# Representing Sentiment Using Colors and Particles to Provide Accessibility for Deaf and Hard of Hearing Players

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***Abstract*—Providing game accessibility to deaf or hard of hearing players is still an issue in the game industry. The most common access feature developed to provide accessibility for players with this type of disability is to implement closed captions and other textual information to detail sentiments. This paper presents another approach to this problem. Based on the study of colors, this work uses the particle system provided by Unity engine and combines these elements into different scenarios where colorful particles propagate in different directions and with different speeds and forms. This paper proposes that these scenarios can express different sentiments. The proposal evaluation was performed through user interviews. The results present a set of scenarios that can be used by game designers to visually express the intended sentiment of the music or game environment sounds and a Unity plugin that support this task.**

***Keywords- accessibility, deaf, hard of hearing, game component***

## I. INTRODUCTION

Even having large audience, most games lack the customization options or configurations that make them more adaptive and competitive for people with some kind of physical disability. The same game can present different challenges (difficulties of being played) based on the type of deficiency that the player has. This is explored in the research done by Coutinho [1]. One of the points of his research is the degree of acceptance of certain categories of the most popular games by the public that has some kind of hearing impairment. In this scenario, the style mostly rejected by the hearing impaired was the genre of first person shooter (FPS) and the most accepted was the platform genre [1], [2]. This is due to the fact that in FPS games the steps and some actions that the player performs produce sounds that can be heard by other players and such sounds can be used in strategies such as to discover the position of the enemy, for example. This can make the understanding of what happens in the game more difficult for those who do not have complete information (absence of sounds).

In addition to sound effects such as step sounds or the sound of a door opening, electronic games also make use of music in their settings. These songs have another purpose; they serve to "transport" the player into the story (which is often referred to as magic circle [3] in the game industry). For example, a game of terror always tries to maintain the atmosphere of suspense making use of "suspense" songs. Another purpose that songs can have in games is to prepare the player for a situation that is about to happen. For example, in Skyrim, a medieval-themed game, there are various dangers like dragons, giants and other creatures. In this game, when a creature is preparing to attack, the game changes the music to indicate that the player has entered battle mode and this song is often perceived even before the danger is sighted [4]. Not being able to hear the song clearly represents a competitive disadvantage to deaf players, which only perceive the danger much later than other players.

Focusing on accessibility in games for the hearing impaired and, more precisely, the musical part of games, this work proposal is to make ways of visually transmitting the sensation that music causes to the player available to game developers. To represent this information visually, particles effects were used. Effects such as explosions, smoke, rain, snow, wind, leaves or water bubbles can benefit from the use of particles. These may consist of innumerous small 2D images or 3D models subject to physics engine action or collision and other effects [5].

The movement of these particles, combined with colors, was used to represent different sentiment (the word “sentiment” is preferred over “feeling” to differentiate psychological sentiments from physical sensations). These combinations of particle configurations are available through a plugin developed using the Unity3D gaming engine.

It is important to emphasize that it is not within the scope of the work the automatic recognition of the sentiment that the sound represents, being the task of those who designed the sounds to choose the desired sentiment and configure the component properly. This paper also doesn’t intend (negative scope) to provide a definitive answer for how every user associate colors and particles with sentiment. These associations can change based on culture, for instance and they are not part of the study. Other aspects of Human Computing Interaction (HCI) as

communicability or usability are also part of the negative scope. It is a decision of the game design when (as representation of background music or a singular music effect) and where (in game or HUD) to apply the results of this work. This is a paper about a plugin to support game development and the research made to evaluate the software decision.

## II. RELATED WORK

To the best of the authors' knowledge, only one previous work is related to this. It is detailed next.

The work of Coutinho [1] surveys the opinion of people with some degree of hearing impairment regarding digital games. It also identifies problems related to accessibility in games in the eyes of a hearing impaired person and proposes an approach to solve the problem of accessibility through synesthesia and the use of particles.

A questionnaire was applied with the objective of identifying the number of deaf people who used to play or who had already played digital games, as well as the genre of games that they used to have more or less affinity with. The study found that 61% of respondents said they had played or were still playing digital games. Regarding the game genre, the work showed that the most appreciated were platform and puzzle, while the less appreciated were FPS and fighting games as shown in Figure 1.

In order to provide a solution, a concept of artistic synesthesia was used. Coutinho's proposal [1] was to present the sounds through visual metaphors. However, not all sounds were "converted" into visual metaphors, because according to the author, too much information would hinder the distinction of the signals. Therefore, only the sound effects were translated (sound of footsteps, the sound of a shot and the sound of a bullet hitting an obstacle). Also according to the author, this information is more important for the FPS genre. To simulate the sound, he had made use of particles. Each sound that one wanted to represent had been formed by a set of particles with tails that moved in a concentrated form and after some time moved away and dissipated. Figure 2 visually illustrates the life cycle of these particles, starting in condensed particles (a), then moving (b), dissipating (c) and disappearing (d).

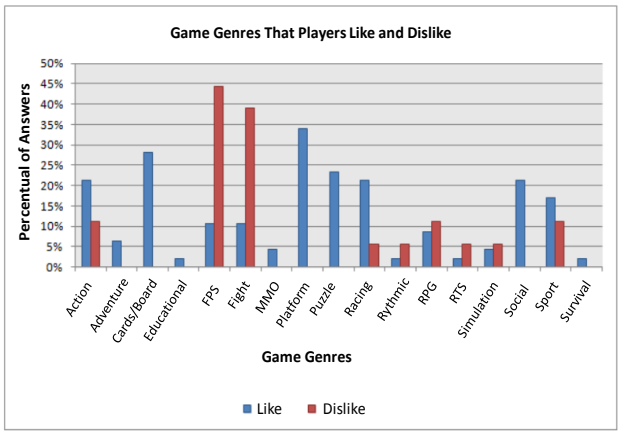


Figure 1. What games do you like to play? [1].

The particles could have had the following attributes configured: color, size, the time they appeared and speed of movement.

This work was based on the same idea of using particles but, unlike Coutinho's work, special attention was paid to colors in the creation of particles to help express sentiments or emotional feelings. It also proposes the use of different forms of representing particles and also presents some differences in the configuration of the particles.

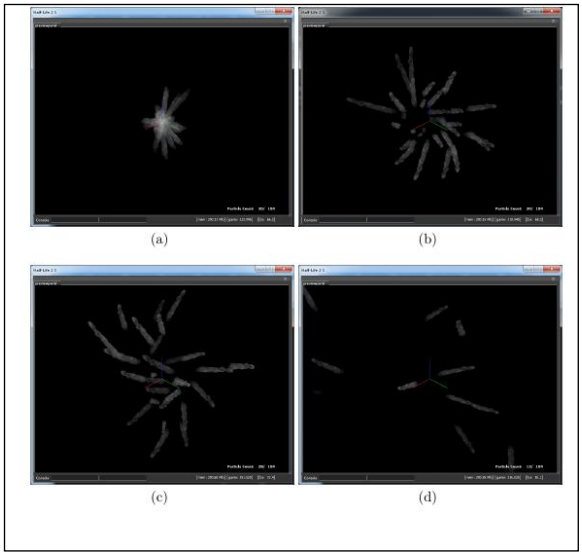


Figure 2. Simulation of sound using particles [1]

Another difference between the works is in which type of information one wishes to represent visually. While the work of Coutinho focuses on more strategic items, this work focuses on the representation of the sentiments that are passed through music to the players. This representation is made available through a plugin for Unity3D that can be used by game designers and developers as an option to provide accessibility to sounds and music in their games.

## III. HEARING DEFICIENCY

Different than what many people think, a person with hearing impairment does not necessarily mean that they are completely deaf. A person may acquire hearing impairment at birth or at any stage in life. Brazilian decree No. 5296 of 2004 [6] characterized hearing loss as: "partial or total bilateral loss of forty-one decibels (dB) or more, measured by audiogram at frequencies of 500Hz, 1,000Hz, 2,000Hz and 3,000Hz ".

The table of values that establishes degrees of hearing loss was created by the ANSI (American National Standards Institute) in 1969. People who have a hearing loss of up to 25 dB are considered normal. People with losses between 25 dB and 40 dB are mildly deaf and, by the Brazilian law, these people are not considered hearing impaired. People with losses greater than 40 dB are considered hearing impaired. Hearing impairment can also be classified into different levels: moderate deafness between 41 dB and 55 dB, intense deafness between 56 dB and 60 dB, severe deafness between 71 dB and 90 dB, profound deafness for those who have hearing losses above 90 dB) and anacusis in case of total loss of hearing [7], [8], [9].

In addition to the degree of hearing loss, there are also classifications of types of hearing loss. Unlike the degree, which is primarily concerned with the impact of hearing loss, the classification of types of hearing loss is linked to the cause or characteristic of hearing loss. They can be:

• Conductive hearing loss – Occurs when there is interference in the transmission of sound from the outer ear to the inner ear. It can be due to an infection in the auditory channels, some problem in the bones of the inner ear that prevent it from vibrating correctly, or other causes [7].

• Sensorineural hearing loss - The ears have nerve cells called the hair cells of the cochlea. These cells are like cilium and some of these cilia are lost as we age, making hearing a little harder, but exposure to loud noises for a long time and some diseases, such as mumps and meningitis, also contribute to the loss of these cilia [10].

• Mixed hearing loss - This case occurs when a person has both conductive and sensory hearing loss [10].

• Neural Hearing Loss - This type of hearing loss specifically affects the auditory nerve. It is perceived in the difficulty of understanding the sound information and occurs due to a change in the information processing mechanism in the brainstem, that is, it involves the Central Nervous System [10].

This work aims to provide accessibility for the hearing impaired, regardless of the type and level of hearing loss, since it focuses exclusively on the visual representation of music in digital games.

## IV. ACCESSIBILITY

The term accessibility was first used in the 1940s. At that time, accessibility was thought to be related only to the access of disabled people to urban buildings and public transportation. Over the decades, the concept evolved and the term has expanded to other areas such as web accessibility or game accessibility [10]. "Accessibility is a paradigm of inclusion, it is understood that the barriers are more complex and go beyond the issue of mobility" [10].

Accessibility and social inclusion are closely related. The first seems to highlight how physical spaces are used, but it is actually a condition of possibility for the transposition of obstacles that represent barriers to the proper participation of people in the various spheres of social life, which is a basic condition for any process of social inclusion. It is presented in many dimensions, such as attitudinal, physical, technological, informational communicational, linguistic and pedagogical [11].

Turning the focus to game development, as the game interfaces are usually presented in a visual format, developers who want to provide accessibility in their games generally focus their efforts on developing solutions that address other types of disabilities such as visual and motor disabilities. The most common strategy used by game developers for the problem of accessibility for the hearing impaired is the use of closed captions [8]. However, this method presents two problems: the first is the difficulty of identifying the distance and the location of the sound (when such information is relevant for the game) and the second problem is the language itself, since the majority of people who were already born with hearing loss or acquired it in the first years of life (before literacy) did not have much contact with their native language.

This work focuses on attending as many people with visual impairments as possible without the need for content adaptation or adaptation for a specific type of disability.

## V. UNITY3D AND ITS PARTICLE SYSTEM

Unity3D is a very popular game engine. From its launch until the third quarter of 2016, 5 billion games were downloaded using Unity3D. From these, 2.4 billion were unique to mobile devices. This popularity comes from a number of factors, including ease of use, a well-organized documentation (many examples and official tutorials), an active community (with many examples, tutorials and resources produced) and the most important point, it has a free license (available for both game development enthusiasts and small businesses) that guarantees access to all essential features for game development.

Unity3D has many features and it is not in the scope of this work to provide some tutorial on using this engine. Only the contents of the particle system will be discussed.

### *A. The Particle System*

In addition to components that control objects' mechanical physics, scene cameras, light and audio, Unity3D has a component category called effects. In this category of components, there is the Particle System component that is responsible for rendering particles in the game scenario. In a game, particles can be used for various types of elements, such as gases, sparks, smoke, bubbles and water [5].

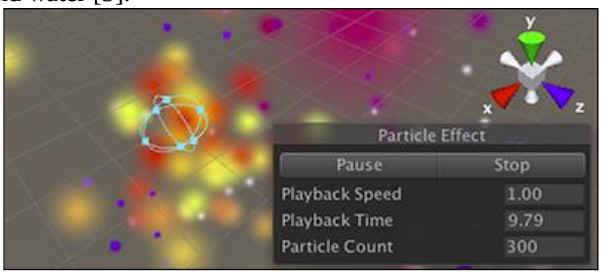


Figure 3. Configuration parameters for the particle system component in Unity3D.

The Particle System component is very complex and has many parameters that can be configured (see Figure 3), but only the important parameters for the development of the plugin developed in this work will be detailed next.

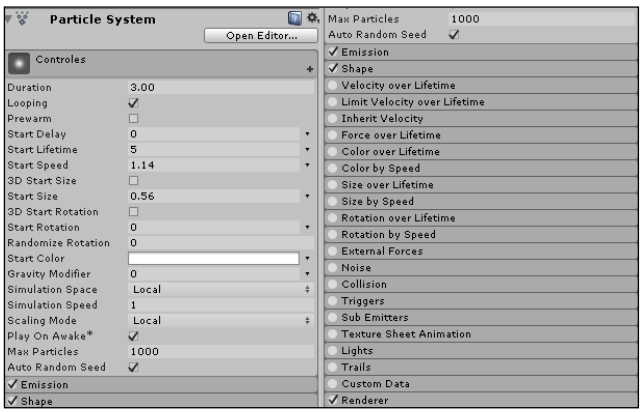


Figure 4. Visual representation of particles in Unity3D.

Figure 4 presents the configuration interface of a Particle System component. The fields that were used to develop the plugin were: Duration, Start Speed, Start Color, Shape, Emission and Limit Velocity Over Lifetime.

- • The Duration attribute controls the life time of the particle, how long it lasts on the screen.
- • Start Speed controls the speed of the particle when it is created.
- • Start Color sets the color of the particle at the time it is created. This color can be altered during the life span of the particle.
- • The Shape is related to the shape in which the particles will propagate. Among several options, the main shapes are conical, spherical and circular.
- • The Emission indicates the particle creation rate, i.e., the number of particles that will be created per second during the life span of the effect.
- • Limit Velocity Over Lifetime controls the reduction of particle velocity as it reaches the end of its life span.

## VI. PLUGIN DEVELOPMENT

The main objective of this work was to develop a plugin to support the game developer in providing accessibility to music for the hearing impaired. The main difference of this work from the state-of-the-art is to combine the studies that map the colors with sentiments and the use of different types of particles to create standard configurations that visually establish the sentiments present in the songs and sounds used by developers in their games. Thus, to achieve this objective, the work proposed a set of scenarios that combine particles of different formats and emission velocities with colors that were classified by users according to the sentiments that these scenarios provoked.

After being classified, the scenarios that could be mapped by most respondents were inserted into the final version of the plugin. Scenarios with inconclusive results (no sentiment was significantly more cited than others) were discarded. Thus, the following sections present the prototype defined for the test of the scenarios, as well as the definition of the scenarios themselves.

### A. *Prototype Creation*

The development of both the evaluation scenarios and the plugin generated as a result of this work was based on 3 main characteristics: the colors, the format and the emission of the particles.

#### 1) *Colors*

The affective association of colors with sentiments defined in "The psychodynamics of colors in communication" [12] was taken as the basis for the selection of the colors of the scenarios proposed in this work. A summary of these results is shown in Table I.

The plugin developed uses the colors black, blue, cyan, green, gray, magenta, red, white and yellow, which are the standard colors for Unity3D (instead of orange, the plugin uses cyan and magenta). In order to avoid any confusion caused by the presence of a myriad of choices of the same color, only one tone of each color was chosen and that chosen tone was the default color tone in the Unity3D Engine for each color used.

TABLE I. ASSOCIATION OF COLORS TO SENTIMENTS [12]

| Color | Affective Association |
|---|---|
| White | Cleanliness, peace, purity, soul, divinity, order, infancy |
| Black | Sadness, misery, melancholy, anguish, pain, intrigue, renunciation |
| Gray | Senescence, wisdom, aforetime/past, sadness, annoyance |
| Red | Strength, energy, passion, vulgarity, courage, fury, violence, heat, action, aggressiveness |
| Yellow | Alert, jealousy, pride, selfishness, euphoria, originality, enlightenment, idealism |
| Green | Well-being, health, peace, youth, belief, courage, steadfastness, serenity, nature |
| Blue | Truth, affection, peace, warning, serenity, space, infinity, faithfulness, deep feeling |
| Orange | Temptation, pleasure, joy, energy, sense of humor, warning |

These colors were used in the scenarios and helped define the expected outcome for the scenario. It is important to emphasize that in the evaluation of the scenarios presented in the results, the color was not always the most important element to map the final sentiment perceived by the user. In some cases, the shape and the type of emission of the particles did influence in different types of results.

#### 2) *Shapes*

The shape represents the direction the particles will follow in space. Three formats were used: circular, spherical and conical. The configuration of the starting point of the particles and direction of the particles are also associated with the shape.

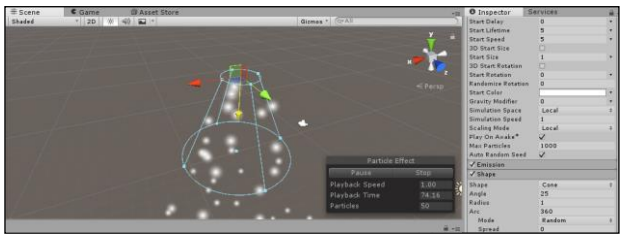

Figure 5. Representation of particle emissions in conical shape.

In the conical shape, the particles are created at the top of the scene and move towards the ground. This creates a visual sensation that is similar to rain or falling snow. The expected result when employing this shape is that it represents negative sentiments, which can be more intense when the particles are moving more slowly.

In the spherical shape, the particles start from the center of the screen and travel in all directions, similar to an explosion of fireworks. The initially expected result of this particle shape was that it represented positive or expansive sentiments, especially when the particles moved faster.

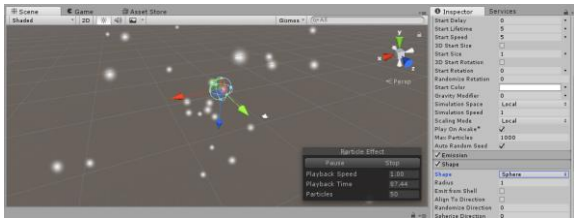

Figure 6. Representation of particle emissions in spherical shape.

The last shape is the circular one. In this shape, particles come from the bottom and propagate only on the

x and y axes (not in the z axis), the effect is similar to the movement of the water in a lake when a stone is thrown at it. This shape was expected to be used to represent calm and serene feelings, especially when used at low speeds.

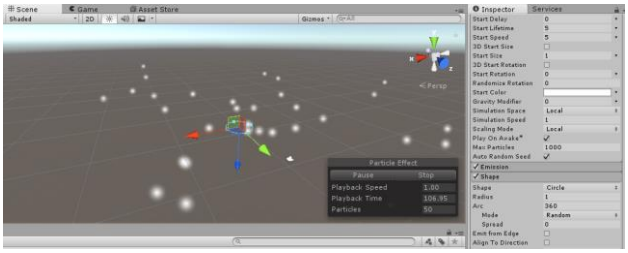

Figure 7. Representation of particle emissions in circula shape.

*3) Emission*

The emission is used to represent the speed at which the particles move and also the number of particles created. Four types of emission were created. In type 1, the emission form is constant and the particles move slowly. Type 2 is similar to type 1, changing only the speed at which particles move: in type 2 they move faster. Emissions of types 3 and 4 are also similar to each other due to the fact that the particles are created at the same time in the form of bursts. The only difference between these latter types is the velocity of the particles since in an emission of type 3 the particles move more slowly and in an emission of type 4, the particles move faster. These possibilities are shown in Table II.

TABLE II. TYPES OF EMISSION

| Emission | Burstiness | Speed |
|---|---|---|
| Type 1 | Constant | Slow |
| Type 2 | Constant | Fast |
| Type 3 | Bursty | Slow |
| Type 4 | Bursty | Fast |

## B. *Scenario Development*

In order to validate the use of particles associated with colors as a way to represent sentiments, a prototype application was developed with several proposed test scenarios. The application implemented used a very simple scenario since the intention was the evaluation of the sentiment information transmitted only by the particle emission tested. The less influence the scenario or other parts of the application interface had on the user, the more the result could be attributed to the selection of particle emission. The environment consisted of a static 3D character with an expressionless face, a green soil (to represent grass) and a simple sky. The scenario did not play any sounds so that it did not obfuscate the sentiment representation proposed by the scenario or the effects applied to the scenario.

Figure 8 presents the scenario of our simulator, as previously described. It also contains a set of 20 buttons just above the character's head. These buttons can be used to change from a scenario to another one. The only thing that changes between a scenario and another one is the configuration of the particles (emission type, shape and color), whereas the rest of the elements (character, sky, floor and buttons) remain unaltered. Following, Table III presents a summary for each of the 20 scenarios along with the expected sentiment result for each particle emission configuration used.

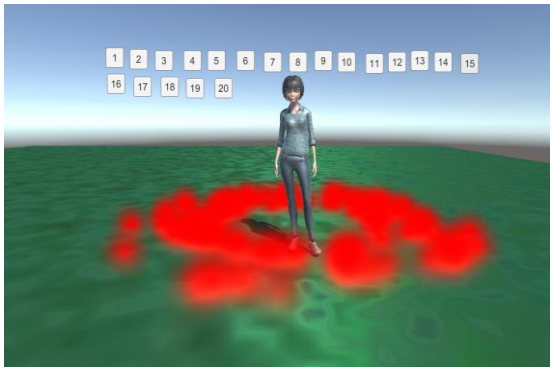


Figure 8. Testing application with 20 scenarios.

TABLE III. SCENARIOS CONFIGURATION

| Name | Configuration | Expectancy |
|---|---|---|
| Scenario 1 | Color = Gray<br>Shape = Conical<br>Emission = Type_1 | Sadness |
| Scenario 2 | Color = Red<br>Shape = Spherical<br>Emission = Type_4 | Rage |
| Scenario 3 | Color = White<br>Shape = Conical<br>Emission = Type_2 | Joy |
| Scenario 4 | Color = Green<br>Shape = Spherical<br>Emission = Type_4 | Joy |
| Scenario 5 | Color = Yellow<br>Shape = Circular<br>Emission = Type_1 | Courage |
| Scenario 6 | Color = Black<br>Shape = Conical<br>Emission = Type_2 | Panic |
| Scenario 7 | Color = Blue<br>Shape = Spherical<br>Emission = Type_2 | Courage |
| Scenario 8 | Color = White<br>Shape = Circular<br>Emission = Type_4 | Peace |
| Scenario 9 | Color = Red<br>Shape = Circular<br>Emission = Type_1 | Pain |
| Scenario 10 | Color = Green<br>Shape = Spherical<br>Emission = Type_2 | Joy |
| Scenario 11 | Color = Blue<br>Shape = Circular<br>Emission = Type_3 | Calmness |
| Scenario 12 | Color Black<br>Shape = Conical<br>Emission = Type_1 | Fear |
| Scenario 13 | Color = Gray<br>Shape = Spherical<br>Emission = Type_1 | Sadness |
| Scenario 14 | Color = White<br>Shape = Circular<br>Emission =Tipo_2 | Courage |
| Scenario 15 | Color = Red<br>Shape = Circular<br>Emission = Type_3 | Amor |
| Scenario 16 | Color =Green<br>Shape = Circular<br>Emission = Type_4 | Love |
| Scenario 17 | Color = Blue<br>Shape = Conical | Calmness |

| | | |
|---|---|---|
| | Emission = Type_1 | |
| Scenario 18 | Color = Yellow<br>Shape = Circular<br>Emission = Type_2 | Courage |
| Scenario 19 | Color =Yellow<br>Shape = Circular<br>Emission = Type_3 | Calmness |
| Scenario 20 | Color = Blue<br>Shape = Spherical<br>Emission = Type_4 | Joy |

### *C. Interview*

The data gathering in these experiments was performed through interviews with the participation of undergraduate students from Federal University of Ceará. These students did not have any hearing or visual impairment. The interviews took place during the first week of June 2016. The demonstrations of the scenarios were carried out with groups of up to 5 people and were attended by a total of 40 individuals. Each student answered a single questionnaire, separately (without talking to other students between watching the demonstration and answering the questionnaire).

The interview was divided into three parts. The first part was the explanation of the project. It was explained for the interviewees that this project was aimed at the hearing impaired. It was also clarified to the students that the project proposal was to stimulate sentiments in a visual form by making use of particles in a game scenario.

In the second part of the interview, the twenty scenarios were displayed and the interviewees were asked about which sentiment they associated for each scenario. It was explained to them that if they did not feel any psychological stimulus or the sentiment information was not very clear they could respond that the scenario does not represent any sentiments. The interview subjects could not talk to each other during the second part of the interview.

After this second stage, the interviewees were already familiar with the particles. In the third part, the operation of the plugin parameters was explained. These parameters are the selection of the values of three field: one that represents the color, another one that represents the shape and a third one that represents the type of emission. After this explanation, the interviewees were instructed to configure the component to represent, in their view, each of three sentiments: anger, joy and sadness. At this point, the interviewees were free to test different types of configurations until they found the configuration that they considered most appropriate for the representation of each of the three sentiments. After this final step for each interviewee, there were sentiments that were associated with the 20 scenarios shown and 3 plugin settings that were related to representing the sentiments of anger, joy and sadness.

### *D. Data Analisys*

Since the answers to the first part of the questionnaire were given openly (i.e., not selected from a list, which means the interviewees could write anything they wanted), a large number of different responses were presented. In total, 72 different sentiments were listed in the questionnaire by the interviewees over the 20 evaluated scenarios.

These 72 different sentiments were grouped into 11 main categories. The categories were: love, joy, calmness, courage, doubt, freedom, fear, anger, sadness, nothing and not applicable (N/A). The category 'nothing' was reserved for when the interviewees felt no psychological stimulus from the scenario or could not describe the sentiment. Also, the category 'not applicable' represents the sentiments that could not be classified in one of the already existing categories and that had a very low representativeness in the results. Table IV illustrates the clustering of sentiments into categories.

TABLE IV. SENTIMENT CLUSTERING INTO CATEGORIES

| Category | Sentiment |
|---|---|
| Love | Friendship, love, engagement, passion |
| Joy | Joy, enthusiasm, euphoria, excitement, happiness, satisfaction, surprise |
| Calmness | Relief, calmness, peace, laziness, purification, reflection, safety, tranquility |
| Courage | Bravery, confidence, courage, determination, empowerment, hope, strength, initiative, struggle, perseverance, power, victory |
| Doubt | Anxiety, confusion, doubt, uncertainty, indifference |
| Freedom | Freedom |
| Fear | Agony, anguish, despair, escape, fear, death, nervousness, disgust, panic, danger, suffocation, tension, terror |
| Anger | Antipathy, rage, hatred, anger |
| Sadness | Fatigue, guilt, depression, discouragement, discomfort, disillusionment, pain, coldness, madness, hurt, pessimism, suffering, sadness |
| Nothing | Nothing (response given when the interviewee did not perceive any psychological sentiment or could not describe it) |
| Not applicable | Agitation, pride, shyness |

## VII. RESULTS

By grouping the results, we have 11 main categories of sentiments. In order to indicate that a sentiment category was chosen to represent a specific scenario, the most voted category for that scenario should have at least 4 votes of difference over the second place.

TABLE V. MOST CHOSEN SENTIMENT

| Sentiment | Scenario | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** |
| Love | 0 | 14 | 0 | 0 | 0 | 0 | 2 | 0 | 6 | 1 | 0 | 0 | 0 | 0 | 6 | 1 | 0 | 1 | 0 | 0 |
| Joy | 1 | 10 | **14** | 7 | 1 | 3 | 7 | 4 | 1 | **22** | 0 | 1 | 1 | **15** | 0 | 8 | 5 | 13 | 2 | 15 |
| Calmness | 3 | 0 | 3 | 1 | 3 | 0 | **12** | 8 | 0 | 0 | 9 | 0 | 5 | 2 | 0 | 2 | 9 | 0 | 1 | 0 |
| Courage | 0 | 3 | 12 | **17** | 8 | 1 | 5 | **14** | 3 | 11 | 4 | 0 | 2 | **14** | 3 | **18** | 5 | **14** | **10** | **14** |
| Doubt | 3 | 0 | 3 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 2 | 4 | 1 | 0 | 0 | 2 | 1 | 0 | 1 |
| Freedom | 0 | 0 | 3 | 8 | 0 | 0 | 2 | 9 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 6 | 0 | 1 | 1 | 2 |
| Fear | 11 | 3 | 1 | 1 | 7 | **23** | 1 | 0 | 9 | 0 | 7 | 24 | 6 | 2 | 5 | 0 | 1 | 4 | 7 | 0 |
| Anger | 1 | 6 | 1 | 0 | 0 | 8 | 0 | 0 | 2 | 0 | 0 | 4 | 2 | 1 | 7 | 0 | 0 | 1 | 0 | 2 |
| Sadness | **18** | 3 | 0 | 1 | **10** | 5 | 1 | 1 | **14** | 0 | **13** | 9 | **10** | 0 | **14** | 0 | 8 | 0 | 9 | 1 |
| Nothing | 2 | 1 | 3 | 5 | **10** | 0 | 9 | 3 | 4 | 4 | 7 | 0 | **10** | 0 | 5 | 4 | 10 | 4 | **10** | 5 |
| N/A | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 1 | 0 | 0 |

For cases in which a category did not have at least 4 votes of advantage, the result was considered inconclusive. The scenarios that had the result different from inconclusive were added to the Plugin in a new setting category entitled 'Sentiment'. These ‘voting’ results are presented in Table V. The chosen sentiment for a scenario has its votes shown in bold typeface. Scenarios without any count shown in bold typeface are inconclusive.

Considering the opinion of the interviewees, each scenario was given a main sentiment category or the status of inconclusive. The expectancy along with the final result for each scenario is presented in Table VI.

TABLE VI. INTERVIEWEES EVALUATION RESULTS

| Name | Expectancy | Result |
|---|---|---|
| Scenario 1 | Sadness | Sadness |
| Scenario 2 | Anger | Love |
| Scenario 3 | Joy | Inconclusive |
| Scenario 4 | Joy | Courage |
| Scenario 5 | Courage | Inconclusive |
| Scenario 6 | Panic | Fear |
| Scenario 7 | Courage | Inconclusive |
| Scenario 8 | Peace | Courage |
| Scenario 9 | Pain | Sadness |
| Scenario 10 | Joy | Joy |
| Scenario 11 | Calmness | Sadness |
| Scenario 12 | Fear | Fear |
| Scenario 13 | Sadness | Inconclusive |
| Scenario 14 | Courage | Inconclusive |
| Scenario 15 | Love | Sadness |
| Scenario 16 | Joy | Courage |
| Scenario 17 | Calmness | Inconclusive |
| Scenario 18 | Courage | Inconclusive |
| Scenario 19 | Calmness | Inconclusive |
| Scenario 20 | Joy | Inconclusive |

Figure 9 shows the count for each sentiment category represented. It is clear that many of the scenarios (9) were considered inconclusive.This happened because the users were free to choose the sentiment that the scenario represented and it was not possible to define a predominant sentiment for all scenarios. In this case, the scenario has been removed from the final version of the plugin. The results for the other scenarios are analyzed next.

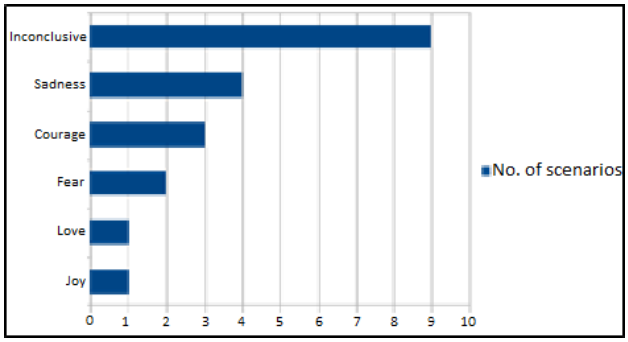


Figure 9. Number of scenarios associated with each sentiment category.

## A. *Result Analysis for Scenario Identification*

The results were grouped by sentiment category for the analysis. Some categories are not shown since they were not selected as the predominant sentiment in any scenario.

### *1) Sadness*

The scenarios that represented sadness were 1, 9, 11 and 15, as already presented in Table 6. Table 7 details the configuration of the scenarios, the expectancy when the scenario was proposed and the results. The results indicated that for this sentiment the respondents took more into account the emission and the format, since Table 7 shows that there were emissions of the Type 1 (2 scenarios) and Type 3 (2 scenarios) where both represent a slow particle propagation, shapes of the type Circular (3 scenarios) and Conical (1 scenario). The colors we had in these scenarios were gray (1 scenario), red (2 scenarios) and blue (1 scenario). Following the affective association of chromatic colors described in Table 1, of these three colors only gray was associated with sadness, while red color was associated with passion, pain and courage, among others, and blue was associated with peace and faithfulness, among others. This result perfectly illustrates the focus of this work since the color choice represents only part of the result and its interpretation can be altered based on the other two fields used to represent particles, which are the shape and type of emission.

As Table VII shows, three of the four cases had different expectation results (it is worth noting that pain is a sentiment in the sadness category). When scenarios 9, 11 and 15 were developed, the results were expected to have a greater influence of colors. However, the result obtained in these cases had little influence of the colors and more influence of the shape and the type of emission of the particles.

TABLE VII. TABLE 7. COMPARISON OF THE EVALUATION SCENARIOS THAT WERE POINTED AS SADNESS

| Name | Configuration | Expectancy | Result |
|---|---|---|---|
| Scenario 1 | Color = Gray<br>Shape = Conical<br>Emission = Type_1 | Sadness | Sadness |
| Scenario 9 | Color = Red<br>Shape = Circular<br>Emission = Type_1 | Pain | Sadness |
| Scenario 11 | Color = Blue<br>Shape = Circular<br>Emission = Type_3 | Calmness | Sadness |
| Scenario 15 | Color = Red<br>Shape = Circular<br>Emission = Type_3 | Love | Sadness |

### *2) Love*

The only scenario that resulted in the Love sentiment was scenario 2. This scenario had red as color, sphere as shape and type 4 emissions. Visually, it is similar to a burst of red fireworks. The color fits into the associations described in Table I for the sentiment of Passion.

We expected the sentiment related to Scenario 2 to be the anger for the fact that it uses the red color and a more explosive type of emission.

TABLE VIII. THE EVALUATION SCENARIO THAT WAS POINTED AS LOVE

| Name | Configuration | Expectancy | Result |
|---|---|---|---|
| Scenario 2 | Color = Red<br>Shape = Spherical<br>Emission = Type_4 | Anger | Love |

### *3) Courage*

Scenarios 4, 8 and 16 had the courage as a result. All 3 scenarios had the type 4 emission that represents an emission of explosive form, which indicates that this was a determining factor for the classification of these scenarios into the courage sentiment category. The shapes were spherical (1 scenario) and Circular (2 scenarios) and the colors configured in these scenarios were green (2 scenarios) and white (1 scenario). While green fits into the association we took as the basis to construct the scenarios,

white did not really fit, since it was considered related to peace and purity (see Table I).

TABLE IX. COMPARISON OF THE EVALUATION SCENARIOS THAT WERE POINTED AS COURAGE

| Name | Configuration | Expectancy | Result |
|---|---|---|---|
| Scenario 4 | Color = Green<br>Shape = Spherical<br>Emission = Type_4 | Joy | Courage |
| Scenario 8 | Color = White<br>Shape = Circular<br>Emission = Type_4 | Peace | Courage |
| Scenario 16 | Color = Green<br>Shape = Circular<br>Emission = Type_4 | Joy | Courage |

*4) Fear*

Scenarios that had fear as a result were scenarios 6 and 12. Both had the black color and the conical shape, but differed in the emissions, with types 1 and 2. Although Table 1 (affective association) did not associate fear itself with any color, we can identify that the color and the shape were important to obtain this result, since both scenarios had these two attributes with equal values.

As shown in table X, the expectations for these scenarios were similar to the interview results (the panic sentiment belongs to the fear sentiment category).

TABLE X. COMPARISON OF THE EVALUATION SCENARIOS THAT WERE POINTED AS FEAR

| Name | Configuration | Expectancy | Result |
|---|---|---|---|
| Scenario 6 | Color = Black<br>Shape = Conical<br>Emission = Type_2 | Panic | Fear |
| Scenario 12 | Color = Black<br>Shape = Conical<br>Emission = Type_1 | Fear | Fear |

*5) Joy*

The only scenario that had the sentiment of joy as a result was scenario 10. This scenario used the green color, the spherical shape and its emissions were of type 2. As can be seen in table XI, the result obtained was consistent with the expectancy for the scenario.

TABLE XI. COMPARISON OF THE EVALUATION SCENARIOS THAT WERE POINTED AS JOY

| Name | Configuration | Expectancy | Result |
|---|---|---|---|
| Scenario 10 | Color = Green<br>Shape = Spherical<br>Emission = Type_2 | Joy | Joy |

*6) Inconclusive*

In 9 scenarios evaluated, the sentiment analysis performed could not select a main sentiment represented by the particle emission shown, which resulted in inconclusive results. We believe that by not restraining the options of sentiments that the interviewee could cite in the answers contributed to a greater appearance of inconclusive results. The number of categories in which sentiments were separated also contributes to a large number of inconclusive results, since fewer categories could aggregate more answers.

In scenarios 3, 14, 18 and 20, the categories of joy and courage were the ones that had the most votes in relation to the other feelings, but, with respect to each other, the results were very similar and, if these groups of feelings were grouped in the same category, some of the inconclusive results would converge on this new category created (joy and courage). This could have been done based on the idea that both categories represent positive sentiments and in some cases, the interviewees were divided between these two categories at the time of classification (which was mentioned after the classification). However, the authors found relevant to the result that these two groups were separated to preserve the richness of responses and the freedom of definition given to the interviewees. These four inconclusive scenarios are shown in Table XII.

TABLE XII. INCONCLUSIVE SCENARIOS FOR JOY AND COURAGE

| Name | Configuration | Expectancy | Result |
|---|---|---|---|
| Scenario 3 | Color = White<br>Shape = Conical<br>Emission = Type_2 | Joy | Inconclusive |
| Scenario 14 | Color = White<br>Shape = Circular<br>Emission = Type_2 | Courage | Inconclusive |
| Scenario 18 | Color = Yellow<br>Shape = Circular<br>Emission = Type_2 | Courage | Inconclusive |
| Scenario 20 | Color = Blue<br>Shape = Spherical<br>Emission = Type_4 | Joy | Inconclusive |

Scenarios 5, 7, 13, 17 and 19 had a high count of the 'nothing' category which, as previously explained, is the response used when the interviewee did not feel any sentiment or did not know how to describe it. These are shown in Table XIII.

TABLE XIII. INCONCLUSIVE SCENARIOS WITH A HIGH COUNT OF 'NOTHING' IN THE RESULTS

| Name | Configuration | Expectancy | Result |
|---|---|---|---|
| Scenario 5 | Color = Yellow<br>Shape = Circular<br>Emission = Type_1 | Courage | Inconclusive |
| Scenario 7 | Color = Blue<br>Shape = Spherical<br>Emission = Type_2 | Courage | Inconclusive |
| Scenario 13 | Color = Gray<br>Shape = Spherical<br>Emission = Type_1 | Sadness | Inconclusive |
| Scenario 17 | Color = Blue<br>Shape = Conical<br>Emission = Type_1 | Calmness | Inconclusive |
| Scenario 19 | Color = Yellow<br>Shape = Circular<br>Emission = Type_3 | Calmness | Inconclusive |

Authors find it relevant to mention that all cases where the yellow color was used resulted in an inconclusive result. The use of the blue color also had similar results because it was applied in four different scenarios but only one resulted in sadness while the other three had as an inconclusive result.

### *B. Result Analysis for the Free Configuration of Sentiments*

After the results were grouped, we decided to do a separate, new interview to elect the best representation setting for each feeling based on the largest number of votes from the setup items. That is, the most chosen configuration for each feeling representation is composed

of the most chosen color followed by the most chosen format, followed by the most chosen type of emission. This stage involved 39 interviewees. All interviewees were undergraduate students from Federal University of Ceará. The chosen settings have been added to the plugin's sentiment setting option. An analysis of these results is presented next.

*1) Anger*

To represent anger, respondents basically used the black and red colors, but the red one took an advantage of approximately 10% on the total responses. As for the shape, the difference between the first and second was approximately 3% (of the total). On the particle emission, the difference was just over 5% between the top two. This shows that for the feeling of anger the color is more representative than the shapes and emissions used upon the particles. These counts are shown in Table XIV.

TABLE XIV. RESULTS OF THE FREE CONFIGURATION FOR JOY

| | **Color** | **Count** | **Result** |
|---|---|---|---|
| **Anger** | Black | 17 | Red |
| | Magenta | 1 | |
| | Red | 21 | |
| | **Shape** | **Count** | **Result** |
| | Circular | 6 | Spherical |
| | Conical | 16 | |
| | Spherical | 17 | |
| | **Emission** | **Count** | **Result** |
| | Type 1 | 5 | Type 2 |
| | Type 2 | 15 | |
| | Type 3 | 6 | |
| | Type 4 | 13 | |

*2) Joy*

The results for joy are presented in table XV. The colors most used to represent the joy were the white color, the most cited, and the green color. The difference between these two was just over 5% of the total responses. The most used format was the spherical, with 50% of difference from the second place, the conical. The type of emission most used was type 2 with approximately 22% of (the total) difference from the second place. This shows that for those interviewed the shape was more important to represent the feeling of joy than the color or the emission. Table XV shows these results.

TABLE XV. INCONCLUSIVE SCENARIOS WITH A HIGH COUNT OF 'NOTHING' IN THE RESULTS

| | **Color** | **Count** | **Result** |
|---|---|---|---|
| **Joy** | Blue | 5 | White |
| | Cyan | 2 | |
| | Green | 11 | |
| | Magenta | 1 | |
| | White | 13 | |
| | Yellow | 7 | |
| | **Shape** | **Count** | **Result** |
| | Circular | 1 | Spherical |
| | Conical | 9 | |
| | Spherical | 29 | |
| | **Emission** | **Count** | **Result** |
| | Type 1 | 2 | Type 2 |
| | Type 2 | 21 | |
| | Type 3 | 3 | |
| | Type 4 | 13 | |

*3) Sadness*

As shown in Table XVI, the most cited color for sadness was gray, with a 40% difference from the second place. The most chosen shape was the conical one, with 8% difference from the second in relation to the total of responses. The most chosen type of emission was type 1 with 28% difference from the second place. This shows that, for this sentiment, the color is more representative than the shape and emission. Since this setting is exactly the same as the scenario 1 setting, it is already part of the plugin and therefore this setting was not added a second time.

TABLE XVI. RESULTS OF THE FREE CONFIGURATION FOR SADNESS

| | **Color** | **Count** | **Result** |
|---|---|---|---|
| **Sadness** | Black | 10 | Gray |
| | Blue | 1 | |
| | Cyan | 1 | |
| | Gray | 26 | |
| | White | 1 | |
| | **Shape** | **Count** | **Result** |
| | Circular | 9 | Conical |
| | Conical | 21 | |
| | Spherical | 9 | |
| | **Emission** | **Count** | **Result** |
| | Type 1 | 24 | Type 1 |
| | Type 2 | 0 | |
| | Type 3 | 13 | |
| | Type 4 | 2 | |

All the results obtained were added to the plugin. These results are part of a new configuration item called "Sentiment" which contains the following configuration options: Off, Manual, Joy_1, Joy_2, Love_1, Courage_1, Courage_2, Courage_3, Fear_1, Fear_2, Anger_1, Sadness_1, Sadness_2, Sadness_3 and Sadness_4.

The off option serves to disable the sentiment particles. The manual option can be selected when the game developer wants to freely configure the colors, shapes and type of emissions of the plugin.

Table 17 details the configuration of each sentiment along with the source from which this configuration was taken (either the first or the second part of this evaluation). The final version of the plugin, as well as the scenarios used in the evaluation, can be found in a Github repository at: https://github.com/marcosepifanio/tcc-cenarios.

TABLE XVII. SENTIMENT CONFIGURATIONS ADDED TO THE PLUGIN

| **Name** | **Configuration** | **Expectancy** |
|---|---|---|
| Joy 1 | Color = Green<br>Shape = Spherical<br>Emission = Type_2 | Scenario 10 |
| Joy 2 | Color = White<br>Shape = Spherical<br>Emission = Type_2 | Most selected configuration |
| Love 1 | Color = Red<br>Shape = Spherical<br>Emission = Type_4 | Scenario 2 |
| Courage 1 | Color = Green<br>Shape = Spherical<br>Emission = Type_4 | Scenario 4 |
| Courage 2 | Color = White<br>Shape = Circular<br>Emission = Type_4 | Scenario 8 |
| Courage 3 | Color = Green | Scenario 16 |

| | | |
|---|---|---|
| | Shape = Circular<br>Emission = Type_4 | |
| Fear 1 | Color = Black<br>Shape = Conical<br>Emission = Type_2 | Scenario 6 |
| Fear 2 | Color = Black<br>Shape = Conical<br>Emission = Type_1 | Scenario 12 |
| Anger 1 | Color = Black<br>Shape = Conical<br>Emission = Type_1 | Most selected configuration |
| Sadness 1 | Color = Gray<br>Shape = Conical<br>Emission = Type_1 | Scenario 1 and also the most selected configuration |
| Sadness 2 | Color = Red<br>Shape = Circular<br>Emission = Type_1 | Scenario 9 |
| Sadness 3 | Color = Blue<br>Shape = Circular<br>Emission = Type_3 | Scenario 11 |
| Sadness 4 | Color = Red<br>Shape = Circular<br>Emission = Type_3 | Scenario 15 |

## VIII. CONCLUSION

The present work presents a new approach for the accessibility of musically-induced sentiments in digital games, focusing on the representation of sentiments through the visual presentation of moving particles. Particles are a feature often used in digital games, but it is not typically used to address the issue of accessibility.

The use of colors together with the movement of particles as a form of representation of sentiments showed that, even if there is a study that maps colors to feelings, this mapping is sometimes ignored by the game player when the movement to which this color is subject represents a different idea than what was mapped to it. In this study, the shape and type of emission also have a great deal of influence over some of the sentiments represented.

Some interesting research problems were identified as possible continuations of this work. The first of these future works is the addition of more colors and tones of the same color to represent the sentiments. This work can identify different perspectives of the same color, according to its tone. Another future work would be the option to change the particle size in the representations. With this option, the sentiment representation could work in multi-scale game scenarios, as well as assist the representation of multiple simultaneous sentiments in a game. Based on the first and second future work, a third would be the evaluation of new combinations of plugin configuration items. With this evaluation, it may be possible to identify other representations of feelings that could not be identified with the options used in this work. Finally, a fourth future work would be to add questions to the questionnaire so that we have more options to analyze the data, especially questions about the psychological profile and the state of mind of the interviewee before the interview starts.

It was not possible to find in Quixadá deaf players. The plugin should also be evaluated with hearing impaired or deaf players to improve results.

After the questionnaire was carried out with 40 people and the evaluation of the data, it was possible to represent 6 feelings in 13 different ways. That is, the sum of the probable configurations of sentiments yielded a total of 13 possible forms. All the resulting representations have been added to a Unity3D plugin that can be used by game developers to include accessibility to musically-induced sentiments for the hearing impaired players. All the scenarios used in both the evaluation and the final version of the plugin are available on Github.

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