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Soundwalk: Sound Design for Pervasive Application

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Resumo

Esta dissertação aborda a criação de um soundwalk com o objetivo de dar resposta aos desafios enfrentados por pais e filhos que lidam com o risco de cancro hereditário. Com conexão ao projecto "Play-The-Odds", esta aplicação destina-se a oferecer aos utilizadores uma experiência imersiva através de narrativas baseadas na localização onde haverá interação direta com o ambiente. Ao contrário das aplicações tradicionais de realidade aumentada que incorporam sobreposições visuais, este projeto dá ênfase ao aspeto auditivo, tirando partido do design de som.

Esta ferramenta visa envolver ambos os pais e filhos de uma forma lúdica, facilitando-lhes a compreensão de informações de saúde relacionadas com o risco de cancro hereditário, promovendo também uma comunicação aberta entre os membros da família.

O principal objetivo desta tese reside em design de som e criação de soundscape para uma experiência conhecida como soundwalk, com o propósito de enriquecer as experiências dos utilizadores em ambientes naturais através da incorporação de elementos sonoros de forma estratégica. Esta soundwalk foi também concebida para os participantes interagir com locais pacíficos, neste caso a natureza, e para serem vividos em locais de interesse específicos, estrategicamente escolhidos para melhorar a narrativa. O desenvolvimento de duas versões do soundwalk serve como ponto focal deste trabalho, uma versão tradicional, com som pré-composto, e uma versão generativa, em que o som é retirado da base de sons do Freesound e ativado em tempo real com base em variáveis contextuais. Estas versões foram posteriormente utilizadas para avaliar diferentes aspetos da experiência, tais como a qualidade percecionada da soundwalk e os impactos emocionais nos participantes.

Abstract

This dissertation addresses the creation of a soundwalk with the aim of responding to the challenges faced by parents and children dealing with the risk of hereditary cancer. Connected to the "Play-The-Odds" project, this application aims to offer users an immersive experience through location-based narratives where there will be direct interaction with the environment. Unlike traditional augmented reality applications that incorporate visual overlays, this project emphasises the auditory aspect, taking advantage of sound design.

This tool aims to engage both parents and children in a playful way, making it easier for them to understand health information related to the risk of hereditary cancer, while also promoting open communication between family members.

The main aim of this thesis is sound design and the creation of a soundscape for an experience known as a soundwalk, with the aim of enriching users' experiences in natural environments by incorporating sound elements strategically. This soundwalk was also designed for participants to interact with past locations, in this case nature, and to be experienced in specific places of interest, strategically chosen to enhance the narrative. The development of two versions of the soundwalk serves as the focal point of this works, a traditional version, with pre-composed sound, and a generative version, in which sound is taken from the Freesound soundbase and activated in real time based on contextual variables. These versions were later used to evaluate different aspects of the experience, such as the perceived quality of the soundwalk and its emotional impact on participants.

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Abbreviations and Symbols

HNPCC	Hereditary Nonpolyposis Colon Cancer
USA	United States of America
GPS	Global Positioning System
PSST	Product Sound Sketching Tool
IRCAM	Institut de Recherche et Coordination Acoustique/Musique
IAMR	Interactive Auditory Mediated Reality
AR	Augmented Reality
MATLAB	MATrix LABoratory
FSR	Force-Sensitive Resistors
EEG	Electroencephalogram
MFCC	Mel Frequency Cepstral Coefficients
BIC	Bayesian Information Criterion

1. Introduction

Within the domain of healthcare, effective communication and understanding of genetic risks play essential roles in allowing people and families to explore hereditary conditions such as cancer.

At the heart of this attempt lies a technology that holds immense potential to revolutionize how people interact with information and narratives in their physical environment. The proposed idea within this project is the creation a soundwalk with location generative sounds that provide a shift in attention that could change how we attend to the world.

This application serves a dual purpose: to educate users about their genetic predispositions and associated health risks, and to foster communication and understanding within families. By using music as a central tool to influence emotions and support emotional regulation, the app enhances users' motivation and engagement, creating a more meaningful and satisfying experience.

Central to the success of this activity is the design of soundscapes inside the application. These soundscapes will serve as the auditory background for the user's journey, enhancing immersion, and directing the narrative flow.

Through iterative research and development, the goal is to create diverse auditory experiences that not only engage users but also educate and empower them on their journey toward better health understanding and communication

In order to do this, two soundwalk experiences will be created: one utilizing a traditional linear method and another utilizing an interactive generative system created from internet sound libraries. This makes it possible to create versatile, location-responsive audio experiences anywhere. The goal is to examine these formats' emotional influence on users as well as their quality.

1.1 Context / Framing / Motivation

The ultimate objective of the project is to include true stories and personal experiences so that listeners can gain knowledge from others and feel emotionally connected to their own situations. This approach is especially relevant for individuals dealing with hereditary cancer, as it fosters empathy, awareness, and emotional support through shared narratives.

In order to achieve this goal, it was determined that the sound environment should remain calm and neutral, allowing for reflection without becoming overwhelming. The ambient soundscape subtly reinforces the emotional impact of each story thanks to the sound atmosphere's adaptability to various situations.

This experience in modern healthcare, effective communication and understanding of hereditary risks are vital, especially within the context of genetic conditions like cancer. The Play-The-Odds project develops as a response to the squeezing need for innovative tools to help people and families in navigating the complexities of genetic predispositions.

Making this dissertation in Master's in Multimedia, my goal with this is to incorporate this knowledge in my compositions, and production of music and sound design that I want to develop in the cinema, animation and video games industry.

1.2 Project

This project involves the development of a gamified tool inside the Play-The-Odds initiative, pointed at helping families facing hereditary cancer risks. Particularly, the project centers on designing an augmented reality (AR) application, leveraging sound design, to create immersive location-based narratives. The tool seeks to engage both parents and children in an interactive experience while addressing the serious health implications of hereditary cancer.

The activity that is going to incorporate all off this is a soundwalk, which will be analysed through two different versions to undergo evaluation to determine variations in user experience.

1.3 Problems, Hypothesis, and Research Objectives

The main challenge in this experiment lies in developing a location-based generative soundscape. Accurately generating context-sensitive audio using resources like the Freesound library presents technical and creative limitations. This makes it difficult to ensure that the soundscape aligns naturally with the user's environment and emotional experience.

Another significant difficulty is designing interactive narratives that successfully engage both parents and children while addressing sensitive subjects such as hereditary cancer risks. These narratives must balance emotional sensitivity with educational clarity, and selecting the most effective storytelling approach from multiple possibilities adds further complexity.

It is hypothesized that incorporating thoughtfully designed sound within an augmented reality (AR) application can significantly enhance user engagement and support open, meaningful communication among family members.

So, the objective of this study is to explore how sound design can be effectively integrated into an AR environment to improve user experience and facilitate better understanding of health-related information within a shared, interactive space.

1.4 Research Methodology

In this thesis the methodology begins by establishing a state-of-the-art foundation through a comprehensive review of existing research across several key areas. It first explores literature on genetic cancer, focusing on the implications of inherited predispositions and the psychological and social dimensions associated with genetic risk. Following this, it examines strategies for communicating sensitive health information within families, emphasizing the emotional and interpersonal challenges that arise in such contexts. The review then turns to technical concepts central to the project, including soundwalks, sound design, soundscapes, and the generation of location-based generative soundscapes. These frameworks provide critical insight into how sound can influence perception, emotion, and interaction within augmented environments. Finally, the state of art reviews related work at the intersection of AR, audio design, and health communication, highlighting gaps and opportunities to guide the research.

In the development phase, two different soundwalk versions were created: a Traditional linear version and a GPS-triggered version. These were evaluated using a structured questionnaire designed to assess participants' responses in terms of emotional impact, affective qualities, and perceived authenticity. This dual-version approach allowed for a comparative analysis of how different sound delivery methods influence users' emotional engagement and their perception of realism and coherence in the context of sensitive health-related storytelling.

1.5 Dissertation Structure

In addition to the introduction, this dissertation is structured into six further chapters. Across all chapters, it becomes evident that the core objective is to explore and develop the soundwalk as a medium for emotional engagement.

Chapter 2 describes the state of the art and presents related work. It covers genetic cancer communication and emotional wellness and examines how to communicate sensitive information throughout families. As part of this review, it is necessary to examine a more technical part, such as soundwalks and soundscape composition theory. The chapter also covers augmented reality, locative media, and sound design, along with pertinent case studies and current resources that guide the project's development.

To develop my first project, consisting of a traditional recreation of the route’s environment as a soundscape, and a GPS-triggered system, it was first necessary to study other similar works that could help the creation of the project. This includes conceptual frameworks such as Russell’s Circumplex Model of Emotion, which makes a deeper understanding of the emotional dimensions associated with sound. Additionally, this chapter presents the development process of both soundwalk versions and their unique tools.

Examining how each version influenced users’ perception, emotional engagement, and overall experience is the focus of the fourth section where the overall results are presented. The interpretation of these results is explored in depth in the “discussion” chapter.

The study's shortcomings are noted in the conclusion, which also offers suggestions for future research The dissertation is complemented by the bibliographical references section, which lists all the sources cited throughout the text.

2. State of Art

2.1 Background

This section will provide in-depth information and context on relevant topics such as genetic risk, pervasive applications in the healthcare industry, and family communication. The aim is to enhance the understanding of the work conducted in this thesis.

2.1.1 Genetic Cancer

The knowledge that cancer has a genetic component date back more than a century. This knowledge has been actively considered and significantly progressed in just the past few decades, significant progress has been made in understanding and elaborating the specific genetic factors that contribute to hereditary cancer susceptibility. Genetic mutations in certain genes can cause various diseases, in this case cancer, this is the result of abnormal functioning of genes, causing disorders such as uncontrolled cell growth and the inability of cells to repair themselves properly (Turnbull & Hodgson, 2005).

In modern times, genetic centers have historically had a broader focus but are now primarily concerned with assessing an individual's likelihood or probability of developing cancer. Hereditary factors contribute to about 10% of all cancer cases, two well-known examples of hereditary cancer syndromes are hereditary breast-ovarian cancer syndrome and hereditary nonpolyposis colon cancer (HNPCC). With that in mind, research studies have concentrated on studying families recognizing patterns and characteristics that may indicate a hereditary component to cancer within families, such as rare cancers accompanied by phenotypic abnormalities, different types of cancer running in the family or having an excess of a common type of cancer, manifesting particularly in the pediatric age group. Therefore, if a person has high-risk characteristics, it is recommended to identify family members at risk, this may include options such as conducting genetic testing to identify potential genetic factors and adopting risk reduction measures. In some cases, a combination of both approaches may be recommended to comprehensively understanding and management the identified risks (Turnbull & Hodgson, 2005); (Saletta et al., 2015).

The advent of genetic testing represents an important advance in cancer treatment, allowing for proactive approaches to surveillance and early intervention. This innovative technology has significantly reduced the average mortality rate for families affected by hereditary cancer, leading to improved outcomes and longer lives, but before a family member can undergo genetic testing, they must first receive counselling.

During these consultations, counsellors assess risk and identify individuals with a comprehensive understanding of their suitability for testing (Saletta et al., 2015). Through counselling, individuals gain a comprehensive understanding of their genetic condition and its associated risks. The primary goal of the consulting expert is to gain a deep understanding of the disease and provide strategies to manage the risk of disease outbreaks. At the same time, their goal is to provide this information without causing further problems such as anxiety, depression, or other cancer-related concerns (Braithwaite et al., 2004).

Providing clear and specific evidence related to an individual's likelihood of experiencing a particular health condition forms the basis of the effectiveness of genetic counselling, Simultaneously, the process of genetic counselling aims to improve the understanding of the genetic factors associated with this disease. This is achieved without any negative emotional impact on the person giving the advice. This emphasizes that it is important that individuals make decisions with clearly understand of the information provided and at the same time receive the appropriate support they need (Braithwaite et al., 2004). Despite advances in the understanding of the genetic factors that predispose people to cancer and the development of better diagnostic tools, healthcare professionals still face significant challenges in providing care to patients with this genetic predisposition (Strahm & Malkin, 2006).

Counselling is also important after taking a genetic testing. Face-to-face sessions with a counsellor take a thoughtful and comprehensive approach. This process was the main objective to ensure that the information provided was fully understood by the person, this includes communicating genetic test results to those seeking advice, remembering to speak with empathy and help people comprehensively understand of all the information included in the test, but at the same time, it's important to explain the impact of the results on the risks posed by specific types of cancer. The emotions expressed by patients are very important, and healthcare professionals must carefully assess and understand the patient's emotional response to the information provided, addressing these feelings requires appropriate support based on the individual's emotional needs (Trepanier et al., 2004).

The consultation process includes consideration of screening and risk reduction options. If necessary, the counsellor will refer the person to a specialist. The important responsibility of communicating test results to families is emphasized and ethical considerations are carefully considered. In cases where a high-risk client chooses not to receive information, there is a possibility of seeking ethics consultation. Both individuals at high risk and families with negative results are advised to stay in touch with the assessment center to receive updates, receiving support and information, regardless of the test results (Trepanier et al., 2004).

2.1.2 Genetic Counselling and Communication in Healthcare

Limited access to genetic counselling services can create barriers to obtaining critical information and support related to genetic diseases, especially for communities out of reach living locations that are distant from urban centers, resulting in poor accessibility or proximity to healthcare facilities. Disparities in access to genetic counselling services and identification of high-risk individuals based on ethnicity or race can impact treatment effectiveness. Unequal access and identification can lead to disparities in the success of medical interventions and treatments across populations. The profession of genetic counselling, which began in the United States in 1969 with the first master's-level program at Sarah Lawrence College, has since expanded globally, with nearly 7,000 genetic counsellors practicing in over 28 countries as of 2018. However, in many countries—particularly across South America, Africa, and parts of Asia—genetic counselling services are still primarily provided by physicians, and the development of the profession remains in progress, often lacking formal training programs or national regulation. This uneven global distribution contributes to the disparities seen in access and quality of care (Ormond et al., 2018). To address health disparities, health departments are using telemedicine to assess genetic cancer risk and provide advice to underserved populations, especially Hispanics living in the Texas-Mexico border region. Targeting underserved minority communities (Mette et al., 2016).

A post-program survey indicates that the majority of participants receiving services via telemedicine expressed high satisfaction with this genetic risk assessment program. With the majority of people being satisfied this suggests that the video conferencing method was a well-received and innovative form of service. However, it is important to note that all individuals can benefit from telemedicine services, this is not limited to any particular ethnicity or race. Telemedicine has been extensively studied and has demonstrated its effectiveness in providing health care services to diverse populations and demographic groups and improving access to health care resources.

However, there are limitations that indicate that not all areas may have the necessary infrastructure or personnel to support an effectively telemedicine implementation, particularly the need of accessible communication technologies, such as video conferencing tools, and the necessity of trained personnel at remote locations who can perform tasks such as collecting specimens and interacting with patients (Mette et al., 2016).

The fast advances in digital technologies often outpace health systems' ability to effectively integrate them. The introduction of digital technologies in healthcare must align with the specific needs and conditions of less accessible regions like in rural and remote areas that face some challenges and limitations. Rural environments differ greatly from one another and require telemedicine solutions that are specifically designed to address the distinct challenges presented by these diverse rural settings. The primary objective is to make healthcare more available and accessible to people who face challenges due to significant distances in their geographic location. This objective aligns with the World Health Organization's definition of telemedicine, which underscores the utilization of technology to provide health services, particularly in situations where geographical distance is a significant obstacle. Customized telemedicine interventions, designed to address the unique challenges of rural areas, can help overcome obstacles in accessing healthcare and lead to improved health results for individuals who live in remote areas (Goodridge & Marciniuk, 2016).

2.1.3 Communication Among Family Members

Communicating genetic test results within a family is a delicate and complex process, as the information can significantly affect the lives of relatives. Patients who undergo genetic testing often face difficulties when sharing these results with family members. According to Chivers Seymour et al., (2010), studies reveal that the communication to a relative after genetic testing can be influence by some key elements:

1. What an individual is feeling while being responsible for telling a family member about the results of the genetic test, sometimes, they may feel unfit for the task. Additionally, participants may experience various emotions, such as having to communicate detailed and difficult-to-hear information.
2. Family members perceive the relevance of the test results differently, with some considering it more significant than others based on factors such as gender. There is evidence suggesting that female relatives attach greater importance to the information compared to their male counterparts. Additionally, the age of the relative plays a role, with children sometimes deemed "too young" to handle the information. Furthermore, assessments consider the life situation and personality of the family member, which may render them more vulnerable.
3. There is a challenge when sharing this information with family members who have limited and infrequent interactions. Typically, families tend to update close relatives, like children, cousins, and parents, more frequently.
4. Family experiences with cancer often influence decisions around genetic testing. Family communication often follows established hierarchies, with information flowing from one generation to the next, such as from parents to children, rather than between members of the same generation, like cousins.
5. The timing and method of communication play a crucial role in effectively informing relatives. Choosing an appropriate time to share this information is essential to prevent adding extra stress to a relative already facing additional challenges, which depends on each person.
6. The information and expertise of health professionals in explaining the genetic test results in detail are crucial, providing valuable assistance to families. While some individuals prefer to manage the communication themselves, others often rely on professionals for accurate and comprehensive information.

Furthermore, parents often struggle with deciding when and how to share information about genetic conditions with their children, considering age-appropriate concerns. They also face challenges in determining the amount of information to disclose, how to frame it, and how to present it in a way that fosters a positive and optimistic understanding (Metcalfe et al., 2008).

Research shows that parents who choose to disclose genetic information to their children generally stand by their decision. Their goal is to reduce the children's anxiety, build a foundation of trust, and eliminate the confusion that secrecy can cause. In response, children tend to respect their parents' openness. Open discussions can strengthen family bonds and promote mutual support in coping with the condition. While open communication may not completely alleviate emotional pain, it empowers families to address their concerns together.

Equally, when families maintain secrecy and avoid open communication, anxiety often develops, creating an uncomfortable family environment. Many parents keep this information secret believing it protects their children. However, secrecy can backfire, especially if they're already adults, leading to feelings of betrayal and eroding trust within the family (Metcalfe et al., 2008).

In essence, the communication of genetic test results within families is shaped by a range of emotional, relational, and contextual factors. Individual readiness, perceived relevance of the information, and the dynamics between family members all contribute to how and when this information is shared. While some relatives may be considered too young or emotionally vulnerable, withholding information can lead to long-term trust issues and emotional strain. Open, age-appropriate, and well-timed communication—especially when supported by healthcare professionals—can foster trust, reduce anxiety, and strengthen family cohesion. Ultimately, transparency, empathy, and sensitivity are essential for navigating the complexities of genetic risk communication within families.

2.2 Technic

This section covers four key areas relevant to the project.

First, it introduces sound design by defining what it is, outlining the processes involved in creating sounds, highlighting the core disciplines sound designers rely on, and exploring its application in the film industry. Next, it examines the concept of soundscape, detailing its definition, how soundscapes are composed, and how they differ from music. The section then explores the practice of soundwalking, tracing its development over time and its role in artistic and sensory engagement. Finally, it discusses location-based generative soundscape creation using platforms like Freesound, focusing on techniques related to interactive and auditory-mediated reality.

2.2.1 Sound Design

2.2.1.1 Definition

Sound design is when a new sound is created for the use of a specific purpose, this includes targeting and creating sounds that may not exist in traditional databases or that cannot be directly recorded in the desired format. While listening is about interpreting and understanding sound, sound design focus on *creating* sound with a clear intention. This intent often emerges in the early stages of conceptualizing an object, system, or idea, and encompasses considerations of both *form* and *function* (Susini et al., 2014).

"Form" means that sound is considered an important factor in how well the final product looks and feels. The emphasis is on ensuring that sound fits well with the identity of the object and contributes to its overall appeal and aesthetic experience. So, this is used to elevate the quality and perception of the object.

"Function" means that the sound is seen as a tool that conveys important information to interact with objects in specific ways. This information needs to be clear and understood, however it can also raise emotions making it more captivating. Like a warning signal.

2.2.1.2 The Process of Sound Design

Intentional and consequential sounds are deliberately designed to enhance the overall user experience of a product. These sounds are created to fit product's context while also helping to define and reinforce its brand identity. They need to be designed with user expectations and emotional reactions in mind to be effective. For example, depending on the intended interaction and desired user experience, warning noises can be made to feel less obtrusive or more "inviting."

According to Langeveld et al., (2013) the process of creating this sounds involves four iterative stages:

- **Stage 1 - Sound analysis**: this stage begins with conducting observational research to pick up bits of knowledge into different viewpoints of how an item produces sound and its interaction with clients and the surrounding environment. This research involves observing the real-life circumstances of the product and recording its audio-visual information with the goal to understand the setting of human-product interaction.

A number of important things need to be taken into account during this observation. These include knowing how the environment's acoustics affect how sound is produced and perceived, recognising background noise that could obstruct or obscure the product's sound, assessing how users interact with the product and react to its sounds, figuring out when these sounds occur, taking into account how long typical user interactions last, and assessing how sound affects the product's overall usability.

Following the evaluation of these factors, the product sounds are captured in a controlled studio setting in order to separate the acoustic content. This makes it possible to compare the sound of the product directly to the noises of the surrounding environment. The product is also dismantled, and every step of operation is recorded independently to find any parts that could be causing unwanted noises. These methods provide insightful information to inform and guide successful sound design while revealing the ways in which sound affects user-product interaction.

- **Stage 2 - Conceptualization:** in this stage designers first need to analyse any problems with the existing sounds with the objective to understand how they adjust with the specified user experience and identify areas for improvement, creating new sounds that match the desired experience. In this stage designers utilize methods like mind mapping, bodily explorations, and acting out to characterize the emotional and physical qualities related with the specified user experience.

When the concept is chosen designers use sound sketching with the purpose to translate conceptual thoughts into sound-related expressions by experiment with various methods such as tinkering with physical objects to produce sounds, vocalizing sounds, or utilizing specialized tools like PSST (Product Sound Sketching Tool).

When a sound sketch is created with the purpose to represent the specified auditory expression for the product, those sketches serve as an outline for implementing the sounds into prototypes.

- **Stage 3 - Embodiment:** when designers are in this stage, they engage with the actual sounds that are produced by the newly designed product. This time, they must work with modifying or even replacing out the physical components of the product with the intension to achieve a more accurate match with the sounds and guarantee that the final product transmits sounds that are consistent with the required auditory experience sketched out earlier within the design process. While doing this analysis they need to resolve issues related to sound production.

To evaluate how the changes affect its sound output, the designers initially make prototypes of the product so that they can assess whether the emitted sounds match the required sound-related features.

To ensure that the final product delivers the desired auditory impression, each sound that is modified has to be systematically examined to understand its acoustic properties using techniques such as sound recording and spectrogram analysis to study various aspects of the sound, gaining bits of knowledge of the product characteristics. However, these sounds focus not only on technical aspects but on whether the sounds match the desired goals of the earlier sound design.

The approach to designing and implementing sound in a product depends on the type of sound. It could be used intentional sounds design that typically involves digital techniques and consequential sounds design that uses more analogue methods.

- **Stage 4 - Detailing:** in this stage it's emphasized that the sound in the final prototype has to be more detailed and it is given specific considerations to a more refined sound making it more realistic. For more accurate results the designers study to gather more detailed information on the user preferences with the product's sound. Designers may still need to refine the components of the product to play down any unwanted interference that may affect the overall sound quality. Completing all of this stages the main product can go directly to the manufacture stage.

2.2.1.3 Product Sound Designer Essential Disciplines

Acoustics: Acoustics is a branch of science that investigates various aspects of sound, including how it travels through different mediums studying the sound propagation, that will help understand how sound waves move through different materials like air, water, or other, and how they interact with different surfaces, also includes the mathematical models used to describe its behavior, and the physical properties that determine its characteristics, both will quantify sound properties such as intensity, frequency, and wavelength.

Acoustics focus primarily with studying the physical properties of sound sources, such as the materials involved, their size, shape, and geometry, while also delves into how these properties play a significant role in influencing the propagation and characteristics of sound waves. It is known that sound propagation is not static so properties of sound can alter over time, resulting in modifications to its spectral-temporal composition.

When designing product sounds, there's a need to have a profound understanding of how sound behaves and how it can be manipulated so it's essential to know his acoustic nature. This is due to the fact the acoustic analyses are the process of studying and simulate various aspects of sound, these aspects can be frequency, intensity or decibels, and amplitude. Tools like the spectrogram is very useful, because it gives the visualization of the frequency content and intensity variations of sound over time which allows the designers to see how the different characteristics of the sound change over time. Despite that, in the acoustic field there is techniques for simulating realistic sounds objects, typically using computer technology. These simulations help to anticipate how some sounds will be seen by users (Langeveld et al., 2013).

Engineering: Engineering such as mechanical, electric-electronics, and material engineering utilize scientific principles to create tangible solutions for designing product sounds. It works on the physical elements of a product such as its components, mechanisms, and the materials utilized. Their objective is to ensure that will these elements fulfil their functional roles within the product, they also contribute positively to the generally sound quality experienced by users.

Engineers utilize knowledge from physics and mathematics to understand how energy is transformed into sound or vibration utilizing different methods, including computer simulations, experiments conducted in laboratories, and building prototypes, to create and upgrade product sounds in an organized and controlled way (Langeveld et al., 2013).

Psychology: Sound design takes into consideration not only how to make a sound technically, but also how individuals will understand and respond to it based on their psychological associations, meaning that people interpret the sound based on what they've listened before and what they know from past experiences and associations about the world, even without seeing the object itself making the sound. The way a sound is produced, such as the movement of objects, can influence how it's perceived.

When an individual listens to a sound related with a product, our brains consequently make associations based on different aspects of the sound. Like what is making the sound and what are its actions, localizing where certain sounds within the environments is the product is commonly used, evoking basic emotional responses, making psychoacoustic Judgments of the quality of the sound like its sharpness, loudness, or roughness, deducing the properties of the source such as its interacting sizes and materials, and evoking abstract concepts.

Understanding how users perceive and interpret the sounds transmitted by products is vital for successful sound design. So, it’s important to consider both cognitive and emotional associations of sound during the design process by the design teams. Incorporating questionnaires made to understand the psychological and cognitive effects of the sound with the main goal to ensure that the sound fits well with the product and its environment (Langeveld et al., 2013).

2.2.1.4 Intentional and Unintentional Sounds

Was we know the environment was an infinite catalog of sounds, but with the huge differences between all of them there was a need to categorize the sounds as intentional being purpose manipulated by people like communicating information, and those that are unintentional that aren’t consciously created for communication, but is generated as a result of everyday activities like car engines and alarm clocks. These two categories together contribute to a comprehensive listening experience in our daily environment (Susini et al., 2014).

2.2.1.5 Industrial and Cinema

In the late 20th century, European industrial designers became increasingly concerned with minimizing unwanted and disturbing noise from their products. This was a challenged for them because they didn’t have any method that could predict unintentional noises. So, without these tools, this became difficult for designers to manipulate or anticipate specific sounds that might be produced and had limited ability to control the sound characteristics of their products.

In the late 1980s, the industry of automotives progressed by incorporating active noise cancellation technology that emits sound waves with opposite frequencies and can cancel out undesired noises in their vehicle.

Although there was a focus on cancelling these noises, in the 1990s, those focus had change. Now these unintentional noises that were produced by the products weren't unwanted. There was an idea that the sounds can serve a purpose beyond just noise, they are intentionally designed to provide meaningful information to users like the characteristics of the product. Some unintentional sounds could be a characteristic of quality or identity from the product.

While this sounds, being label as sound quality, were aimed on improving the overall sound experience of existing products dealing with improving unintentional sounds, another contrast approach had emerged, called sound design, that are concerned in the purpose creation and design of intentional sounds for specific reasons, they are carefully selected and created with specific objectives and goals in mind and are selected and incorporated to contribute to the overall quality and identity of the product. This all-tock place in Europe, while in North America, the term sound design was already used in the 1970s in cinema. Walter Murch is credited with introducing the term "sound designer" into the film context (Susini et al., 2014).

In context of cinema Murch said that the idea of a sound designer is to have overall responsibility for planning, creating, and manipulate the sound elements of a film, considering the entire listening experience throughout the filmmaking process from the beginning of production until the final stage. Many people didn't adopt this definition by Walter Murch, and a new definition was proposed by Sound Design and Perception research group at IRCAM which said that sound design emphasized the creation of targeted sounds to convey specific meanings, emotions, and information to improve your overall listening experience with a clear intention behind the selected sounds.

So, we can say that sound design is used to convey information about the characters, deferent emotions and locations with the objective to create a rich visual narrative having an important role in in shaping the overall cinematic experience. The creative process of creating sound goes beyond dialogue and includes elements such as background noise, effects, and music. So, this work comes sometimes from a team that consisting in a sound editor, director and mixer that will work together. While this enhance the atmosphere of films it also is important in other fields like video games and the already mentioned product design that was dominant in Europe.

With the advance technology in cinema the voices overs and other sound became more distinguish being able to make more significant changes and treatments to the voices increasing even more the quality and expression of the experience in film for the audience (Pauletto, 2012).

2.2.2 Soundscape

2.2.2.1 Definition

The concept of soundscape, initially introduced by Southworth in 1969, gained popularity through Schafer's work in the 1970s, particularly in highlighting the threat of noise pollution to human health and culture (Grinfeder et al., 2022).

Soundscape is a very complex experience that can be described in deferent ways, but simply put it is shaped by geophonic, biophonic, and anthrophonic elements, reflects the composition of sounds within a given location, influenced by the landscape's structure and functioning (Farina, 2013).

2.2.2.2 Soundscape Literature Terms

The term "soundscape" is used according to the definition by Genuit and Fiebig. They emphasize the distribution of sound through the environment and describe the soundscape as a region composed of multiple sound sources distributed in space. This allows the research to analyse and represent the distribution patterns of sounds in spatial contexts with the help of knowledge from various fields (Barakat, 2016).

There are terms that are adopted from soundscape literature, such as soundscape ecology and aural architecture, and those terms include:

1. **Receiver / Sensor:** Refers to a person who actively listens to and experiencing sound in a particular space. And refers to anyone operating or holding the measuring device during measurement.
2. **Sonic Event / Sound Source / Signal:** These terms help classify and focus foreground signals and distinguish them from background signals, contributing to the analysis of urban acoustic environments.
3. **Auditory Channel:** An "audible channel" occurs when a listener detects a signal and is able to distinguish it from an audio event based on the distance between them.
4. Acoustic Horizon: The acoustic horizon is the space around the listener, determined by the amount and intensity of the auditory channels that connect the listener to acoustic events.
5. **Acoustic Arena / Acoustic Space / Patch**: It emphasizes the dimensions and characteristics of the space in which sound events are perceived by the listener, based on the listener's sensitivity to different frequencies.
6. **Edge:** The term "edge" refers to a situation where multiple adjacent sound events create overlapping acoustic arenas with connected auditory channels. There are two scenarios. In the first case, it is assumed that the receiver is located in the dominant region assigned to the strongest auditory channel and the transmitted signal becomes dominant. In the second case, if the strengths of the connections are equal, the receiver is not connected to any auditory channel and is placed in the "edge" domain.
7. **Soundscape Pattern:** refers to a spatial configuration influenced by acoustic arenas (or patches) centered on spatially distributed sound sources and edges that appear between these arenas. The unique characteristics of each soundscape are defined by the distribution of events in space, resulting in different morphological patterns in each soundscape (Barakat, 2016).

In 1969, Michael Southworth emphasized the influence of urban noise on the quality of life in cities. He conducted a study of the Boston Soundscape that included participants with a variety of sensory abilities, including those who were deaf, blind, or had both vision and hearing aiming to influence the acoustic stimulation on urban life.

Murray R. Schaefer, credited with popularizing the term "soundscape", played an important role in documenting changes in the acoustic environment. Through his project called Through the World Soundscape developed in the 70s with the intuit to record and analyse changes in the acoustic environment and highlight historical and cultural aspects that influence the soundscape. Soundwalking, a technique introduced by Schaefer, played an important role in identifying and recording these changes in different locations.

In the eyes of Westerkamp, she emphasized that the goal is to familiarize participants with all the sounds in their environment and encourage them to actively listen and engage with the different acoustic components present. Fundamentally, soundwalking is seen as a way to help individuals develop a deeper, more conscious understanding of the sounds that make up their listening experience.

The effectiveness of soundwalking in achieving intended goals and results is not well researched and documented in the existing academic literature. However, The Positive Soundscape Project recognizes the existing gap in the evaluation of soundwalks utility and effectiveness in academic projects. In addition to using soundwalks in academic projects, this project also actively works on the further development and refinement of the soundwalk concept. The main goal is to actively contribute to the evaluation of how soundwalk works as a methodology (Adams et al., 2008).

2.2.2.3 Soundscape Composition in Sound

Soundscape composition is a creative practice that involves manipulating and mixing different sound recordings to inspire particular auditory experiences and trigger associations in listeners and also resonates psychologically with the audience. It includes a wide range of imaginative approaches, extending from depicting real-world environments to creating imaginary sonic landscapes through extensive processing.

The composition of a soundscape normally involves processing and combining audio segments that have been classified into different categories. Compositions also usually involves layered channels that are going to be generated by a module system.

To achieve a simulation of a decision-making process, it is used an agent-based model a program that operates autonomously, making decisions based on its environment. They are responsible for processing different audio segments and combining them according to a set of heuristics.

The heuristics guiding the agent can by inspired by different other sources like location generative soundscape, production notes and more. The most know model on how a composition should be realized is the agent-based model that sequentially processes background regions to create textured backgrounds, foreground regions they are the attention-grabbing elements that stand out against the background, and background with foreground regions that combine elements from both the background and foreground layers.

Each agent in the system works independently and applies the composition model individually to handle different audio files. When processing an audio file, an agent analyses its region labels to decide which segments to work with. The agent selects, processes, and combines, based on these labels, the audio regions according to the rules outlined in the composition model.

When the system starts running, it sets a limit on the maximum number of agents it will utilize to process audio files. If there is a bigger number of audio files results than agents, the results that are extra are ignored, and when there are agents without tasks they are temporarily disregarded (Thorogood & Pasquier, 2013).

Soundscape composition shows two essential strategies: fixed spatial perspective, that are works where there's a sense of spatial continuity where the audience perceives a consistent environment without critical changes in spatial orientation, and the other strategy is moving perspective this works, the spatial transitions play a crucial role on the listener, those transitions create a dynamic experience in the spatial orientation, as if the listener is journeying through different sonic spaces creating a sense of travel (Truax, 2008).

2.2.3 Soundscape vs. Music

The totality of sounds presented in a given location serves as the foundation for the soundscape influencing how it is perceived and experienced. Theres a process that involves distinguishing meaningful signals from background noise because signals can clarity impact information processing and attention. So, soundscape is valuable to explore the typical attention given by listeners to each form of auditory experience.

The complexity of soundscapes presents challenges for auditory perception and behaviour, which are influenced by both the richness of auditory information and individual subjective factors (Welch et al., 2022).

Engaging with soundscapes, individuals develop a sense of empathy and communion with the environment, fostering a deeper connection to nature and promoting empathy towards the environment. The perception of the soundscape is subjective and varies depending on individual experiences and preferences (Polli, 2011).

Like soundscape different models were developed to understand the response of people to music, how people perceive and how influenced it can be.

Researchers use established psychological models to understand how music influences human emotions. One important model is the hybrid model of emotional response to music, it offers a multi-level system for understanding how music evokes emotional experiences. This model sets three particular levels of emotional response: low-level, core affect; basic emotions; and higher-level emotions.

Temporal nature of music is a crucial aspect that involves how changes in musical elements such as tempo, rhythm, dynamics, and structure influence listeners' experiences over time. Music unfolds over time, constantly evolving and changing as it progresses. Unlike other forms of art, it depends on the passage of time to communicate its message and inspire emotional responses that could change through the piece (Welch et al., 2022).

Music has long been recognized for its ability to evoke emotions and create mood-enhancing atmospheres depending on the musical compositions. Incorporating music into various environments, such as hospitals, where patients may experience stress, anxiety, and discomfort, music can serve as a therapeutic instrument to reduce negative emotion (Song et al., 2022).

The comparison between traditional music and soundscape perception can be categorized, according to Polli (2011) into three subsections:

1 - How the sound is presented, this differs between music and soundscape. Music is experienced most commonly using an orchestral analogy, with users facing the source of the sound. While soundscape is regularly experienced as a surrounding method of listening, making the sound be around the user.

2 - The way sound is notated and recorded is important for the development of the world view. While music typically places emphasis on quantitative aspects of sound, particularly pitch, soundscapes tend to focus more on qualitative aspects of sound, particularly the source and quality of the sound. However, in the practice of acoustic ecology, aspects like loudness are quantitatively considered, despite the qualitative focus of soundscape perception.

3 – And the reception and interpretation that is different in music and soundscape. When individuals listen to music, they actively focus their attention to it, consciously immersing themselves in the auditory experience. But soundscape perception often refers to the environment surrounding a person that is unconsciously passively aware of the soundscape without making a conscious effort to analyse it, diverting his attention.

2.2.4 Soundwalk

Soundwalking is a relatively small but essential activity within experimental music and sound art, integrating knowledge from music, architecture, sociology, and more. The participant engages in specific excursions or walks with a clear objective, focusing on attentive listening to the surrounding sounds, making it an activity directed towards engaging directly with the environment, regardless of the location (Saunders, 2017).

Through the 20th century, mainly in the middle of the century, the sound art movement amplified its presence because noise pollution became increasingly important due to technological advances and changes in everyday noise. Advances in recording technology began with the phonograph, radio, and tape recorders, which reproduce sound. Still, a more sophisticated technology has developed with time, resulting in computers that make sampling and editing more complex. With this recording technology, sound artists can create and share their work beyond limitations, such as places and schedules (Butler 2006).

Over time, recording tools had their cost decreased, which made a more accessible product for people, making a broader community to experiment with sound, notably London’s radio station Resonance FM (Butler 2006).

In the 20th century, Aldous Huxley called this era the "Age of Noise" because of the implementation of more urbanized locations that included various types of noise complexes to place and identify by ear, like factories, car engines, and fans. This type of noise was used in 1913 by Italian futurist Luigi Russolo in his work called the Art of Noises manifesto, which stated that we use urban noises in his compositions (Butler 2006).

In 1952 composer John Case made a music piece called 4’33” that only features silence, the main objective of this was to make the audience to concentrate on the surrounding noise. With Case’s (1952) idea, others artist emerges like Max Neuhaus and Bill Fontana that used sound to

draw attention to urban landscapes. Sound artists had the need to break away from conventional norms and explore the possibilities of noise and everyday sounds.

The way sound is began to be used in music challenged traditional ideas and contributed to broader discussions about our understanding of place, mobility, history, and memory.

Case (1952), Neuhaus and Fontana ideas made the basics for every soundwalk.

The activity of soundwalk itself encourages exploration in various environments where sound exists, not limited to specific types of locations, like the everyday life, the audience needs to move through the environment and establish a good connection with the sounds they hear, this emphasize that their presence makes a huge part of the experience, where interaction is described as an unfolding narrative, with the story steadily evolving across time and space. This differs from the traditional performances by music artist, where the audience usually stays in one place and concentrates on the music being played, which often take place in formal settings such as concert halls or churches.

Depending on the goals and motives of the artist, a soundwalk might achieve a variety of goals. Depending on the method used, it can take on several shapes, providing for a range of interpretations and experiences instead of being limited to a single, set structure. With that, some soundwalks are already planned and composed by the artist as they already know the outcome making a linear path for the participants, and on the other hand, soundwalk can be improvised allowing the experience to be control be the environment that can change the sounds of the experience. The use of headphones and GPS-guided navigation has become increasingly common in soundwalk practices, enhancing the immersive and location-specific nature of the experience.

Because of this, the conventional hierarchical roles of composer, performer, and participant are not clearly defined, regardless of the composer's impact on the soundwalk or the degree of technical participation. The creator's position can often be lost or unclear as a result of these roles blending (Saunders, 2017).

When interacting with the environment, a person's ear can distinguish between sounds that are important and those that are not, as well as between sounds that are aesthetically pleasing and those that serve certain functional functions. This is a sensory process which helps in gathering information more effectively. Because of that, every person's experience of the soundwalk is unique and is influenced by their everyday encounters with the outside world, personal attitudes, and sensitivities (Saunders, 2017). As Westerkamp (1974) highlights, attentive listening is key to revealing the often-overlooked acoustic layers of our surroundings, turning ordinary spaces into rich soundscapes (Junior, 2019).

This experience was also driven by the necessity of making people more active. The issue of inactivity is very common in general and is one of the causes of some health problems. So, in making a soundwalk, there's a need to motivate an individual to participate. Traditional soundwalks set specific training goals and rewards for achieving them, turning the act of walking and listening into a meaningful and health-conscious activity (Tajadura-Jiménez et al., 2015).

2.2.5 Location Generative Soundscape Generation (Freesound)

2.2.5.1 Technique

This technique revolves around sorting sounds stored in a database into two essential categories that are textures that are sounds that contribute to the overall background atmosphere and objects that refers to sounds that are intended to capture the listener's attention. By categorizing sounds based on their semantic identifiers, this methodology permits for a more systematic and organized approach to sound design, guaranteeing that each type of sound serves its intended reason within the overall soundscape. These identifiers can either be physically assigned tags or determined automatically using a recognition model that analyses the characteristics of the sound (Finney & Janer, 2010).

2.2.5.2 Interactive Auditory Mediated Reality

Interactive Auditory Mediated Reality or just simply IAMR revolves around three fundamental concepts, that are mediated reality that is a process that through a device it manipulates human sensation. It represents a combination of augmented reality (AR) and diminished reality, advertising the capability to intentionally include, change, and remove content from any human sense. The other concept is human augmentation that involves using technology and other methods to improve various aspects of human abilities, both physical and cognitive. Includes assistive technologies designed to support individuals with disabilities. And the last concept is hearables, a wireless earbud, that plays a crucial role in IAMR by handling real-world sounds before playback to the user. This capability enables users to actively manage their auditory environment by selectively modifying specific sound sources.

AIMR concede the users the ability to manipulate their auditory experience through technological devices that mixes both real-world sounds and virtual sound components. In altered and curated soundscape, users may see a combination of sounds from their immediate physical surroundings along with digitally generated. The appearance of different technologies has driven to an increase in ambient noise levels, overshadowing natural sounds and silence (Haas et al., 2020).

2.2.5.3 Location Generative Soundscape Generation (Related Work)

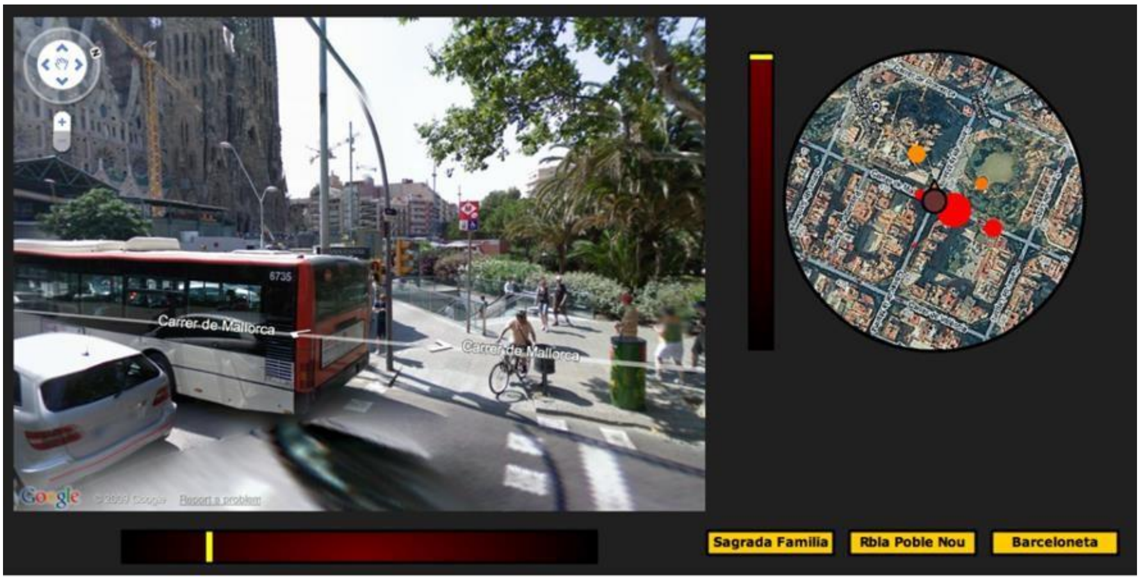

Figure 1. Local soundscape generator (Finney & Janer, 2010)

The figure involves the use of the textures and objects until the final stages. This separation permits a more controlled and clarified distinct processed of those sounds over the soundscape composition. The Textural Parameters and Playback Strategy blocks are essential components within the system's architecture, contributing significantly to the management of the soundscape. These blocks enable designers to parameterize sound synthesis effectively, offering the flexibility to manipulate the soundscape according to specific requirements.

The Textural Parameters block is responsible for deciding different attributes of the textural components display within the soundscape. These attributes incorporate spatial distribution, which refers to how sounds are spread out over the auditory environment, frequency content, which describes the range of frequencies display within the soundscape; and temporal behaviour, which relates to how sounds advance over time. While the Playback Strategy block administers the strategic playback of sounds inside the soundscape that includes decisions with respect to the sequencing, timing, and dynamic adjustments of sound elements. This design aspect can be adjusted by users. MATLAB Force-sensitive resistors (FSR) Electroencephalogram (EEG).

The process on this image uses a method called MFCC-based Bayesian information criterion (BIC) segmentation to combine together the original audio files. Involves analysing the recordings to find the best points where the audio files can be divided considering the spectral properties of the sounds, which relate to their frequency content and how it varies over time. The Mel-scale is a perceptual scale of pitches that's based on the human auditory system's reaction to sound frequencies. It's designed to imitate how people see the contrasts in pitch, by using this the analysis can better capture how changes in frequency influence the seen timbre.

This study created a system capable of autonomously generating immersive soundscapes within a visually realistic but static environment. The sounds utilized in the generation process were sourced from unstructured databases, meaning that they were recovered from collections of sound recordings without a predefined organization. It uses a visually realistic, static environment comparative to those seen in Google Street View. This environment permitted users to explore through distinctive locations inside a city interactively. To make these immersive soundscapes, the system utilized recorded sound samples sourced from the Freesound Project, with a specific attention given to selecting samples that loyally captured the auditory substance of Barcelona and Spain, guaranteeing realness within the generated soundscapes.

When users navigate in different locations within the environment, the application dynamically altered the volume levels and spatial positioning of audio sources to create a more immersive auditory experience.

This application was programmed utilizing ActionScript 3.0, It dealt with both the synthesis of sound and the interaction with users. The audio files were analysed offline using MATLAB helping identify optimal points for segmenting the audio files and determining the probability of selecting each segment during playback (Finney & Janer, 2010).

2.3 Related Work

This section presents an overview of related works, focusing on previous experiences with soundwalks and the use of sound design to support communication and health-related studies.

2.3.1 As Light as your Footsteps

This soundwalk was the main approach to promoting physical movement and improving self-esteem by leveraging multisensory experiences, particularly by controlling the auditory feedback people receive while walking. While manipulating sensory feedback, particularly the sound of footsteps during walking, they can target the user perceptions of body weight and potentially motivate him to engage in healthier behaviours.

This experiment started by recruiting of twenty-two participants, with ages between 18 and 35, to record their body weight and height. A prototype was developed by the researchers that enabled real-time alteration of footstep sounds while simultaneously measuring changes in walking behavior. It includes strap sandals equipped with microphones to capture the sound of the user's footsteps, the microphones are connected to a stereo pre-amplifier that boosted the captured sound signals, and a graphic equalizer that allowed the researchers to dynamically modify the frequency components of the footstep sounds in real-time. The sandals also have a Force-sensitive resistors (FSR) attached to the insoles to detect the exerted force by the feet against the ground. And in addiction to this, it also has a triple-axis accelerometer attached to the ankle that record data related to foot movements. These attachments produce signals that are transmitted to an Arduino Uno microcontroller board that processed the incoming data and sent it to a computer. The sound feedback was altered using a stereo pre-amplifier and graphic equalizer. And also wore closed headphones designed to block out external noise and provide high passive ambient noise attenuation, ensuring that the participants primarily heard the modified footstep sounds fed back to them (Tajadura-Jiménez et al., 2015).

Figure 2. Prototype (Tajadura-Jiménez et al., 2015)

The experiment took place in a controlled environment: a quiet, dimly lit room with a specially constructed corridor made from wooden boards measuring 8.5 meters in length and 1.22 meters in width. In these settings, it was established three distinct sound feedback conditions: Control, High frequency, and Low frequency. In each condition, adjustments were applied to the frequency components of the footstep sounds. To evaluate the user experience different measurements were taken, like perceived body weight using a body visualization tool, analysis of gait patterns, emotional responses using graphic scales and physiological measurements, and perceived body behavior through a questionnaire.

A within-subjects approach was adopted, meaning that each participant underwent all experimental conditions. To mitigate the potential effects of practice or habituation bias, the order in which participants experienced each condition was randomized. During each block of the experiment, participants engaged in two distinct phases: a marching phase followed by a walking phase, in which it was recorded their gait patterns and emotional responses. After completing each block of the experiment, participants engaged in avatar adjustment, where they use body visualization tool to match their perceived body dimension, and complete a questionnaire assessing various aspects of their experience (Tajadura-Jiménez et al., 2015).

2.3.2 Sound Design Used to Facilitate Communication and for Health Studies

2.3.2.1 Survey: Digital Music Interventions for Stress and Anxiety

In this work a survey explores the potential of music as a therapeutic method in addressing personal stress and anxiety, going into the historical origins of music therapy and its evolution into modern applications. Going deep in the different practices and advances in music therapy, demonstrating how relevant these applications are and its effectiveness in addressing these problems in contemporary settings. It also discusses the psychophysiological relationship between stress, anxiety, and music therapy, highlighting research findings on its effectiveness.

It addresses the obstacles encountered when attempting to expand music therapy programs to a wider scale, recognizing the need of trained therapists to facilitate treatment sessions and the limitations associated with research methods.

Recent option is the incorporation of biosensing technology, especially wearable devices (like the Apple Watch) that are promptly accessible to buyers, into music therapy practices, these devices are used to improve treatment sessions, and they give a means to accumulate information to how individuals physiologically react to music. So, it is important to investigate whether these technologies can effectively facilitate music therapy sessions and if can they be a right move for stress and anxiety.

While stress and anxiety may have some similar effects on the body, they are different in terms of duration. Stress arises most commonly from external factors and typically don´t last for an extended time, while anxiety is caused internal reactions to past events and usually persist longer periods. Whereas stress and anxiety have distinct characteristics, the digital music systems examined in this study do not differentiate them, so the term “stress” includes both concepts (Ferguson et al., 2023).

2.3.2.2 The Emotion Model

A visual representation of the emotional spectrum was created in 1980, in this case an emotional state wheel, known as Circumplex Model that is introduced by James Russell, which is a two-dimensional model that utilized to categorize emotions based on two key dimensions. One is valence that is represented by the x axis which can be categorize as being pleasant when is on high valance and unpleasant when is on low valence, the second is the arousal represented by the y axis, when y is on positive it represents arousal or active while on negative represents deactivated mean a calmer emotion.

The Circumplex Model employed in therapeutic music is integrated with Electroencephalogram (EEG) technology, which measures electrical activity in the brain. With this integration the researchers can detect how music influences brain activity and emotional responses in real time. In a particular study, participants were exposed to soundscape sounds while wearing EEG headsets enabled researchers to monitor changes in brain activity using a fractal-based emotion recognition algorithm. This algorithm analysed the EEG data to identify and categorize the different emotional responses by participants as they listened to the sounds. Researchers modified aspects of the music like the speed, pitch, amplitude and the tone, based on the brainwave information that is given by participants. This work provided a valuable insight into the potential for individuals to influence the characteristics of music playback based on their emotional state (Ferguson et al., 2023).

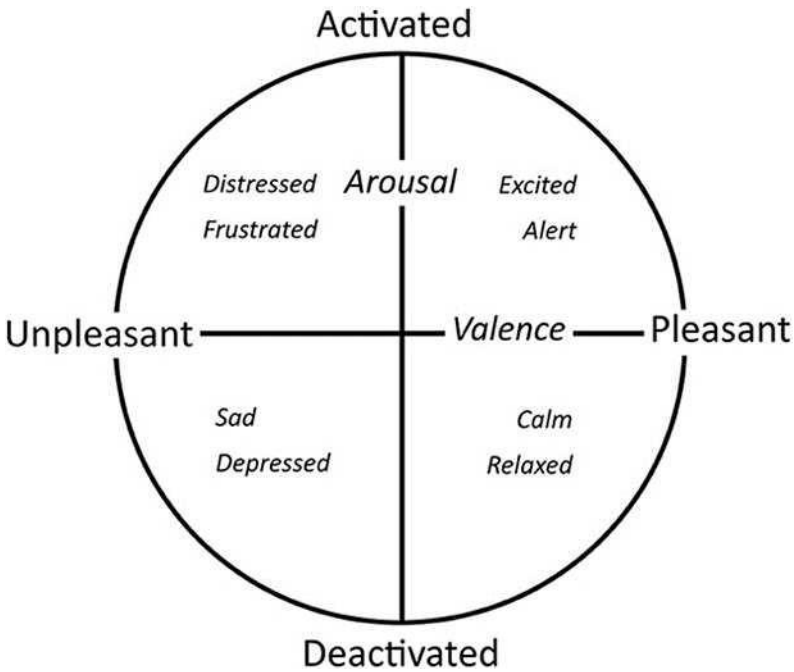

Figure 3. Circumplex Emotion Model (Ferguson et al., 2023)

3. Methodology

3.1 Mapping Soundscapes

The mapping between perceived effective dimensions and the spectral characteristics of audio in soundscape recordings is explored throughout this section. The objective of the project is to develop a unique set of audio descriptors that effectively represent the emotional dimensions outlined in Russell's Circumplex model (Russell, 1980).

3.1.1 Russell`s Circumplex Model of Affective States

In affective psychology, a longstanding challenge is precisely assessing emotions. Emotions are complex and subjective experiences that shift broadly between people, making them difficult to measure objectively. The issue arises from the perception of emotions as interconnected and overlapping rather than distinct and separate. Similar to how colors blend on a spectrum, emotions often lack clear boundaries, making it difficult to differentiate one emotion from another. James A. Russell suggests that this lack of discrete borders complicates the ability to clearly distinguish between emotions, leading to ambiguity in their perception and understanding. This perspective challenges the traditional view that emotions can be neatly categorize (Russell & Fehr, 1994).

Researchers developed a circumplex model to understand how and individual perceive emotions (Russell, 1980). Emotional experiences are complex and can't continuously be neatly categorized into just one emotion (Watson & Clark, 1992). Dimensional affective models particularly explore how emotions are interconnected, showing that different emotions are not completely isolated (Russell, 1980). Indicating that emotions don't exist in segregation; rather, they impact and are affected by other emotions, showing a complex web of connections inside and among individuals (Russell & Carroll, 1999).

The circumplex model organize feelings in a circular space characterized by two dimensions: pleasure-displeasure and arousal-sleepiness. Being consistent across different languages and cultures (Larsen & Diener, 1992), (Russell, 1980). Although the model is very promising in understanding emotions, it's also comes with its challenges. The labels got to precisely reflect the emotional states they represent, but there may be contradiction or vulnerability about which terms best describe these dimensions, making it difficult to ensure that the model is accurate and generally understood (Larsen & Diener, 1992).

In Russell's circumplex model of affect it suggests that any particular emotion can be plotted on a circular diagram based on how it scores on these two dimensions, with emotions positioned around the circle depending on their levels of arousal and valence (Russell, 1980).

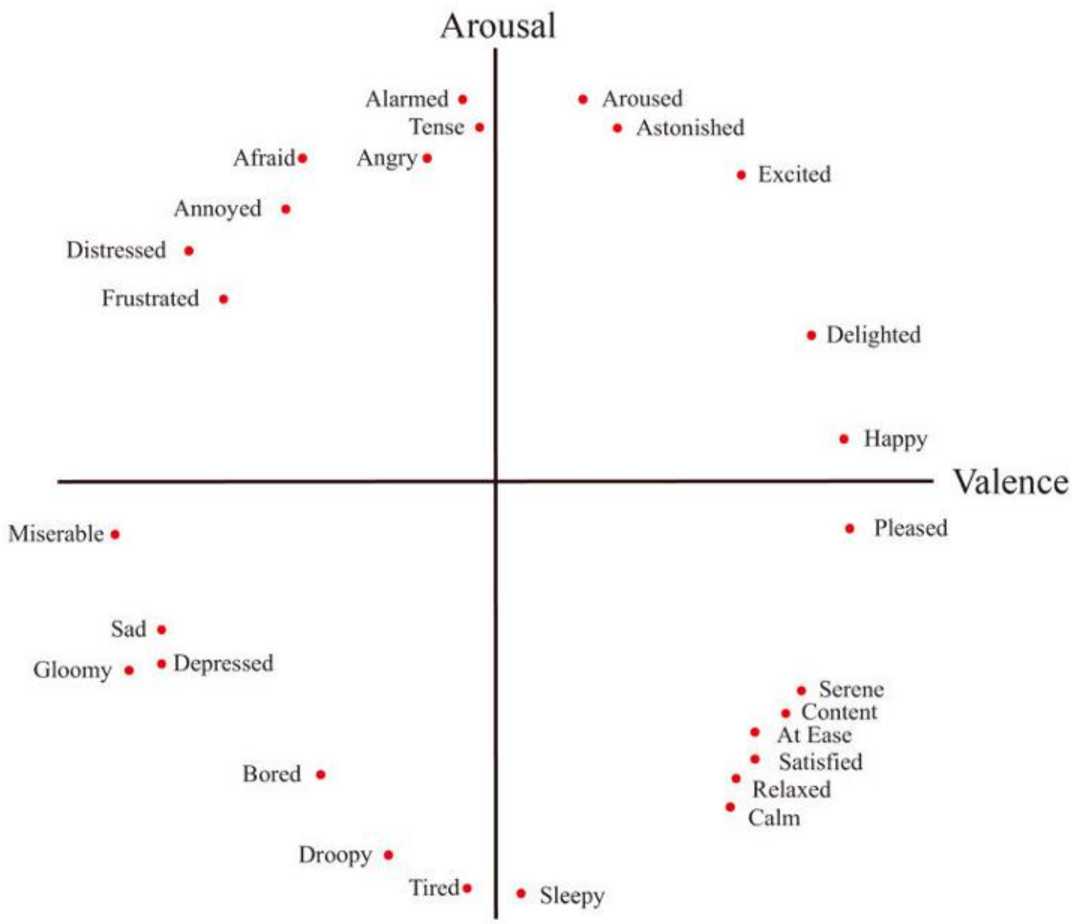

Figure 4. Russell's Circumplex Model (Seo & Huh, 2024)

In Russell's circumplex model of affect it suggests that any particular emotion can be plotted on a circular diagram based on how it scores on these two dimensions, with emotions positioned around the circle depending on their levels of arousal and valence

In this Circumplex model by Russell (Figure 4) the valence dimension, represented on the x axis, ranges from displeasure to pleasure, demonstrating the degree of pleasantness or unpleasantness of the emotion. The arousal dimension, represented on the y-axis, ranges from calm to excited, reflecting the intensity or activity level of the emotion (Seo & Huh, 2019), (Russell, 1980).

By mapping emotions onto this diagram according to two-dimensional levels, the model facilitates a detailed understanding of enthusiastic experiences and their relationships (Seo & Huh, 2019).

For example, by analysing the Circumplex model (Figure 4), we can determine that a specific emotion like anger is conceptualized as an emotional state that combines negative to moderate valence with high arousal. In contrast, sleepiness results from a combination of low arousal and neutral to slightly positive valence.

3.1.2 Emo-Soundscapes: analyse soundscapes based on emotional impact.

The MIR (Music Information Retrieval) community has made significant efforts to develop computational models (or algorithms) that can automatically detect and label the emotions in audio by recognizing affective states conveyed, in particularly, through music and speech signals as a source, focusing on the extraction of meaningful acoustic features, including timbre, rhythm, pitch and spectral properties, which have been shown to correlate with human emotional responses (Grekow, 2016), (Kobayashi & Calag, 2013).

Researchers can utilise psychological models, such as the Arousal-Valence space, to translate complex emotional experiences into a clear, structured, and quantifiable format (Kobayashi & Calag, 2013). Due to the lack of existing soundscape databases annotated with emotional labels, recently, research into retrieving emotions from audio signals has expanded to include sounds from soundscapes. So, one important contribution for this as the Emo-Soundscapes dataset, that centers on recognizing emotions conveyed in soundscape (Fan et al., 2017). The dataset contains 1213 short (six-second) soundscape clips, each of which has emotional labels (valence and arousal) and detailed technical audio features.

In the Emo-Soundscapes Dataset it was used the site freesound.org as a tool to find and retrieve 600 soundscape sounds directly from there. And the remaining 613 clips were created by mixing different combinations of the 600 sounds (MSchafer, 1977). The selected 600 sounds from freesound, were evenly distributed across six soundscape categories based on Schafer´s Taxonomy (Fan et al., 2017).

Table 1. Schafer's Taxonomy (Fan et al., 2017)

Categories:	Examples:
Natural	Wind, Birds, River
Human	Talking
Sounds and Society	Stores
Mechanical	Engines
Silence and Quiet	Quiet Park
Sounds and Indicators	Clocks

When the 613 soundscapes were created, the method of mixing the sounds was by manually combining two or three audio files from the initial set of 600 sounds. These combinations were made both within the same category and across different categories defined by Schafer's Taxonomy (Fan et al., 2017).

Each of the clips is connected to tags that describe its meaning, ensuring the selected audio segments accurately reflect the original sound with all those sounds being standardized to a duration of approximately six seconds, in line with prior research indicating that this length is sufficient for emotion annotation (Fan et al., 2017).

3.2 Walking Path, Soundscape Structure and Recreation

The walking path used in this project was initially designed by the research group of the Psychology Center of the University of Porto, under the project titled PLAY-THE-ODDS" (2018). It was created as a result of the discoveries from the earlier "TOGETHER" project, which indicated a demand for mental health support resources for families affected by hereditary cancer syndromes.

The soundwalk developed in this thesis supports this initiative by providing an engaging and emotionally resonant experience, grounded in participatory and context-relevant soundscapes, signifying a significant addition to the project team. Together, we develop new solutions to support parents and children in navigating the difficult topic of hereditary cancer risk.

Figure 5. Play the Odds Logo (Play the Odds, 2018)

Participants follow a path that is divided into five specific points, moving from point to point starting at Point 1 and ending at Point 5, which marks the conclusion of the soundwalk. As participants reach each new point, a new sound is introduced into the soundscape, and in some cases, previously played sounds are removed to reflect changes in the acoustic environment.

The first task in developing this project was to familiarizing with the sound environment. To do so, I walked the entire route, seen in Figure 5, several times, paying close attention to the sonic details of each section.

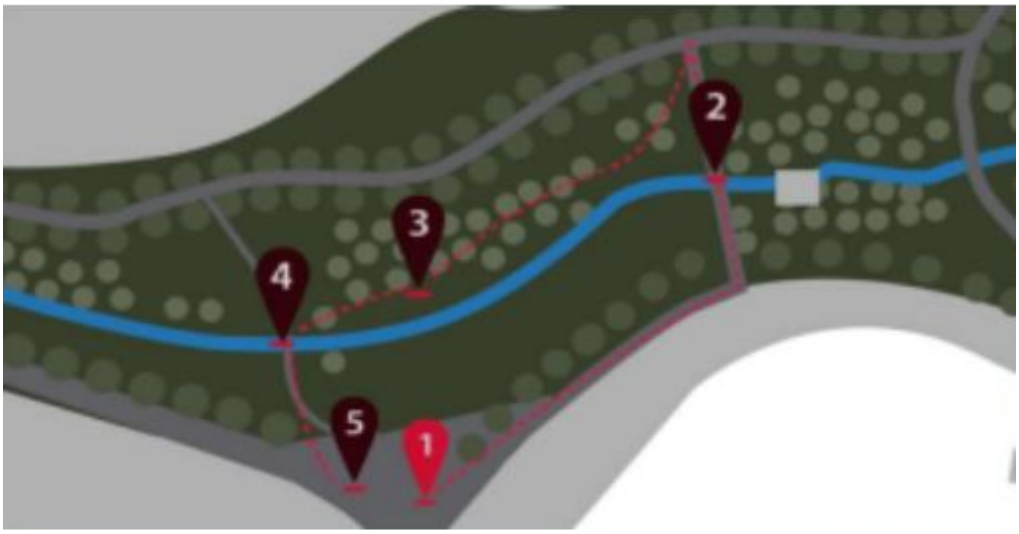

Figure 6. Soundwalk route map (Play the Odds, 2018)

The sound along the walking path was recorded and divided according to the five designated points. To accurately capture the acoustic environment, I made field recordings while walking from point to point at a steady pace. These recordings were used as a guide to create realistic soundscapes and choose relevant audio samples from a online source.

At each point along the path, 20 seconds of ambient sound were recorded while standing still, whereas the recordings made between points varied in duration. These audio segments were later used to map and structure the soundwalk's soundscapes. The duration of each segment is detailed in Table 2.

Table 2. Duration of each segment

Segments:	Duration:
Point 1 to Point 2	01:46 min
Point 2 to Point 3	01:25 min
Point 3 to Point 4	00:43 min
Point 4 to Point 5	00:41 min

To recreate and design a traditional soundscape, Ableton Live Suite was the digital audio workstation (DAW) selected, as it is well-suited for this kind of layered audio design. In Ableton, all field recordings were imported and structured into separate clips representing each point and the transitions between them.

Every clip was thoughtfully created to capture the unique environmental features of its location. To create an authentic and immersive soundscape, a variety of environmental sounds, such as wind rustling through trees, birds singing, distant traffic, and flowing water, were carefully selected and layered. These elements were combined to enhance the listener's sense of place by faithfully reflecting the acoustic qualities of each spot along the walking trail.

3.3 MaxDSP Patch

A Max/MSP patch, based on another patch named MScaper, was developed as part of the technical development of this soundwalk in order to dynamically download ambient sounds from the Freesound.org internet sound database. Using semantic tagging, this patch enables the real-time incorporation of contextually relevant audio into the soundwalk experience.

This project uses a tool provided by Freesound.org that enables researchers and developers to programmatically access its vast collection of user-uploaded sound recordings. This tool, known as the Freesound Application Programming Interface was integrated into a custom Max/MSP patch to enable real-time sound retrieval during the design phase of the soundwalk. So, this makes possible the support of advanced search features based on duration, license type, sound description, and keywords (tags). For example, by inputting a tag such as "wind" into the patch interface, the system searches the Freesound database and automatically generates a URL link containing audio clips labelled with that tag. The user can copy and paste this link into a web browser, which opens the Freesound website directly at the search results page showing sounds associated with that tag. This allows the user to easily download the more relevant sound files to be used in the soundwalk composition.

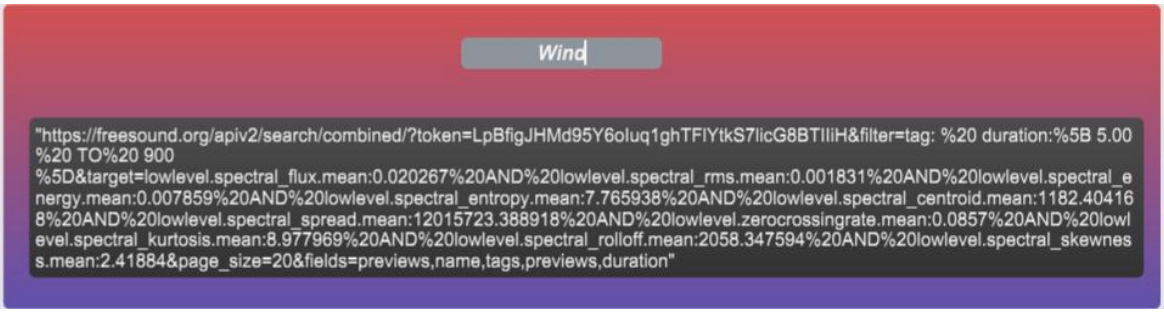

Figure 7. Patch interface

This patch was used to search for five different sounds, each corresponding to a specific section of the walking path. The selected sounds were: "wind," which plays continuously throughout the entire route to reflect the general atmospheric environment; "cars," associated with the segment from Point 1 to Point 2, representing the sound of passing traffic; "river," used from Point 2 to Point 3 to evoke the presence of flowing water; "birds," mapped to the section from Point 3 to Point 4, where loud bird calls are prominent; and finally, "people," assigned to the stretch from Point 4 to Point 5, capturing the ambient sound of people talking.

3.4 Echoes App

To use the sounds from Freesound with my Maxdsp patch, I employed a mobile application called Echoes. This tool uses GPS to trigger sounds at specific locations. It is well known for enhancing soundwalks through its location-based experience, allowing creators to map audio zones onto real-world spaces using a web-based interface. The Echoes app was crucial to this project since it allowed the soundscape to be delivered in real time while the participant moved physically along the walking trail.

To develop the experience for the Echoes app, it was first necessary to access the Echoes web platform to carry out the sound mapping for the soundwalk. Through the browser-based interface, I was able to create routes within the park by placing audio zones directly on the map. The platform also allowed me to upload curated sounds from Freesound and assign them to specific GPS-triggered zones along the walking path, ensuring that each location delivered a contextually meaningful auditory experience.

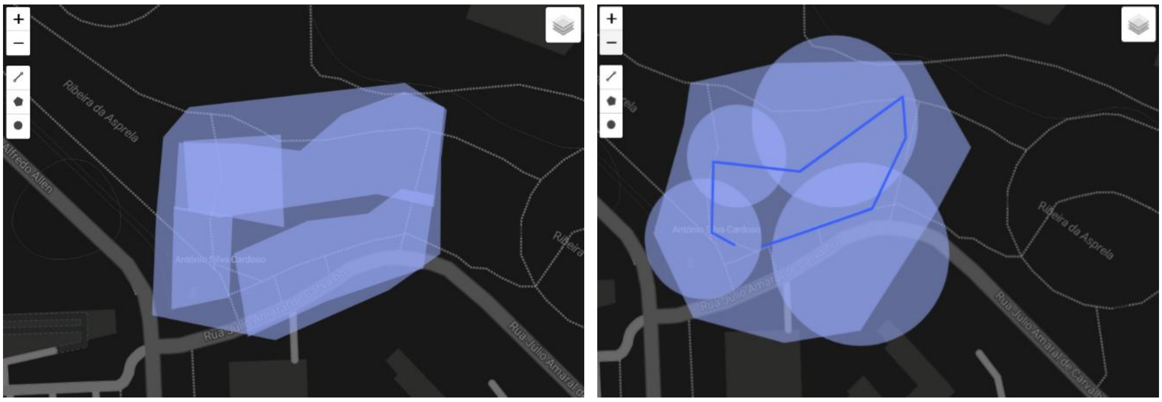

Figure 8. Echoes soundwalk v1 and v2 (browser)

After completing the sound mapping and configuring the audio zones on the Echoes web platform, the next step was to publish the soundwalk. Publishing made the project accessible via the Echoes mobile app, allowing me to test and experience the soundwalk in real time using the phone GPS.

Four different GPS-based locations were established along the walking path as part of the sound mapping procedure. Each of these locations was assigned a unique sound, carefully selected to reflect the specific sonic characteristics or emotional atmosphere of that point in the route. In addition to the four location-specific sounds, a continuous ambient sound was also included throughout the entire path. This sound plays along the entire soundwalk to reflect the natural environment of the park and provide a consistent atmospheric layer. The selected sounds were chosen to closely match the elements of my soundscape composition. These included the sounds of cars, a river, birds, and people talking. And the continuous sound was wind and birds.

Although arousal (activation level) and valence (pleasantness) are the two main dimensions along which Russell's Circumplex Model of Emotion arranges emotions, my soundwalk experience created through the Echoes app takes a more spatial and contextual approach to emotional engagement. Rather than directly mapping sounds to these emotional dimensions, my version was designed to maintain a neutral emotional tone. Instead of explicitly manipulating arousal or valence, the soundwalk uses location-triggered auditory cues to produce place-based atmospheres and emotional tones, such as social energy from talking people or tranquility from the river.

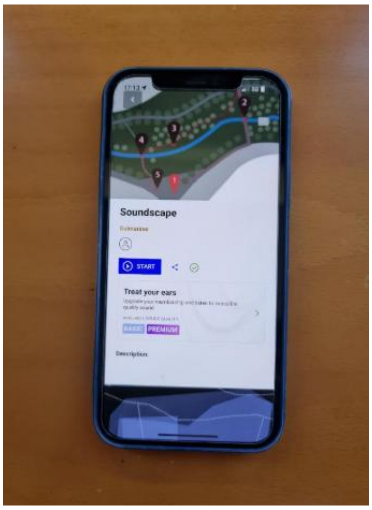

Figure 9. Echoes App

4. Evaluation and Results

4.1 Evaluation

Participants were instructed to walk the predefined route under similar environmental conditions on two separate occasions, ideally with some time in between to minimize memory bias. No explicit instructions were given regarding how to respond to the audio, to allow for natural and personal engagement with the soundscapes.

Following the completion of both walk iterations, participants were invited to consider and evaluate their experiences through a survey form:

4.2 Perceived Sound Sources

First participants were asked about what sound sources did they remember most vividly in each soundwalk:

Table 3. Perceived sound sources results

Sound Types	**Traditional Soundscape**	**GPS-triggered soundwalk**
Wind	0 Participants	0 Participants
Cars	1 Participants	0 Participants
River	2 Participants	4 Participants
Birds	2 Participants	1 Participants
People	0 Participants	0 Participants
Other	0 Participants	0 Participants

In the results of the table 3 the recall of river sounds was the most obvious difference, where only two participants in the traditional soundscape recalled river sounds, while four in the GPS-triggered version. This implies that the river sound felt more present due to location-based triggering. This is probably explained by the fact that the sound was highly associated with its actual location, which increased its perceptual sensitivity during the walk.

Two participants in the traditional version noticed birdsong, while only one person did so in the GPS version. This could be due to variations in time or spatial context.

It is noteworthy that car sounds were recalled by just one participant, and exclusively in the traditional soundscape. The remaining sound sources, such as wind, people, and other ambient elements, were not mentioned by any participants in either version.

4.3 Perceived affective qualities

Each participant was asked to rate how well the following affective qualities—pleasant, annoying, tranquil, chaotic, and lively—described their soundwalk experience.

These responses were measured using a 7-point scale where 1 is "not at all" and 7 is "completely".

Table 4. Perceived affective qualities results

	Pleasant		Annoying		Tranquil		Chaotic		Lively	
Participant	Trad	GPS	Trad	GPS	Trad	GPS	Trad	GPS	Trad	GPS
1	6	4	1	3	4	4	2	2	6	3
2	4	6	4	2	4	5	2	2	4	7
3	5	5	3	3	4	4	3	2	3	6
4	7	4	2	5	5	2	2	6	3	5
5	7	3	2	5	5	3	2	6	7	6
Mean	**5,80**	**4,40**	**2,40**	**3,60**	**4,40**	**3,60**	**2,20**	**3,60**	**4,60**	**5,40**
STD	**1,17**	**1,02**	**1,02**	**1,20**	**0,49**	**1,02**	**0,40**	**1,96**	**1,62**	**1,36**

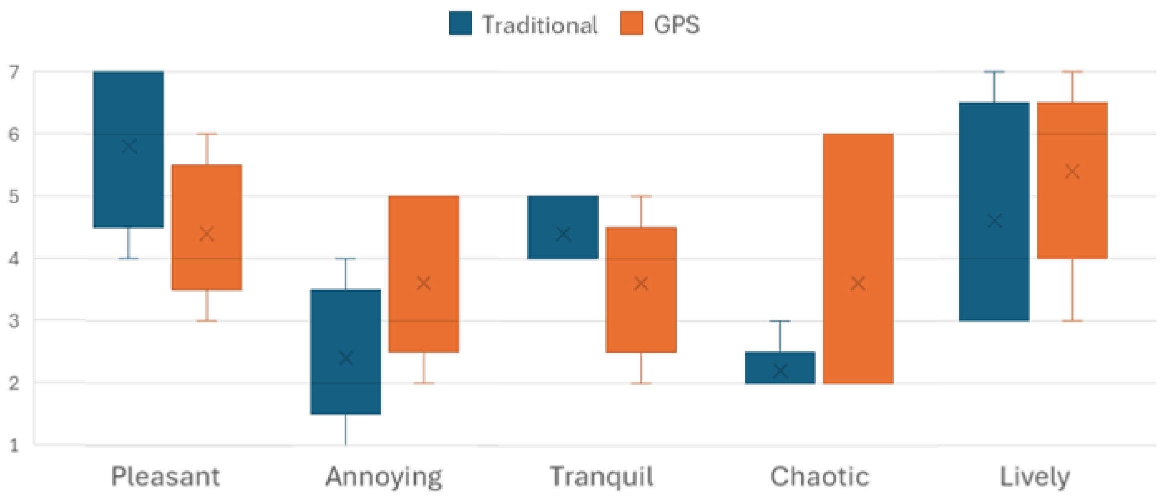

Figure 10. Perceived affective qualities (box plot)

The Traditional soundwalk received higher ratings on **Pleasant** and **Tranquil** and lower ratings for **Annoying** and **Chaotic**. In contrast, the GPS-triggered version showed the opposite layout of the results, receiving higher ratings for **Annoying** and **Chaotic**, and lower scores for **Pleasant** and **Tranquil**. In terms of the quality **Lively** the GPS version has higher results.

4.4 Emotional Response

Participants were asked to score their emotions using semantic differential measures to determine the emotional impact of each soundwalk. As indicated in table, these were measured using a 7-point bipolar scale.

Each scale went from one extreme of emotion to the opposite, such as **Calm to Excited**, **Happy to Sad**, and **Tense to Relaxed**. Immediately following each soundwalk, participants chose a number on a range of 1 to 7 to indicate how they felt.

To understand better the scale is interpreted like for exemple 1 represents the most extreme feeling on the left side of the scale (completely calm, extremely happy, deeply tense), while 4 indicates a neutral emotional state. On the right side of the scale, 7 represents the most intense emotion (entirely excited, very sad, completely relaxed).

Table 5. Emotional response results

	Calm---Excited		Happy---Sad		Tense---Relaxed	
Participant	Traditional	GPS	Traditional	GPS	Traditional	GPS
1	2	4	4	5	4	3
2	3	2	4	2	5	6
3	1	4	2	4	7	2
4	2	3	4	3	6	4
5	2	3	3	4	6	3
Mean	**2,00**	**3,20**	**3,40**	**3,60**	**5,60**	**3,60**
STD	**0,63**	**0,75**	**0,80**	**1,02**	**1,02**	**1,36**

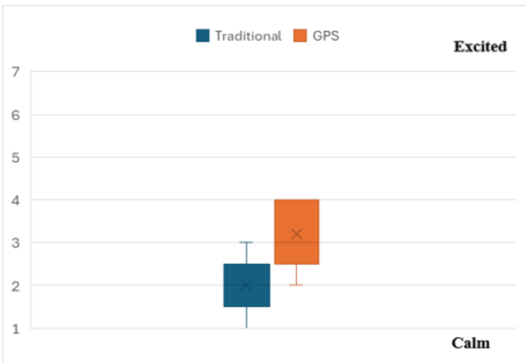

Figure 11. Calm to Excited (box plot)

Figure 12. Happy to Sad (box plot)

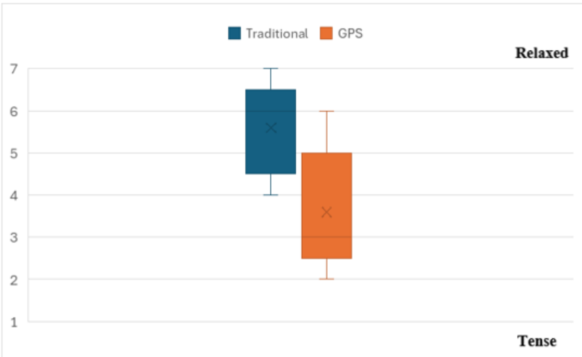

Figure 13. Tense to Relaxed (box plot)

In the emotional response ratings, participants reported feeling calmer and more relaxed after experiencing the Traditional soundwalk. On the other hand, the GPS-triggered version showed lower ratings for relaxation and indicating slightly higher tension, but also higher excitement.

The **Happy–Sad** scale showed minor differences, with the GPS version trending slightly toward the sadder or more neutral side. while the traditional version offers a more stable and calming auditory journey.

4.5 Perceived Veracity/Authenticity

Similar to the emotional response section, a 7-point scale was used to gather a Perceived Veracity/Authenticity assessment from participants to determine how real or fake each soundwalk felt. Participants were asked to rate their experience with 1 meaning "Not at all authentic", 4 as neutral and 7 being "Completely authentic.

This made it possible to understand how well each soundwalk matched actual expectations of sound in space in an accurate way.

Table 6. Perceived veracity/authenticity results

	Not at all authentic --- Completely authentic	
Participant	Traditional	GPS
1	5	1
2	3	4
3	6	5
4	6	4
5	6	3
Mean	**5,20**	**3,40**
STD	**1,17**	**1,36**

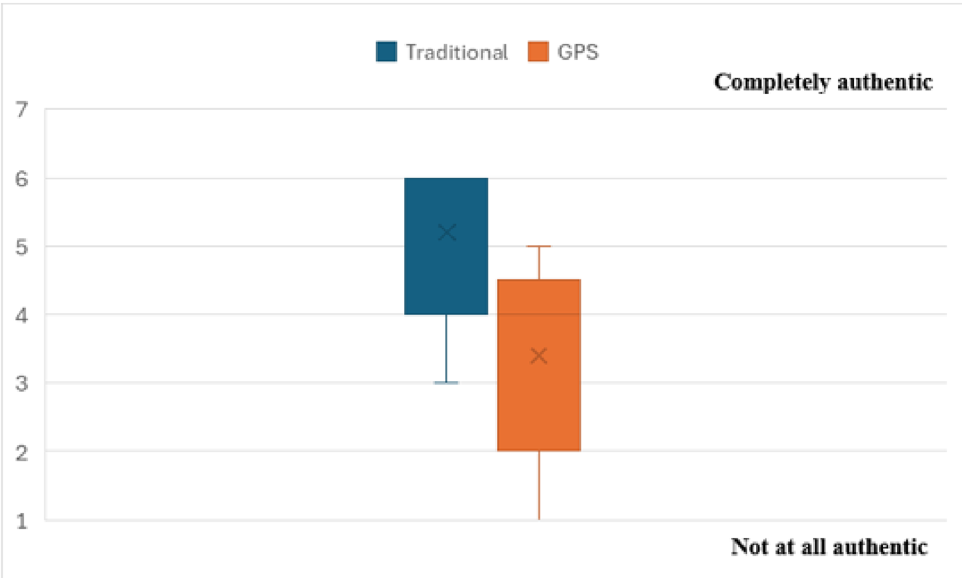

Figure 14. Perceived veracity/authenticity (box plot)

According to the results, participants rated the GPS-triggered version of the soundwalk as less realistic or natural than the traditional version, which was generally thought to be more authentic.

5. Discussion

The purpose of this study was to analyse the emotional response, perceived affective qualities, and authenticity of two different kinds of soundwalks: a traditional linear soundscape and a GPS-triggered version that uses Echoes.

The conclusion that is taken from this is that in the traditional version, the sounds feel more evenly distributed across the route, while in the GPS-triggered version, certain sounds feel more intense or concentrated at specific locations. This difference stems from the fact that the traditional version was linear, meaning that all participants heard the same sequence of sounds, regardless of their movement or position. As a result, the auditory experience was consistent across users. In contrast, the GPS-triggered version depended on the participant's physical location and timing, making the experience more dynamic and personalized, but also more variable between individuals.

The two versions also differ a lot from each other in terms of qualities. The Traditional soundwalk was rated lower for annoyance and chaoticity and was generally thought to be more pleasant, tranquil. This suggests that its linear, consistent structure allowed for a smoother and more relaxing experience, as all participants heard the same curated flow of sounds regardless of their physical position.

The GPS-triggered version, on the other hand, was viewed as being more annoying but also more chaotic. This suggests that, despite being dynamic and interactive, location-based interactivity may also bring emotional unpredictability, particularly if sound triggers happen suddenly or without clear surrounding context.

Notably, the GPS version received higher ratings for Liveliness, implying that participants perceived it as more engaging, even if it came at the cost of their relaxation. These results support the idea that spatial sound mapping can intensify emotions, but if not properly balanced, it may also downgrade the experience. This might be partially because some of the sounds from Freesound.org are either intended to play in a loop or have inaccurate durations, which might alter the accuracy of the walk.

When making the analyses of the emotional response a similar pattern to the Russell's circumplex model was in the mind even though the arousal and valence were not directly measured. This led to an analysis of concepts such as Calm-Excited, Happy-Sad and Tense-Relaxed.

Following the Traditional soundwalk, participants reported feeling calmer and more relaxed, with higher emotional response ratings indicating greater emotional comfort. However, the GPS-triggered variant displayed higher excitement ratings, implying greater stimulation, and lower relaxation ratings, suggesting slightly higher tension.

Through this analysis, it was determined that the Traditional soundwalk is the most suitable format for carefully addressing sensitive subjects like genetic cancer because it provides a more steady and emotionally supportive experience.

In the open feedback section, some participants shared additional impressions. Several notes that in the GPS version, the bird sounds felt unnatural or artificial, which made the overall soundscape feel somewhat confusing when the sound of birds play. Another recurring comment was that the Traditional version felt more natural, but also somewhat monotonous, lacking the variation or interactivity of the GPS-triggered experience.

6. Conclusion

Through a examination of the state of art, sound design, located generative soundscapes, and health communication strategies, we gained valuable insights into the technical aspects of our project. I created a strong theoretical framework for my study and prototype development by drawing on relevant works in emotion modelling, location generated soundscape.

Understanding how various sound distribution techniques impact users' feelings, perceptions, and experiences during the walk was the goal. So, the development of both versions (Traditional and GPS-Triggered) highlights the role of soundscapes and location-based mapping in shaping immersive experiences.

In conclusion, this work represents a significant contribution to the field of augmented reality applications for health communication, particularly in the context of addressing hereditary cancer risks, other field are experimental music and soundscape within a soundwalk perspective.

The incorporation of procedural generation techniques to automatically produce the coordinates of soundwalk points based on the user's location will be a significant component of this project going forward. This procedural generation approach presents a significant challenge but holds immense potential in enhancing the user experience by dynamically adapting the soundwalk to the user's surroundings. Implementing procedural generation, users will be able to initiate the soundwalk from any location.

Furthermore, incorporating music and soundscapes into the soundwalk will be essential for improving mental engagement and immersion. This will enrich the story by introducing a variety of musical styles meant to evoke different feelings. Also, leveraging soundscapes generated from Freesound in specific locations will further enhance the realism of the soundwalk

Future developments will focus on implementing a system that will automatically create a soundwalk experience based on where the user is and how they move, instead of following a fixed, pre-set route.

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8. Annexes

8.1 Annex 1: Link for Both Version

Link for the Traditional Version:

https://drive.google.com/file/d/1TuzX6fOn3Cd0htK_ZsEHGGVVsrfWbaeG/view?usp=sharing

Link of the GPS-Triggered version:

V1: https://explore.echoes.xyz/collections/fMV8UzGJ41f8zxqG

V2: https://explore.echoes.xyz/collections/nK9YBv7RhIvBQgar

8.2 Annex 2: Survey Form

Soundwalk Survey Form

Participant ID: __________ Date: __________

Route: [ ] SoundWalk #1 [ ] SoundWalk #2

Age: ________

Gender: [ ] Woman, [ ] Man, [ ] Non-binary, [ ] Prefer not to say

Expertise:

[ ] Professional musician, sound designer, or audiovisual producer

[ ] Training in music, sound design, and audiovisual production, without greater professional experience

[ ] No training in music, sound design, and audiovisual production

1. Perceived Sound Sources

What sound sources did you remember most vividly in the soundwalk?

2. Perceived Affective Qualities

Please rate how much each of the following qualities best describes the experience of the soundwalk.
Scale: 1 = Not at all • 7 = Completely

Quality	1	2	3	4	5	6	7
Pleasant	○	○	○	○	○	○	○
Annoying	○	○	○	○	○	○	○
Tranquil	○	○	○	○	○	○	○
Chaotic	○	○	○	○	○	○	○
Lively	○	○	○	○	○	○	○

3. Emotional Response

How did the soundwalk make you feel?

Calm ○ ○ ○ ○ ○ ○ ○ Excited

Happy ○ ○ ○ ○ ○ ○ ○ Sad

Tense ○ ○ ○ ○ ○ ○ ○ Relaxed

4. Perceived Veracity/Authenticity

How natural or authentic did this soundscape feel to you?

Not at all authentic ○ ○ ○ ○ ○ ○ ○ Completely authentic

5. Open Feedback (optional)

1) Did anything feel unnatural or artificial?

2) Any final comments on the overall experience?