperacusis.

lectual Disabilities [2].

S6 - a) elaborating simple solutions for problems; b) inserting elements that represent physical objects that can be manipulated in the game.

R1 - a) the simple navigation results in game play flow; the fluidity navigation with simple tool and short cognitive processing is the secret for the fluidity; b) the graphics interface is a window for stimulating the curiosity [26]; c) inserting concrete and personal objects in game can result in an immersive experience and better creative experience to the player [27].

P7 - Communication. This condition is characterized by deficits in acquisition and use of the language, speech, and communication due to failure in the production or comprehension of vocabulary, sentence structure, and discourse. It is a classic symptom of *Communication Disorders* [2].

S7 - a) avoiding complex verbal language; b) exploring graphic language can help learning a game; c) creating navigation flow with common graphic sign; d) using methodology based in a conversation between designer and user through interface for interaction model.

R2 - a) concrete objects such as cars and dolls are considered favorite because the users do not understand how to the system works [27]; b) the use of the interaction sensors can give enjoyable and functional experiences to general children but mainly to the disabled [27].

P8 - Coordination. This condition is characterized by impairment in motor skills requiring coordination. In addition, these skills also vary according to age, and performance or participation in daily activities in family, school, social, or community life. It is a typical symptom of *Developmental Coordination Disorder* [2].

S8 - a) creating activity with simple interaction such as pressing or dragging game objects; b) creating intuitive game design when using motion sensing; c) developing the system to customize performance gradually; d) developing direct manipulation game.

R3 - a) multi-touch interaction is broader than computer possibilities [28]; b) game controllers that go beyond "button press" interaction can improve attention, expressiveness, and performance [27]; c) design project should not overwhelm the user and have limited cognitive process to a minimum necessary performance [26]; d) simple system should present user-centred experiences because depending on the mood of the user the interface can be surprising. For this reason it is important for the system to have customization options [26];

P9 - Learning. This condition is characterized by essential feature of specific learning disorder is persistent difficulties learning keystone academic skills. It is classic symptom of *Specific Learning Disorder* [2].

S9 - a) developing gradual game design with an increasing learning level while playing; b) creating clean graphic interfaces; c) creating navigation from phase to phase; d) creating a tutorial video before the phases; e) creating game scene and graphic elements corresponding to the scene.

R4 - a) stimulating visual and tactile perception can increase not only player engagement with the learning process, but also the comprehension of experiment subjects [29]. These elements are directly connected to the way one can see the objects/environments and in turn, the way we explore them [29]; b) it is not only necessary to see the object, but also to manipulate it, considering that touch is linked to the cognitive processes and also in the understanding of the concrete experiences – comprehension increases the engagement in the learning process [29]; c) discovery through action is a game plan which lets the person to add complexity in how they animate the interface through their interaction [26]; d) avoid dispensable details that requires cognitive level ability or users' interest [26].

P10 - Attention. This condition is characterized by insistent pattern of inattention and/or hyperactivity-impulsivity that interferes with functionality or development. In Inattention the patient manifests difficulty sustaining focus. Impulsivity refers to hasty actions, without forethought. Also, Hyperactivity refers to excessive motor activity. It is a typical symptom of *Attention-Deficit/ Hyperactivity Disorder* (ADHD) [2].

S10 - a) drawing player's attention through graphics and sounds elements; b) trying to keep player's attention through animations or activities that always something have on in the game; c) constantly changing scenes; d) creating game screen: time is over; e) definging a time limit for each game phase; f) triggering curiosity through rewards.

R5 - a) color, light, texture and sound can set the experience and afford both an aesthetic platform for imagination [26]; b) trigger curiosity through repetition can create rhythms and patterns that enhance interest through experience [26]; c) experimentation can result in improvement in the children [14]; d) autistic players speak to a number of different game features that relate to their overall enjoyment such as presence of the achievement and challenge artifacts allowing creativity or autonomy. These factors and also interesting story elements and emphasizing artistic elements are important for them

P11 - Social Interaction. This condition is characterized by deficits in social communication and social interaction across multiple contexts such as, in social-emotional reciprocity; in nonverbal communicative behaviors used for social interaction; in developing, maintaining, and understanding relationships; repetitive patterns of behavior; inflexible adherence to routines, in general issues. It is a typical symptom of *Autism Spectrum Disorder* (ASD) [2].

S11 - a) developing game in which it is possible for two people to play simultaneously; b) choosing game activities that can help in player's performance such as repeating a specific movement, involving more than one player, among others; c) creating a therapist profile with phases or activities that can be sent to each individual user in the game; d) storing data on users' performance and activities in the game; e) creating activities which can be played in face-to-face groups such as in a classroom.

R6 - a) positive emotions can express positive results in building vocabulary, encouraging vocalizations, and communication forms [30]; b) sharing among the children can be promoted through multi-touch technology, passing the mobile from hand to hand [30]; c) research proper tools to aid the user in expressing himself through the system [31].

P12 - Specifiers. Severity specifiers are used to describe the current symptomatology, and may vary with the patient's context. The specifiers depending of the severity level such as: Level 1 - requiring support, Level 2 - requiring substantial support, and Level 3 - requiring very substantial support [2].

S12 - a) searching and defining the target audience of the game; b) using appropriate methodology that can help understand needs of the game audience; c) considering mild level severity specifiers of the player; d) setting age range for the user; e) use of reflexive theories about system communication; f) use cognitive process methodologies.

R7 - a) studies involving the games' production show diverse audience both in age range and in pathology support tool. Bozzi [32] created for children from 5 to 9 years old, Malinverni [33] from 4 to 6 years old, and Wrońska [30] for children from 8 to 12 years old. In terms of diagnostic Challis [27], developed a game for users with motor disabilities, Cibrian [14] for ASD, and Gehlhaar [31] for broad of disabilities spectrum.

5. APPLIED STRATEGIES IN THE GAME

Based on the principles and recommendations identified and strategies proposed we have developed the game Sêntimus. In this section we present how the strategies proposed were applied in designing the game.

The main goal in the game is popping balloons by touching them on the screen. The punctuation is associated to the number of ballonns popped, each popped balloon scores one point, and as the player makes more points, the intensity of the ambient sound in the background increases. It is divided in 4 phases: Level 1 - *Learning Mechanics*; Level 2 - *Birthday Party*; Level 3 - *Ghosts*; and Level 4 - *Relaxation*, as depicted in Figure 1. For each level, there is delimited time, and this can be modified in the configurations. The user plays first the Level 1, second Level 2, third Level 3, and finally the Level 4. For each level there are different graphic interface, sound elements and characters. The system records the player's performance data, and this data is taken into consideration in the following level.

Figure 1. The four levels of the game Sêntimus.

E1 - Sound Exposure Gradually. We created the game level with ambient background sound and graphic elements of a birthday party. If the player pops balloons, it increases the intensity of the ambient sound layer. Each balloon popped scores one point in the game. We developed an *Intensity Model* and the sound dynamic is: in Level 1 and 2 the sound is enriched gradually, increasing tension sensation/intensity levels; in Level 3 there is sound impoverishment, decreasing this pressure sensation; in Level 4 the is a leveling sound, stabilizing these sensations.

E2 - Audiological Measures. Audiology test has been conducted using pure tone (sine wave) [3]. Borges [34, p.93] studied music noise, synthesized noise and showed that these elements are associated to the uncomfortable feeling, discomfort or displeasure sensation. On the other hand, harmonic music is normally associated with the feeling of happiness and familiarity. In this work we used the complex tone, in which fundamental frequency presents energy equivalent to stipulate pure audiological tone. We developed a *Noise Model* in Brazilian context. To Level 1 and 2: the little monster characters emit breaking glass sounds and drum plate; the balloons emit popping sounds; the environment sound with people talking; and music composition made specifically for this game. In Level 3 the Model Noise is: the little ghost characters emits thunder sound; the environment sound with people talking; the environment sound with people talking; and sinister music made specifically for this game. In Level 4 we do not apply the Model Noise. The *Frequency Model* is not applied in Levels 1 and 2. In Level 3 the little ghost characters emit this frequency sound: 1047, 1174, 1396 and 523 Hz. In Level 4 there is rhythm and melody random accompaniment sound associated to each balloon. We created 9 tracks: (1) 349.23, 415.30, 698.46; (2) 293.66, 349.23; (3) 329.63, 392.00; (4) 293.66, 349.23; (5) 220.00, 261.63, 311.13, 349.23; (6) 174.61; (7) 349.23, 311.13, 261.63, 233.08, 207.65; (8) 155.56, 207.65; (9) 349.23, 415.30 Hz.

E3 - Applied Relaxation. In this work, we interpret Relaxation with exit de-stress situation, for example, when someone walks out of a noisy environment, this action can give an immediate sense of relief. In this game the Relaxation is removing tension provoked by uncomfortable sounds. In Level 4 we used the music *Happy* [2] and used the scenery of the Minions movie [3].

E4 - Behavioral Activation. Often birthday parties are one of the first collective experiences children have, and this involves different sound types. We create a birthday party environment with music and graphic elements thinking that this environment can be uncomfortable to the hyperacusis, encouraging the player not to avoid it.

E5 - Psychoeducation. We created textual documentation about the game Sêntimus and the treatment inserted in the game such as Sound Exposure Gradually, Audiological Measures among others. We still plan to create audiovisual material on the treatment, for the user's understanding.

E6 - General Mental Abilities. The interaction is simple: a game for popping balloons with concrete elements of a typical birthday party with cake, balloons, music, conversation and unpredictable sounds.

E7 - Communication. The game mechanics occur by experience, direct manipulation, trial, and error. To improve the navigation through the game we used MOLIC [35], an interaction model based on communication among de-

[2] all musical rights reserved for Pharrell Williams.
[3] all rights reserved to Illumination Entertainment.

signer and user through the interface.

E8 - Coordination. The interaction is simple: press the balloon. We created a customization screen that allows the user to change (increase or decrease) the velocity of the balloons trajectory. This configuration can help users touch (and pop) the balloons, according to their coordination needs.

E9 - Learning. In Level 1 we built the game mechanic for the player to learn to gameplay in progress, gradually between phases. The interaction is based on trial and error and individual data storage of the player. Each level has a time limit, changing the level of the game when it ends. Everyday objects are presented in the game, such as ballons and cake.

E10 - Attention. We created the graphic art with real characters mixed with 2D characters to call the attention of the player. In each level there are characters to present an attractive game, there always is some unexpected movement in the screen. The configurations screen can modify the time limit of each level or of the game. If the player does not interact for 20 seconds (does not touch the screen), a message of inactivity appears. We built the game in 4 stages to give dynamism to the game.

E11 - Social Interaction. The storage system stores the following data: login, date, time of login, time of logout, number of phase played, total time of the phase played, number of balloons generated in the phase, number balloons popped in the phase, number of characters in the phase, maximum intensity reached in the phase, punctuation in the phase, click position and timestamp of the popped balloons.

E12 - Specifiers. Loureiro [36] highlights that children with mild severity Level 1 and Level 2 Neurodevelopmental Disorders show on average 2 to 3 delay years when compared of the typical children. We defined the users for this system as children diagnosed with Hypersensitivity to Sounds associated with Neurodevelopmental Disorders, with mild or moderate levels of both diseases. We understand that each user may have different special needs, and thus, created a configurations screen. The settings that can be customized are: the speed of appearance of the balloon; the time interval in which the balloons appear; the total time of each levels; the volume of the noise model, the volume of the background music; the percentage of sound intensity for each popped balloon, and the interval of creation of the characters.

6. CONCLUSION

In this paper we have investigated how treatment principles and symptoms for Hypersensitivity to Sounds, Neurodevelopmental Disorders can be taken into account in the design of a game aimed at children with mild or moderate levels of both diseases. As a result we have organized the relevant principles, symptoms and associated recommendations, as well as proposed strategies of how to make considerations in game design that can be associated to them. We have presented Sêntimus, a musical game that illustrates how the strategies have guided design decisions. Although we have associated each strategy to a single principle, we have noticed that strategies may be associated to more than one principle, especially those of Neurodevelopmental Disorders, due to comorbidity [4]. For instance, strategy S10 associated to Attention can collaborate with strategy S9 associated to Learning. The future steps in our research involve evaluating Sêntimus with hyperacusis children as part of musictherapy session. We also intend to further evaluate Sêntimus and the strategies proposed. Interesting future directions include analyzing different relations between the strategies and principles, as well as to analyze strategies S5 e S9 according to Coutinho's classification of sound signs and define how different sound signs could be used in different contexts or as part of an increasing exposure to sound.

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