Journal of the Brazilian Computer Society, 2026, 32:1, doi: 10.5753/jbcs.2026.6576

FeelIt: A Tool for Expressing Real-Time Emotions and Its Influence on the Audience Experience

Genildo Gomes [**Federal University of Amazonas (UFAM)** | ***genildo.gomes@icomp.ufam.edu.br***]
Fernando Nogueira [**Federal University of Amazonas (UFAM)** | ***fernandonogueira@icomp.ufam.edu.br***]
João Gustavo Kienen [**Federal University of Amazonas (UFAM)** | ***gustavokienen@ufam.edu.br***]
Bernardo Scarambone [**Eastern Kentucky University (EKU)** | ***Bernardo.scarambone@eku.edu***]
Desiree Scarambone [**Eastern Kentucky University (EKU)** | ***Joyfullynoisy@yahoo.com***]
Leandro Galvão [**Federal University of Amazonas (UFAM)** | ***leandro@icomp.ufam.edu.br***]
Tanara Lauschner [**Federal University of Amazonas (UFAM)** | ***tanara@icomp.ufam.edu.br***]
Igor Steinmacher [**Nothern Arizona University (NAU)** | ***igor.Steinmacher@nau.edu***]
Tayana Conte [**Federal University of Amazonas (UFAM)** | ***tayana@icomp.ufam.edu.br***]
Bruno Gadelha [**Federal University of Amazonas (UFAM)**| ***bruno@icomp.ufam.edu.br***]

Institute of Computing, Universidade Federal Fluminense, Av. Gal. Milton Tavares de Souza, s/n, São Domingos, Niterói, RJ, 24210-590, Brazil.

Received: 16 September 2025 • **Accepted:** 02 February 2026 • **Published:** 10 July 2026

Abstract. Live music is not only an artistic expression but also a social encounter in which performers and listeners negotiate meaning. While popular concerts often embrace this exchange through collective gestures and technological mediation, classical recitals usually preserve a strictly passive audience role. This work investigates how digital interaction can bridge this gap. We designed FeelIt, a mobile and web-based application that transforms spectators' emotional responses into visual projections, thereby integrating the public into the concert atmosphere without altering the music itself. The system was evaluated during an international piano seminar, where engagement was assessed through direct observation, the User Engagement Scale (UES), and qualitative accounts from both listeners and performers. Audience members highlighted the novelty, aesthetic appeal, and rewarding nature of the tool, though some reported difficulties related to interface design and reaction visibility. Musicians, in turn, emphasized that the visual feedback generated a stronger sense of dialogue with the public and intensified their emotional connection during performance. Beyond reporting empirical evidence, this work contributes by (i) introducing and validating a non-intrusive mechanism for audience participation in classical concerts, (ii) offering insights into how interactive technologies can enrich experiences without compromising artistic integrity, and (iii) providing practical design guidelines for integrating spectators' voices into traditionally passive cultural events.

Keywords: Engagement, Events technolgies, Audience participation, Music performance, Audience experience

1 Introduction

The interaction between audience and artistic performers has been widely explored, focusing on intensifying audience engagement in live events, such as cultural, musical, and performative experiences. Since the 1990s, interactive methods have significantly expanded, applying to a variety of contexts, including educational events [Salovaara *et al*., 2021], musical performances [Oliver Hödl, 2020], sports events [Martins *et al*., 2023], and cultural festivals [Vasconcelos *et al*., 2018; Martins *et al*., 2021]. Instead of a unidirectional experience where the audience acts as observers, interaction fosters a shared experience, where the spectator takes on the role of co-creator of the event [Jacucci *et al*., 2007].

With the advancement of interactive technologies, audience participation and engagement in events have been transformed, enhancing the spectator's experience [Lee *et al*., 2019]. In cultural events, interactive systems enable participants to express their emotions and influence the event's narrative or environment [Martins *et al*., 2021]. Technological tools promote engagement in educational contexts by encouraging student collaboration and active participation [Salovaara *et al*., 2021]. In sports, digital interactions provide a more immersive and connected experience to spectators [Veerasawmy and McCarthy, 2014]. Thus, adopting interactive technologies in different scenarios has enhanced how the audience relates to the event.

In the case of arts and entertainment events, such as musical performances, the audience often manifests their emotions through active behaviors, such as singing along, clapping, or verbally expressing excitement [Otsu *et al*., 2021]. The literature has already documented the use of technologies to enhance audience engagement in these events, promoting interactions that enrich the spectator's experience [Burns, 2016]. For example, Open Symphony allows the audience to control the style of an improvisational music performance through voting [Wu *et al*., 2017]. Similarly, Poème Numérique enables the audience to trigger sounds and colors on their smartphones to create a visual spectacle [Oliver Hödl, 2020]. More recently, light sticks have been used to enhance interaction and enrich the spectator experience during pop concerts [Jia *et al*., 2024].

However, in more formal musical performances, such as orchestra concerts or solo piano recitals, audience participation tends to be more passive, given the traditionally structured nature of these performances.

Designing participation strategies for piano events involves balancing engagement with respect for the musician's performance. Unlike a rock concert or an interactive festival, where the audience's active expression is encouraged, a piano recital requires concentration and technical refinement. Any audience participation mechanism must be carefully designed to avoid negatively interfering with the performance. Therefore, further research is needed to understand how to design participation strategies in the context of formal musical performances, given the traditionally passive nature of such events. Exploring these strategies is essential to provide evidence on new forms of participation and engagement in formal music settings. Gaining perspective on these new strategies helps expand knowledge about designing technologies for audience interaction and engagement in events. It also broadens the vision of event organizers in creating new experiences for audiences through the use of technology.

Given this scenario, the following research question arises: *how can the audience collaboratively contribute to shaping an interactive scenic environment in piano concerts without disrupting the musician's performance?* To address this question, we utilize FeelIt, an application that enables the audience to co-create the visual atmosphere of the event through reactions represented by emojis and short expressions, such as *"bravo"*, *"surprising"*, and *"emotional"*. No prior study was conducted to investigate audience demand for alternative forms of expression. The problem emerged from the practical needs of a classical music event organizer seeking to enhance audience engagement.

The FeelIt application was used during a performance at the International Piano Forum at Federal University of Amazonas. After the application's presentation and use, the audience was invited to answer a questionnaire based on the User Engagement Scale (UES) instrument. The collected data were analyzed, and the results indicate a positive reception of this type of application. In general, the audience appreciated the ability to express their emotions in real-time during the event. However, as a primary negative aspect, participants highlighted that the application's visual design could be more appealing.

In this paper, we explore this collaborative experience and investigate how these interactions can transform the audience experience without compromising the musician's execution, offering an innovative approach to audience participation in traditional musical performances. Thus, we contribute to Software Engineering and Human Computer interaction as follow: Firstly, we propose and validate Feelit, an application that enables the audience to co-create the visual atmosphere of the event through reactions represented by emojis and short expressions. Secondly, we offer insights into how technology influences audience engagement during musical performances, emphasizing the importance of user experience, real-time interaction, and engagement elements in enhancing audience participation. Finally, our findings provide practical guidance for event organizers or researchers to incorporate interaction technology to create engaging experiences for audiences.

This paper is an extended version of a paper published by Gomes *et al*. [2025b] in Brazilian Symposium on Collaborative Systems (SBSC 2025).

2 Background

In this section, we present concepts related to events, audiences, and technologies that will be explored.

2.1 Events and Audience

An event is defined in different ways in the event-related literature. Dolasinski *et al*. [2021] defined events as occurrences that have a temporal element, involve two or more participants, are planned, and are unique opportunities.The study of events has been widely explored in the field of tourism, as events are an important motivator for tourism. They stimulate the local economy and improve factors such as accommodations, support services, and transportation [Getz and Page, 2016].

Getz and Page [2016] state that event tourism is an important and rapidly growing segment of international tourism. Moreover, events can bring several benefits to both society and the region. According to Getz and Page [2019], events can attract tourists, help brand or reposition cities, and make urban spaces more attractive and efficiently used. Biaett and Richards [2020] highlights that events are about experiences, where spectators are motivated to participate because of a special interest in that experience.

Such experiences depend on the type of event in which participants are involved [Biaett and Richards, 2020]. Different emotions and cultural contexts can shape different experiences. For example, sporting events carry a high level of audience energy, similar to music festivals where participants may shout or jump, while business events are focused on exchanging information or acquiring services and products. Therefore, the nature of the event directly influences the audience experience. Dashper and Buchmann [2020] points "research on event experiences needs to move beyond the focus on individual responses and reflections on personal experiences, and to try and account for the social and collective aspects of those experiences." Understanding the types of events is essential for designing and providing better experiences.

Getz [2007] discusses the concept of planned events, which are organized with the main goal of creating meaningful experiences for participants. He proposes a categorization of these events based on their characteristics and functions:

- **Cultural celebrations:** Related to the culture or tradition of a region, people, or community, such as festivals, carnivals, heritage celebrations, parades, and religious rites.
- **Political events:** Produced by governments or political parties, such as rallies, inaugurations, and royal weddings.
- **Arts and entertainment:** Events whose main goal is to provide pleasure and fun, such as art exhibitions, music concerts, and food festivals.

- **Commercial events:** Aimed at promoting, marketing, or directly engaging in commerce, such as trade fairs, product launches, and business conferences.
- **Educational events:** Focused on creating and exchanging knowledge, such as symposiums, workshops, and conferences.
- **Sporting events:** Involving games and competitions, such as soccer matches, the Olympics, and races.
- **Recreational events:** Non-competitive, playful events, usually organized by parks, non-profit organizations, churches, or schools.
- **Private events:** Planned for a restricted group, like family or friends, where the theme and emotional stimulation are essential, such as birthdays and weddings.

During event planning, it is crucial to consider the needs and behaviors of the expected audience to build more meaningful experiences. Mackellar [2013] discusses the importance of understanding the behavior of an event's audience to meet their needs and expectations, proposing a categorization of audiences based on size, purpose, and level of interest:

- **Mass audience:** Interested in the collective excitement of large-scale events, such as Tomorrowland and the World Cup.
- **Special interest audience:** Seeks events related to specific interests, such as fan conventions, jazz festivals, and car exhibitions.
- **Community audience:** Participates in events related to historical and local traditions, such as fairs and craft markets.
- **Incidental audience:** Spontaneous participation due to sudden interest or curiosity.
- **Media audience:** Follows events, usually sports, through TV, radio, and social media broadcasts.

2.2 Technologies and Audience experience

Events have different characteristics that allow audiences to express themselves in various ways depending on the type and context of the event. For example, in lectures or educational events, the audience engages by asking questions, while in sports events or music festivals it is common for the audience to clap or jump. Additionally, events can take place in different formats, such as in-person, remote, or hybrid, which shape how engagement occurs. In this sense, researchers have explored how audience experience can be altered across different types of events based on various factors.

In educational events, it is common to use backchannel systems, which enable a secondary, often discreet, conversation to run alongside a primary activity such as a lecture or presentation [Salovaara *et al*., 2021]. In addition, tools like Kahoot, Mentimeter, or Quizizz are used to promote competitive and collaborative dynamics during interactive lectures or classes. These tools range from creating quizzes, polls, and surveys to creating and storing documents or assignments [Andriani *et al*., 2024]. For example, Duvignau [2025] investigates the effects of Kahoot and Mentimeter on student engagement, boths inscresead the student engagement and shows to be a valuable active learning.

In the context of sports events, competition between teams has been explored through digital banner battles during soccer matches [Veerasawmy and Iversen, 2012]. More recently, research has investigated how to deliver immersive experiences using virtual reality for spectators [Cheng *et al*., 2022; Lo *et al*., 2021]. In addition, with the rise of remote sports events, studies have begun to examine how interactive platforms influence audience engagement and media consumption.

2.3 E-Tax taxonomy perspective

Technologies have enriched audience experiences across different event contexts. The inherent characteristics of each event shape how interaction and participation unfold through technology. Factors such as the type of event, its location, and its format can guide the design of these technologies. Understanding how technology influences the audience experience is essential for creating interactions that are more engaging, satisfying, and memorable. Moreover, this understanding supports the design process, helping to develop interaction strategies that address different audience profiles.

In this context, Gomes *et al*. [2023] proposed E-TAX, a taxonomy designed to support the understanding of concepts related to audience experience across different events. Later, Gomes *et al*. [2025a] expanded the use of E-TAX by conducting a study to explore how it can characterize experiences in events involving technological interaction. E-TAX broadens the knowledge of designers and event organizers by showing how audience experience can be manifested or perceived through the use of technology. The taxonomy is structured around three main lenses: Engagement, Participation, and Liveness.

The Engagement lens brings together concepts related to audience behaviors and reactions during an event. Gomes *et al*. [2025a] organizes these concepts based on the scale of the audience: crowds, defined as large groups gathered in one place; audiences, which are smaller groups that do not necessarily form a crowd; and spectators, representing the individual perspective of event participants. From the perspective of crowds, as commonly seen in stadiums or concerts, the authors highlight the concept of collective effervescence, the shared feeling of excitement, unity, and emotional connection experienced by a group in the same space or event [Otsu *et al*., 2021]. For smaller audiences, engagement is often associated with concepts such as arousal and valence [Latulipe *et al*., 2011]. At the individual level, the Spectator unit emphasizes personal experiences, including immersion, immediacy, interactivity, and sociability [Haimson and Tang, 2017].

The Participation lens helps characterize audience involvement through units of analysis such as time, space, motivation, and qualities of participation. The time unit supports the observation of how the audience engages both during and after the event [Cerratto-Pargman *et al*., 2014], while the space unit highlights how the physical or virtual setting of the event can shape the audience's experience [Wu *et al*., 2017]. The motivation unit addresses why the audience may choose to participate, whether through competitive or collaborative dynamics [Martins *et al*., 2021]. Finally, the quality of participation unit reflects how the audience may be constituted or display

distinct reactions throughout the event [Cerratto-Pargman *et al*., 2014].

The Liveness lens focuses on real-time shared experiences and highlights the feeling of being present at an event [Robinson *et al*., 2022; Webb *et al*., 2016]. It includes the analytical units of Flow [Mueser and Vlachos, 2018] and Presence [Kim, 2017]. Presence refers to the degree of attention spectators devote to the event and encompasses aspects such as Co-presence [Haimson and Tang, 2017] and Immediacy [Haimson and Tang, 2017].

3 Related Work

As previously discussed, several studies in the literature explore audience participation in various event contexts. Audience participation in musical performances has been extensively studied, with various approaches exploring how technology can enhance engagement and interactivity. Traditional concerts often treat audiences as passive spectators. Still, recent advancements in human-computer interaction and interactive music systems have challenged this notion, introducing innovative ways for audiences to participate in performances actively.

One example is Open Symphony [Wu *et al*., 2017], which enables audiences to influence live music performances by voting for different musical modes (typological music attributes). This system facilitates real-time collaboration between performers and audiences through mobile technology and data visualization, allowing spectators to become co-creators of the musical experience. Similarly, the Crowd in C system [Lee *et al*., 2019] incorporates social interaction to sustain engagement in large-scale participatory music performances. Using mobile music instruments, the system enables audiences to collaboratively create musical pieces while exploring the impact of social dynamics on engagement.

Another approach to audience participation in live music events is using smartphones as interactive tools. Oliver Hödl [2020] investigated large-scale audience participation using smartphones, highlighting the potential of mobile devices to serve as both musical instruments and interaction platforms. Their findings suggest that while smartphones provide new opportunities for engagement, maintaining artistic control remains a critical challenge. Additionally, Araújo *et al*. [2022] introduced a collaborative experience where audiences influenced the sequence of musical pieces during a scientific event's networking session. This work emphasized the importance of real-time interaction and engagement in informal musical settings.

Despite these advances, challenges remain in designing interactive music experiences that balance audience engagement with the integrity of a performance. Many existing systems focus on direct audience manipulation of sound or musical structure, which may not be suitable for more structured or classical settings, such as piano recitals. Our work differentiates itself by exploring how audience reactions, represented through emojis and short expressions, can collaboratively shape the visual ambiance of a live piano concert without disrupting the musician's performance. By leveraging the FeelIt application, we provide a novel approach to audience participation that preserves a classical performance's aesthetic and technical demands while enhancing engagement through real-time interactivity.

4 Feelit: A tool for expressing reactions in interactive orchestras

This section presents the design process of FeelIt. From the Double Diamond design process perspective, the section 4.1 comprises the Discover and Define steps. The Discover phase comprises the exploration phase, during which problems and opportunities are identified. The Define phase comprises problem analysis aimed at finding a solution. In the section 4.3, we present the Development phase, including information about FeelIt, the solution chosen for development.

4.1 Designing FeelIt

The Feelit idea emerged during the event Define phase. We carried out a design workshop with four participants: an event manager, a developer, and two researchers. A workshop is a collaborative method to gather data from participants about an innovation or topic under investigation [Storvang *et al*., 2017]. The researchers are specialists in audience engagement using technologies in different events. The event organizer has 30 years of experience planning and organizing music events.

The workshop session was split into two phases. In the first phase, we detailed the event information. Initially, participants were asked to provide their consent through the Informed Consent Form (ICF)[1]. The event under study is an orchestra rehearsal. An orchestra is a musical event conducted by a large ensemble of instruments from various families (e.g. Violin, Cello, Flute or Trumpet) [Broder, 1960]. The primary objective is the "Amazonas Philharmonic Performance," which aims to provide an orchestra presentation for high school students at the local Amazonas Theater in Manaus, Amazonas. One of the researchers shared the Draw.io tool screen through a digital board (Samsung Smartboard), so that all session participants could view it. Draw.io [2] is a tool for creating diagrams, including network diagrams and UML models. To support the ideation process, drawings were made on the board, where the event information was described.

The audience for this event is of special interest because it is a specific public. Their behavior is described as passive; they are typically seated, listening, and they applaud at certain times. After collecting information about the event and the audience, we began the second phase.

In the second phase, a discussion was initiated about the event's timeline of activities and possible technologies to be used. In this sense, an event timeline was drawn to fill the main event information. The event was scheduled to last for three hours, from 9:00 AM to 12:00 PM. The event includes six main activities: the transportation of the students to the venue, the audience's entry into the theater, the first part of

[1]This research was approved by the Ethics Committee under Certificate of Presentation for Ethical Consideration (CAAE), process: 76726923.4.0000.5020

[2]Draw.io link: https://www.drawio.com/

the performance, a short intermission, the second part of the performance, and the closing of the event.

Below the event timeline, we also designed three lanes to better detail the ideas and technologies. The lanes were based on the taxonomy lenses in Gomes *et al*. [2025a]. The Participation lane represents opportunities for interaction, and it's where the user describes the main idea of a technology that encourages audience participation. The Liveness lane represents the transmission of results that reflect this participation, and the user must detail how the audience perceives the outcome of their interaction. The Engagement lane reflects how and what kinds of emotional reactions can occur when the technology is used.

Based on the event's activities, we identified five Interaction Opportunities (IOs). During the first part of the event, we determined the following opportunities: (IO 01) random virtual scenery, (IO 02) collaborative virtual scenery, and (IO 03) collaborative repertoire.

From these options, IO 02 was chosen for the event. This collaborative virtual scenery application lets the audience send emoticons to represent their emotional reactions. The results are displayed on a large screen behind the orchestra, allowing everyone to see the audience's emotions during the performance. Engagement is measured by the number of interactions within the app, specifically through emoticons and predefined words displayed on the screen. This IO2 was selected by the event manager based on its feasibility for development, cost and its potential as the most suitable option for audience interaction.

The results of this dashboard are presented in the Figure 1. The figure presents the timeline of events designed by the event manager. It is organized into four lanes. The first lane shows the event timeline, including the main activities. The timeline colors are illustrative and may be adapted to suit the specific context of each event. The start of the event is represented by an empty circle, while the end of the event is indicated by a circle containing an "X" at its center. The second lane represents Participation according to the E-Tax taxonomy, describing the primary purpose of the artifact used. The third lane represents Liveness, which is associated with feedback, and describes how the audience perceives the use of the artifact. The fourth lane represents Engagement within the E-Tax taxonomy, describing the behaviors or emotions that the audience may exhibit.

4.2 Designing the audience experience

Recognizing the impact of technology on audience experience is essential for designing interactions that deliver more engagement, satisfaction, and lasting memories. Based on the taxonomy proposed by Gomes *et al*. [2023], we characterized technological interaction through the lenses of Engagement, Participation, and Liveness. It is important to note that not all concepts associated with these lenses can be applied to describe the audience experience.

With respect to the Engagement lens, FeelIt is designed for medium-scale audiences (a couple of hundred) [Hödl and Turchet, 2025], meaning it is not intended for large crowds. The Audience lens incorporates concepts of Arousal and Valence. Arousal refers to the level of emotional intensity the audience experiences during an event [Latulipe *et al*., 2011], while Valence refers to positive and negative feelings [Latulipe *et al*., 2011]. In the case of FeelIt, arousal can be observed through the reactions triggered during the event, which may reflect the audience's excitement. Reactions such as "heart" or "love" can represent positive responses, while reactions like "angry" or "sad" can represent negative ones. From the spectator's lens, Interactivity and sociality stand out. Interactivity concerns how Immediacy occur and whether they enhance or hinder the audience experience. In this case, interaction occurs through a web application that allows the audience to submit reactions that reflect their emotions. Immediacy reflects the experience of following the event in real time. Accordingly, reactions sent through FeelIt are displayed instantly, creating an immersive virtual environment.

Regarding the participation lens, when analyzing participation in relation to the event space, FeelIt was designed for use with a local audience, where the event takes place in a physical space and the audience is co-located. However, since FeelIt is a web application, its use with remote audiences still needs validation. The E-Tax taxonomy considers the audience's perspective as part of the event space, such as how the audience's position within the venue can influence participation. In the case of FeelIt, however, participation does not depend on specific positions in the physical space. Considering the qualities of participation, the epistemic quality stands out, since the reactions sent by users can represent each spectator's experience. In this way, every participant can view the audience's collective reactions to the performance.

At the same time that users participate through FeelIt, they also collaborate toward a shared goal. This goal is expressed by sending reactions that collectively create a visual spectacle during the performance. FeelIt does not include any features designed to promote competitive dynamics among the audience.

Regarding the Liveness lens, FeelIt is designed to be used in real time, where reactions are immediately reflected in the visual environment. This interaction can influence the sense of Presence, that is, the degree of attention spectators devote to the event. Through audience participation, the engagement and focus fostered by FeelIt may also trigger the concept of Flow.

All these concepts help characterize the audience's experience at an event. Although not all concepts may be applicable, the taxonomy provides insight into how technology can shape audience participation. Event researchers and organizers can use it to better understand the impact of technology on the spectator's experience. In this sense, researchers may apply the taxonomy as a lens to interpret and analyze results.

4.3 Developing FeelIt App

To explore how the audience can actively shape an interactive scenic environment in piano concerts without disrupting the musician's performance, we developed FeelIt, an application designed to enable real-time interaction between performers and spectators. Traditional classical music concerts often feature passive audience behavior, with engagement limited to applause at the end of a performance. Advances in interactive technology offer new ways to enhance audience participation

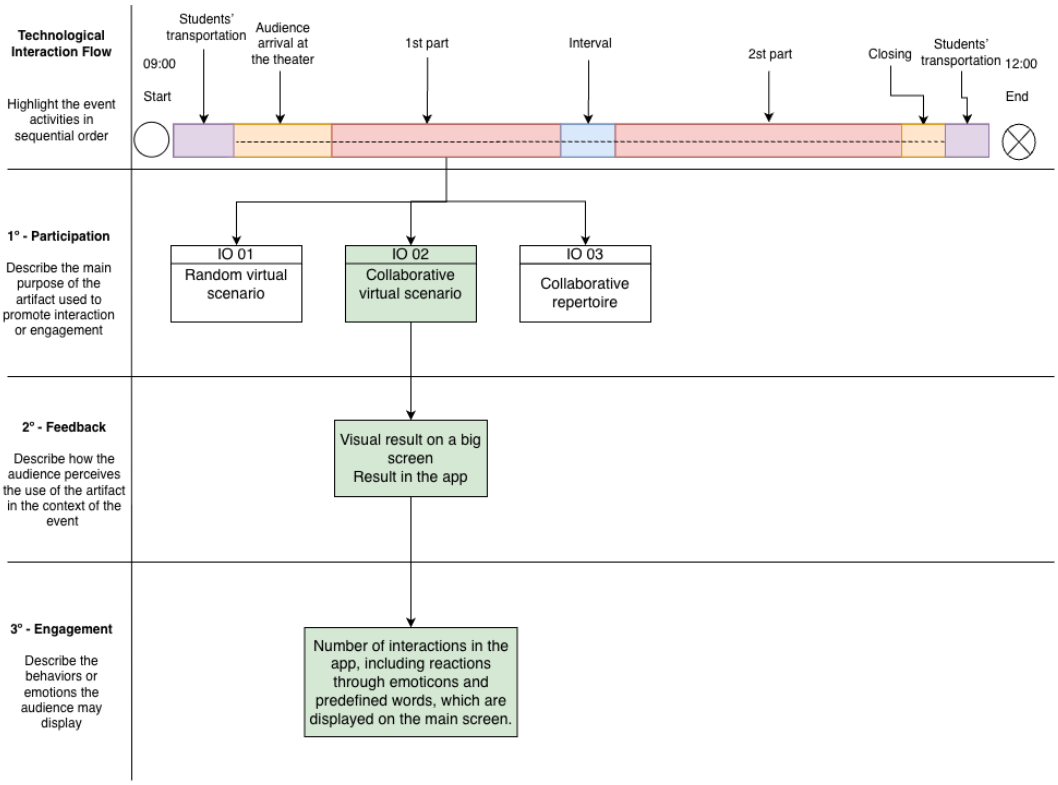

Figure 1. Workshop session results

while preserving the integrity of live performances. FeelIt was created to address this need, allowing spectators to express their emotions visually and dynamically throughout a recital, fostering a more immersive and participatory experience.

With the idea defined, weekly meetings were conducted with the developer team to guide the FeelIt design. The team included two researchers, one developer, and two musicians (stakeholders). One musician was the decision-maker, while the other focused on validating FeelIt. The weekly meetings were intended to check with stakeholders the fulfillment of the defined requirements for the tool and to gather their feedback. For example, one of the discussion topics was how musicians would perceive FeelIt results while playing their instruments, since they don't see/perceive/feel the audience's response. To avoid distraction and high cognitive load, we decided not to show this feedback to the musician during the performance.

FeelIt was developed as a Web/Mobile application designed to provide an intuitive and seamless way to communicate spectators' emotions during a musical performance and designed to be easy to access through a link/QR code. The FeelIt architecture uses a modular design. The frontend was developed with the React framework and communicates with the backend via HTTPS. The backend is the system's core and is implemented in Node.js. For data persistence, we use a NoSQL (non-relational) database managed by Firebase. Figure 2 illustrates the FeelIt Architecture.

The system consists of two interconnected modules: the Spectator Module and the Feedback Module. The Spectator Module serves as the primary interface for audience interaction, enabling users to select from emoticons and predefined words that best represent their emotions at any moment. The spectator module comprises two screens: the Main screen and the About screen. The Main screen presents a sequence of buttons, represented by emoticons and labels, to support audience interaction. The About screen provides information about how FeelIt can change the audience experience. This module is accessible to the spectators, who can use it on their mobile devices.

The spectators select the reactions in the app, which are sent in real-time to the Feedback Module. This module comprises a single screen that processes and displays the reactions in the concert environment. The main requirements to use this module are an external display (e.g., a second monitor, projector, or LED panel) and a laptop with an internet connection. The Feedback Module ensures that audience emotions are visually represented in a way that enhances the performance without distracting the musician, creating a balanced integration of audience participation. Figure 3 illustrates both the Spectator (A) and the Feedback modules (B).

Although FeelIt supports different reactions, the following reactions were determined by the event manager: Love (Heart), Anger, Applause, and Frustration. Additionally, six words were chosen to express further audience sentiment: Fabulous, Surprising, Brave, Emotional, Confused, and Sad. According to the event manager, these emoticons represent typical audience emotions during a piano concert.

By integrating these two components, FeelIt transforms the traditionally passive concert experience into an interactive and immersive event while maintaining the formal nature of classical music. The following section details the methodology used to evaluate the system and assess its impact on audience engagement.

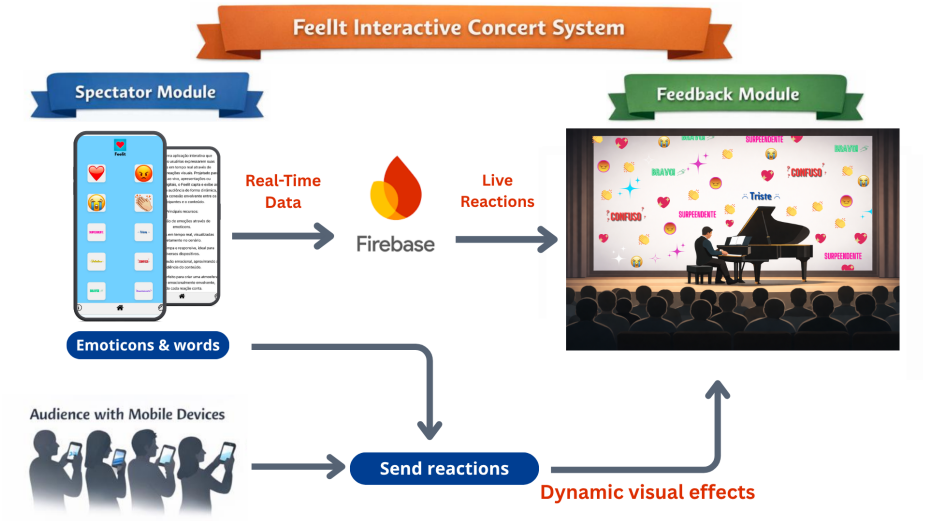

Figure 2. FeelIt architecture. Created by the authors and enhanced with AI.

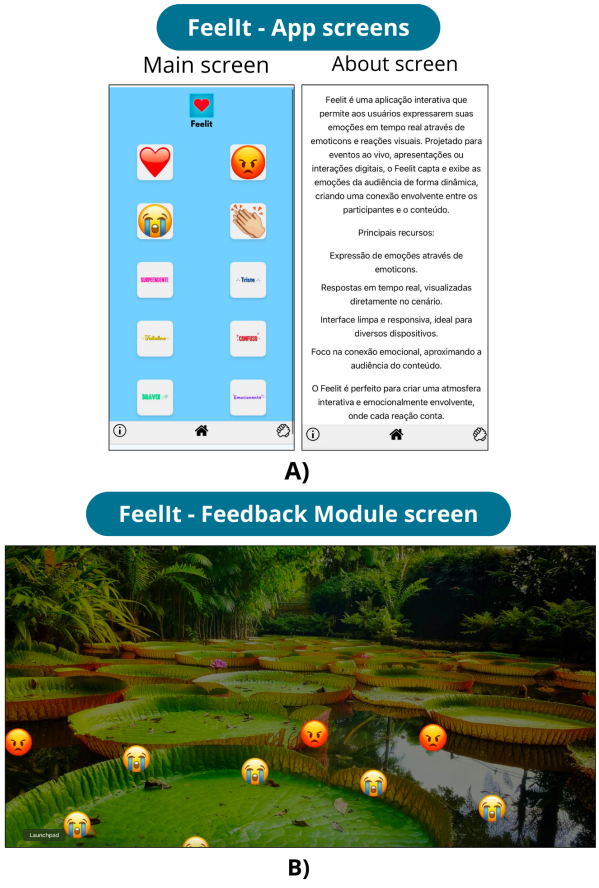

Figure 3. Screens of the FeelIt application. Figure A presents the Spectator Module, which includes the Main and About screens. Figure B shows the Feedback Module, illustrating an example of emerging reactions.

5 Case Study: International Piano Seminar

This study investigates how the audience can collaboratively contribute to shaping an interactive scenic environment in piano concerts without disrupting the musician's performance. We conducted a case study using the FeelIt application during a live piano concert at the International Piano Seminar & 2nd National Seminar on Arts Memory in the Amazon (2024). This setting allowed us to examine how interactive audience participation through FeelIt influences engagement while maintaining the integrity of classical music performance.

The study followed an exploratory case study design, as recommended by Yin [2009], which is particularly suited for answering "how" and "why" questions when researchers have little control over ongoing events. A single-case embedded design was chosen, with the unit of analysis being the audience's interaction with the application during the performance. This approach enabled us to investigate real-time engagement and participation without interfering with the musical execution.

The study took place during a speaker's presentation on arts and technology, followed by a live piano performance. The session began with a presentation on innovative technologies for audience engagement, providing attendees with insights into technological solutions designed to foster interactive experiences. Participants were then introduced to FeelIt, and a QR code was provided for easy access to the application. A brief tutorial was offered to explain its functionalities before the performance commenced.

Participants were encouraged to express their emotions freely using FeelIt during the live piano recital. The app does not limit the number of reactions the users can submit, and their responses, represented by emojis and short text expressions, were projected in real-time as part of the concert's interactive scenic environment. This setup enabled an immersive and collaborative experience, aligning with the study's objective of analyzing audience engagement through technology. Figure 4 illustrates the moment when FeelIt was used during the study, showcasing audience reactions projected in

the background as the pianist performed.

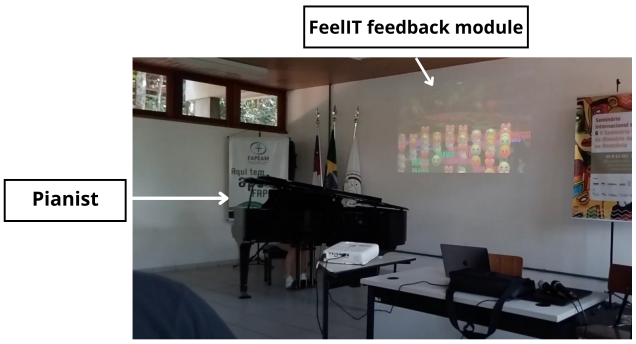

Figure 4. FeelIt in use during the pilot study. A pianist performs while audience reactions are shown in the background.

To enhance methodological rigor, data collection incorporated both quantitative and qualitative methods. Following Yin [2009] principles, multiple sources of evidence were used to enhance validity, maintain a chain of evidence, and create a structured case study database. The primary data sources included direct observations of audience behavior. By observing the audience, we saw how they engaged with FeelIt and reacted to each emotion, and the excitement of being able to express their reactions during the event became clear. We also collected responses from a questionnaire based on the short version of the User Engagement Scale (UES) [O'Brien *et al*., 2018], and open-ended feedback collected from participants regarding their experience with FeelIt, and the musician perspective feedback about the FeelIt use. The performance was recorded and made available online [3]. A total of 55 participants attended the session, and 23 completed the feedback questionnaire.

Data Analysis: Data analysis employed a mixed-method approach, integrating quantitative and qualitative analyses to provide comprehensive insights. Quantitative data from the UES questionnaire were analyzed using descriptive statistics, including frequencies and percentages, to identify engagement patterns across different dimensions (Focused Attention, Perceived Usability, Aesthetic Appeal, Reward Factor).

The UES is a questionnaire used to measure the user engagement with interactive systems, considering human-computer interaction factors [O'Brien and Cairns, 2015; O'Brien *et al*., 2018]. Engaging experiences, such as FeelIt, involve different dimensions. We chose the UES questionnaire due to its capacity to gather initial reactions to technologies and their engagement during the use of technology. This allowed us to assess overall engagement quantitatively and pinpoint the application's specific strengths and weaknesses.

Qualitative data obtained from musician perspective and open-ended feedback were analyzed. The qualitative analysis enriched our understanding by providing context and depth to the quantitative findings, enabling clearer interpretation of participants' perceptions, motivations, and suggestions for improvement.

6 Results

The analysis of the User Engagement Scale (UES) and qualitative feedback provides a detailed understanding of how participants interacted with FeelIt during the piano performance. The findings highlight aspects related to engagement, usability, aesthetics, and the rewarding nature of the experience while identifying areas for improvement. The UES questionnaire data were analyzed and are presented in Figure 5. We structure our results based on the four dimensions of UES.

6.1 User Engagement Scale (UES) Analysis

In the Focused Attention dimension, responses indicate that engagement levels varied among participants. When asked whether they "lost myself in this experience", 12 participants strongly disagreed, 6 disagreed, and 4 remained neutral. Similarly, for "The time I spent using FeelIt just slipped away", 7 participants neither agreed nor disagreed, 3 disagreed, and 3 strongly disagreed, while 4 agreed and 1 strongly agreed. In the statement "I was absorbed in this experience", 7 participants remained neutral, 4 agreed, and 3 strongly agreed, but a considerable portion (9 participants) disagreed or strongly disagreed. These results suggest that while FeelIt engaged some users, it did not fully capture the attention of the majority, as a significant number of participants did not experience deep immersion.

The Perceived Usability category revealed notable usability challenges. The statement "I felt frustrated while using FeelIt" received strong disagreement from 15 participants, disagreement from 6, and only 1 agreement, showing that while most users did not find the tool frustrating, a few struggled. However, in "I found FeelIt confusing to use", 18 participants strongly disagreed, 3 disagreed, and no one agreed, highlight that users had no difficulty using FeelIt. The statement "Using FeelIt was taxing" also reflected similar concerns, with 13 participants strongly disagreeing, 6 disagreeing, and only 3 showing some level of agreement. These findings highlight that FeelIt was not confusing and overwhelming for users.

In the Aesthetic Appeal dimension, it received predominantly positive responses. When asked whether "FeelIt was attractive", 11 participants agreed, 2 strongly agreed, 5 remained neutral, 3 disagreed, and only 2 strongly disagreed. In the statement "FeelIt was aesthetically appealing", 10 participants neither agreed nor disagreed, 3 agreed, 3 strongly agreed, 4 disagreed, and 3 strongly disagreed. In "FeelIt appealed to my senses", 8 participants agreed, 1 strongly agreed, 9 neutral, 3 disagreed, and 2 strongly disagreed, demonstrating that the application's visual design was generally well received. These results suggest that participants appreciated the aesthetic and visual aspects of FeelIt.

The Reward Factor also showed strong positive feedback. When asked whether "Using FeelIt was worthwhile", 11 participants agreed, 5 strongly agreed, 5 remained neutral, and only 2 disagreed. Similarly, in "My experience was rewarding", 8 agreed, 6 strongly agreed, 6 were neutral, and only 3 disagreed. In "I felt interested in this experience", 8 agreed, 6 strongly agreed, 4 were neutral, 3 disagreed, and 2 strongly disagreed. These findings indicate that most users found

[3] FeelIt use record: https://youtu.be/Xe7BZKHWn0k?si=JQ2HD6DDmvRd16di

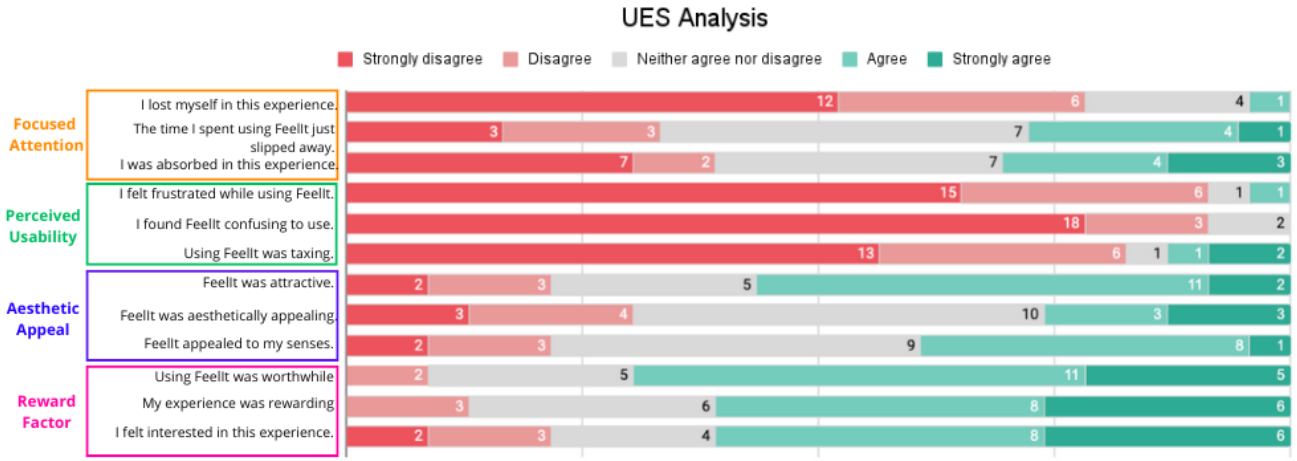

Figure 5. UES analysis based on audience responses collected after the performance using FeelIt.

FeelIt to be a valuable and rewarding tool for engagement during the event.

6.2 Qualitative Feedback Analysis

The qualitative results comprise feedback from open-ended questions collected after the UES items in the questionnaire. In these questions, participants were asked about the difficulty of using FeelIt, its contribution to audience engagement, their self-perception of using FeelIt during the performance, and suggestions for improvement.

The qualitative feedback reinforced these findings while offering deeper insights into user experiences. Most participants described FeelIt as user-friendly, with comments highlighting its simplicity and intuitive design (e.g., "It was simple and easy to use" - P05, "Easy to understand" - P23). However, some reported technical difficulties, such as challenges scanning the QR code ("Reading the QR code was difficult" - P10, "I couldn't scan the QR code" - P16) or typing responses due to interface constraints ("It was somewhat difficult to type" - P13). Additionally, internet connectivity issues occasionally affected user experience ("At the moment, my network was slow, but that has nothing to do with the application" - P20).

Participants consistently reported that FeelIt significantly enhanced their engagement. Users noted the application encouraged active participation ("It made everyone participate" - P02, "It made me feel like I was actually participating" - P12) and provided valuable insights to performers regarding audience reactions ("It helps presenters understand the audience's opinion" - P16, "It helps see what the audience is feeling" - P06). Several participants expressed that the application made the event more enjoyable and interactive ("Fun" - P07, P20, "Exciting" - P23). Nonetheless, some experienced confusion regarding their visible impact on the collective display, noting difficulty recognizing their contributions amidst many simultaneous reactions ("There were too many reactions at the same time, and I couldn't tell if mine was going through" - P21, "I took some time to understand that it would appear on the front screen" - P17).

Users provided actionable recommendations for improving the application's usability and enhancing overall engagement. Many suggested clearer visual feedback when selecting reactions, such as implementing animations or visual cues to confirm their interactions ("The reaction button could interact in some way, blinking or something similar" - P12, "An animation on the emojis would make it more fun" - P08). Participants also recommended refining the overall interface to increase visual appeal ("A more attractive interface" - P16, "Improve the app's design" - P23) and allowing reaction customization to enhance user confidence in participation ("Customize reactions so the person can be sure they are participating" - P21). Layout improvements were also suggested, including enlarging reaction buttons and enabling landscape mode for improved usability ("The words are quite small; it could be used in landscape mode" - P15). Additionally, participants recommended adding features for user interaction, such as commenting capabilities and user-to-user interaction ("Comment option" - P10, "Interaction with other users" - P10), and conducting test runs before live events to ensure smoother experiences ("Do a test before it officially counts" - P17).

The results indicate that FeelIt was well received in aesthetics and rewarding engagement. However, usability remains an area for improvement, as some users reported difficulties with navigation, real-time feedback visibility, and interface design. While the application successfully engaged many participants, the findings suggest that future iterations of FeelIt should focus on optimizing user experience by enhancing visual feedback, refining the interface, and incorporating additional features to ensure a seamless and interactive experience.

7 Discussion

Technologies have changed the way audiences interact in music events. Our article aims to address the following research question: *How can the audience collaboratively contribute to shaping an interactive scenic environment in piano concerts without disrupting the musician's performance?* We

approach this question by proposing FeelIt, a tool designed to transform the environment in piano concerts. The core contribution of FeelIt lies in its ability to transform the traditionally passive audience experience into an active, collective interaction that complements the musical performance. Unlike classical concerts, where audience responses are largely restricted to applause at predetermined moments, FeelIt facilitated a continuous and dynamic engagement. Through real-time reactions projected onto the stage, spectators collectively influenced the concert's visual atmosphere. This aligns with previous studies on interactive performances, such as Open Symphony [Wu *et al*., 2017], which emphasize that audience participation, when structured effectively, enhances engagement without disrupting artistic integrity.

However, the degree of collaborative immersion varied among participants. While some users reported feeling deeply engaged in shaping the scenic environment, others remained neutral or uncertain about the impact of their contributions. This aligns with findings from Wu *et al*. [2017], which suggest that audience engagement in interactive performances is maximized when participants can perceive how their actions influence the event. The lack of immediate and individualized feedback in FeelIt may have contributed to this disparity, as some users reported difficulties recognizing their participation within the collective display. Addressing this challenge through enhanced visual feedback mechanisms, such as interactive animations highlighting individual contributions before integrating them into the collective display, could strengthen users' sense of unity in the collaborative experience.

Another essential aspect of audience collaboration in FeelIt was its ability to create a shared emotional expression during the concert. The reactions projected onto the stage represented individual sentiments and formed a collective narrative of how the audience experienced the music. This form of emotional synchronization aligns with research on digital participation [Edelman and Singer, 2015], highlighting that audience engagement increases when spectators perceive themselves as part of a more extensive, interconnected experience. Future iterations of FeelIt could explore mechanisms to enhance this aspect, such as grouping reactions into thematic visual patterns that evolve dynamically based on audience input, reinforcing the idea of a collectively shaped concert environment.

Despite the positive reception of FeelIt's collaborative aspects, usability challenges impacted the fluidity of participation. Some users reported difficulty perceiving whether their reactions were registered, which may have limited their confidence in contributing to the experience. This issue reflects broader challenges in designing interactive audience systems, as discussed by Veerasawmy and McCarthy [2014], who emphasize that the effectiveness of participatory systems depends on the clarity and immediacy of feedback. To address this, future improvements should include real-time feedback indicators, such as temporary highlights on selected reactions, and an improved user interface that allows participants to track their contributions in the scenic projection better.

7.1 Musician Perspective

At the end of the event, we had an unstructured interview with the three musicians involved in the performance to collect their perspective, one of whom was the event manager. We only asked for their feedback on the first experience with FeelIt during the concert.

The meaning of music emerges from the dynamic interaction between the music and its context, shaped by factors beyond the musical text itself, such as individual motivations, sociability, and both prior and concurrent experiences. This aligns with the idea that the meaning of a musical experience is co-constructed by musicians and audiences within specific social and cultural contexts [Cook, 2012]. Moreover, the experience is time-dependent, with meaning evolving as ideologies, associations, and circumstances change [DeNora, 2000].

The analysis of musicians' experiences in performances that incorporate real-time visual reactions is crucial for evaluating the impact of this technology on the artistic and technical aspects of contemporary concerts. The performers' perspective helps identify key elements of the performance process and contributes to improving the integration between music, technology, and audience, expanding the collaborative possibilities of live presentations.

Musicians perceived the on-stage visual reactions as factors that significantly shaped the performance environment. The visual effects enhanced their sense of connection with the audience, making audience responses more evident. The musician 1 said: *"The reactions there during the performance reflected the mood of the presentation, it was awesome!"*. While the musician 2 said: *"With those visuals, I felt closer to the audience, it seemed like I understood better what they were feeling."*

This co-participation in the experience and construction of meaning between performers and listeners leads us to three points: first, the growing interest in studying specific types of musical experiences, such as concerts [Brown, 2013; Wald-Fuhrmann *et al*., 2021]; second, alongside this focus on the concert as a musical event, there is increasing attention to the collective experience of audiences [McPherson and Schubert, 2022; O'Neill and Sloboda, 2017] and third, the context of the performance shapes group experiences, particularly within concert-specific musical genres such as pop, classical, and jazz [Dearn and Price, 2016; Radbourne *et al*., 2013; Brand *et al*., 2012].

An increase in emotional involvement among both the audience and the musicians was observed, with the public participating in the performance through reactions captured and visually displayed, as highlighted by the P2 - *"You could feel an involvement from everyone, the reactions that appeared there made the audience participate, almost as if they were part of the performance itself, really nice experience."* In pop concerts, technologies such as video, images, and lighting contribute to shaping the social dynamics of the musical event, allowing the audience to develop a shared sense of collectivity. In contrast, classical music audiences may value the focused listening required, believing that it deepens their aesthetic experience of performances [Pitts *et al*., 2013]. These studies highlight how the unique contextual possibilities of differ-

ent musical events can shape both the aesthetic and social dimensions of the audience experience.

One of the musicians reported noticing greater audience engagement, describing the impression of a "dialogue" between participants: *P3 - "There was a moment when I felt the audience was much more present; it even seemed like a kind of "dialogue" was happening during the performance.* The analysis of the musicians' perspective shows that the use of applied technology can enrich the performance experience, fostering greater collaboration and emotional involvement between stage and audience. However, it is essential to strike a balance between visual and musical stimuli so that technological innovation acts as a catalyst for art rather than a competing element. Ongoing dialogue between musicians, developers, and the audience is crucial for the evolution of the tool and the creation of truly integrated artistic experiences.

With the growing use of new technologies in concert music performances, there is a unique opportunity to examine how these innovations are reshaping audience experiences as concert habits evolve. While pop concerts have a long history of incorporating technological elements [Brown and Knox, 2017], concert music has only recently begun to adopt such innovations.

7.2 Implications for Design

The findings from this study highlight several implications critical for the design of interactive systems in performing arts contexts. Firstly, ensuring clear and immediate feedback is vital, enabling users to quickly and confidently recognize their contributions. Secondly, designing intuitive interfaces that minimize technical barriers such as QR code scanning difficulties or text input limitations is essential for enhancing accessibility and usability. Additionally, considering variations in technical infrastructure, such as inconsistent internet connectivity, should inform the design of robust, adaptive systems. Finally, incorporating adaptive visual strategies to manage large numbers of simultaneous user interactions could significantly improve user experience and engagement.

A key takeaway from this study is that collaborative audience participation in classical concerts can be successfully integrated when designed as an augmentative, rather than disruptive, experience. FeelIt demonstrates that by providing structured yet flexible mechanisms for audience expression, spectators can meaningfully contribute to shaping the concert atmosphere without affecting the musician's performance. This differs from interactive performances that allow direct manipulation of musical elements, as explored in Open Symphony [Wu *et al*., 2017], and instead offers a model where the audience's role is to enhance, rather than alter, the artistic delivery.

Future research should explore how different concert settings, audience sizes, and cultural contexts affect collaborative engagement through FeelIt. Additionally, investigating the potential for adaptive interaction models, where audience reactions influence scenic elements in more nuanced ways (e.g., tempo-sensitive visual transformations), could further expand the impact of interactive audience participation in live music performances. By refining and optimizing its collaborative framework, FeelIt paves the way for a new paradigm of audience engagement in classical concerts, transforming spectators into active participants in the artistic experience.

7.3 Limitations and Threats to Validity

While this study provides valuable insights into audience engagement in interactive concerts, several threats to validity must be considered. Below, we identify these threats and discuss how we mitigated them.

One potential threat is the novelty effect, where participants may have been excited about using a new technology rather than responding to the actual effectiveness of FeelIt. To mitigate this, we ensured that our analysis included quantitative and qualitative data, allowing us to capture long-term engagement indicators beyond initial enthusiasm. Additionally, we examined whether users reported usability issues that could hinder engagement rather than assuming a positive response was purely due to novelty.

The study was conducted in a single event with a specific audience demographic, which may limit generalizability to other types of performances or cultural contexts. To address this, we compared our findings with related literature on audience engagement in interactive concerts [Jacucci *et al*., 2007; Wu *et al*., 2017], ensuring that our observations align with broader patterns in the field. Future studies should apply FeelIt in different musical genres and settings to further validate its effectiveness.

Another possible threat is response bias, where participants may have provided socially desirable answers rather than their genuine opinions. To reduce this risk, we included anonymous surveys and open-ended questions, allowing participants to express positive and negative feedback freely. The balance of supportive and critical responses in our results suggests that participants felt comfortable sharing honest opinions.

Given that the study involved subjective user experiences, there is an inherent challenge in ensuring consistency in responses. To enhance reliability, we used the validated User Engagement Scale (UES) [O'Brien *et al*., 2018] structured measurement and complemented it with qualitative analysis to gain deeper insights into user perceptions. Repeating similar studies in future iterations of FeelIt will help confirm whether these findings remain consistent across different contexts.

Additionally, the application of the UES scale presents limitations due to the innovative context of music and events, which may influence engagement factors and make it more difficult for users to fully understand the instrument. In addition, the UES may not capture all the nuances of this specific type of engagement. Regarding FeelIt, it has technical limitations such as scalability to support large numbers of users and simultaneous reactions. From an emotional perspective, the FeelIt may not capture the full complexity of the performance; although the musician defined the initial categories, additional emotional expressions should be explored in future work.

By addressing these threats, we aimed to strengthen the validity of our findings and provide a more robust understanding of how FeelIt contributes to interactive audience participation in live concerts. Future work should build on this foundation by expanding the scope of the study and refin-

ing the methodology to further enhance generalizability and reliability.

8 Conclusion

This study explored how the audience can collaboratively contribute to shaping an interactive scenic environment in piano concerts without disrupting the musician's performance. By leveraging the FeelIt application, we introduced a novel approach that enables spectators to engage in real-time, expressing their emotions through visual reactions without interfering with the artistic execution of the performance.

The findings indicate that FeelIt effectively facilitated audience engagement, with many participants appreciating the opportunity to interact with the concert dynamically. The User Engagement Scale (UES) results highlighted positive aspects of the tool's aesthetic appeal and rewarding nature, reinforcing its potential to enhance the audience experience. However, usability and real-time feedback perception challenges emerged, with participants suggesting improvements in interface design, reaction visibility, and interaction mechanics.

Compared to previous research on interactive musical experiences, FeelIt offers a unique contribution by focusing on non-intrusive audience participation. Unlike systems that modify the musical structure or directly influence performance, FeelIt enhances engagement while maintaining the formal and technical integrity of classical music concerts. This aligns with prior studies on digital audience interaction but extends their applicability to traditionally passive performance settings, such as piano recitals.

Future work should address the usability challenges identified in this study by refining visual feedback mechanisms, expanding reaction customization options, and exploring different performance contexts to assess the tool's adaptability. Future work should focus on the development of a musician module. As musicians perform while FeelIt is being used by the audience, they are unable to see which reactions are coming through. A musician module should therefore provide real-time audience feedback in a way that supports performers without compromising their attention. Additionally, further studies could investigate the long-term impact of interactive audience experiences on musical performances and the potential for integrating machine learning techniques to personalize engagement strategies. In addition, we intend to further investigate the audience experience, as individual users may have different perceptions. It is particularly important to examine whether FeelIt may negatively impact the audience experience and to understand why some users may lack the intention to participate. One alternative is to collect quantitative data based on the frequency of each element, the moments at which they appear during the performance, whether they occur in clusters or are dispersed, and their proportion relative to the audience size.

By bridging the gap between active participation and artistic preservation, FeelIt presents a promising avenue for enhancing audience engagement in live performances. As digital interactivity shapes cultural events, tools like FeelIt pave the way for more immersive and inclusive musical experiences, fostering deeper connections between performers and audiences.

Declarations

Authors' Contributions

Genildo Gomes: Conceptualization, Methodology, Software, Writing - Original Draft, Writing - Review & Editing, Conceptualization, Methodology. **Fernando Nogueira**: Conceptualization, Methodology and Software. **João Gustavo Kienen:** Conceptualization, Methodology and Writing - Original Draft, Project administration. **Bernardo Scarambone:** Funding acquisition. **Desiree Scarambone:** Funding acquisition. **Leandro Galvão:** Funding acquisition **Tanara Lauschner:** Funding acquisition **Igor Steinmacher:** Writing - Review & Editing **Tayana Conte:** Funding acquisition and Supervision. **Bruno Gadelha:** Conceptualization, Methodology, Software, Writing - Original Draft, Writing - Review & Editing, Conceptualization, Methodology, Supervision, Project administration.

Competing interests

No potential conflict of interest was reported by the author(s).

Acknowledgements

The authors thank the Federal University of Amazonas (UFAM), Northern Arizona University (NAU), and Eastern Kentucky University (EKU) for their support. We are also grateful to the musicians, participants, and event managers involved in the study, as well as the members of the SPHERE Research Group and the Arts College (FAARTS).

Funding

We would like to thank the financial support granted by CNPq 314797/2023-8; CNPq 443934/2023-1; CNPq 445029/2024-2; CNPq - 313137/2025-0; CNPq 406506/2025-6; CAPES - Financing Code 001; Amazonas State Research Support Foundation - FAPEAM - through POSGRAD 2026-2027.

Availability of data and materials

The datasets (and/or software) generated and/or analyzed during this study will be made available upon request.

References

Andriani, R., Mellyzar, M., Lukman, I. R., Muttakin, M., Pasaribu, A. I., and Fadli, M. R. (2024). A review of digital assessment in education: Tools, feature, and effectiveness. In *Proceedings of Malikussaleh International Conference On Education Social Humanities And Innovation (Miceshi)*, volume 1, pages 0023–0023. Available at:`https://proceedings.unimal.ac.id/miceshi/article/view/490`.

Araújo, C. G., Martins, G., Gomes, G., Kienen, J. G., de Freitas, R., Castro, T., and Gadelha, B. (2022). Coffee break virtual: uma experiência musical interativa e colaborativa. In *Simpósio Brasileiro de Sistemas Colaborativos (SBSC)*, pages 132–145. SBC. DOI: 10.5753/sbsc.2022.19482.

Biaett, V. and Richards, G. (2020). *Event experiences: measurement and meaning*, volume 12. Taylor & Francis. DOI: 10.1080/19407963.2020.1820146.

Brand, G., Sloboda, J., Saul, B., and Hathaway, M. (2012). The reciprocal relationship between jazz musicians and audiences in live performances: A pilot qualitative study. *Psychology of Music*, 40(5):634–651. DOI: 10.1177/0305735612448509.

Broder, N. (1960). The beginnings of the orchestra. *Journal of the American Musicological Society*, 13(1/3):174–180. DOI: 10.1525/jams.1960.13.1-3.03a00130.

Brown, A. (2013). All the world'sa stage: Venues and settings, and their role in shaping patterns of arts participation. *The Audience Experience*, pages 49–66. DOI: 10.2307/j.ctv36xvtc6.9.

Brown, S. C. and Knox, D. (2017). Why go to pop concerts? the motivations behind live music attendance. *Musicae Scientiae*, 21(3):233–249. DOI: 10.1177/1029864916650719.

Burns, L. A. (2016). The concept album as visual—sonic—textual spectacle: The transmedial storyworld of coldplay's mylo xyloto. *IASPM journal*, 6(2):91–116. DOI: 10.5429/2079-3871(2016)v6i2.6en.

Cerratto-Pargman, T., Rossitto, C., and Barkhuus, L. (2014). Understanding audience participation in an interactive theater performance. In *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational*, pages 608–617. DOI: 10.1145/2639189.2641213.

Cheng, K., Koda, K., and Masuko, S. (2022). Reimagining the stadium spectator experience using augmented reality and visual positioning system. In *2022 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*, pages 786–787. IEEE. DOI: 10.1109/ISMAR-Adjunct57072.2022.00167.

Cook, N. (2012). Music as performance. In *The cultural study of music*, pages 184–194. Routledge. Available at:`https://pt.scribd.com/document/1022551967/Nicholas-Cook-Music-as-Performance`.

Dashper, K. and Buchmann, A. (2020). Multispecies event experiences: introducing more-than-human perspectives to event studies. *Journal of Policy Research in Tourism, Leisure and Events*, 12(3):293–309. DOI: 10.1080/19407963.2019.1701791.

Dearn, L. K. and Price, S. M. (2016). Sharing music: Social and communal aspects of concert-going. *Networking Knowledge: Journal of the MeCCSA Postgraduate Network*, 9(2). DOI: 10.31165/nk.2016.92.428.

DeNora, T. (2000). *Music in everyday life*. Cambridge university press. DOI: 10.1017/CBO9780511489433.

Dolasinski, M. J., Roberts, C., Reynolds, J., and Johanson, M. (2021). Defining the field of events. *Journal of Hospitality & Tourism Research*, 45(3):553–572. DOI: 10.1177/1096348020978266.

Duvignau, R. (2025). Kahoot vs. mentimeter for active learning in computer and engineering education–who won? who's next? In *Proceedings of the 30th ACM Conference on Innovation and Technology in Computer Science Education V. 1*, pages 214–220. DOI: 10.1145/3724363.3729086.

Edelman, D. C. and Singer, M. (2015). Competing on customer journeys. *Harvard business review*, 93(11):88–100. Available at:`https://hbr.org/2015/11/competing-on-customer-journeys`.

Getz, D. (2007). *Event studies theory, research and policy for planned events*. Routledge. Available at:`https://www.researchgate.net/publication/43498021_Event_Studies_Theory_Research_and_Policy_for_Planned_Events`.

Getz, D. and Page, S. J. (2016). Progress and prospects for event tourism research. *Tourism management*, 52:593–631. DOI: 10.1016/j.tourman.2015.03.007.

Getz, D. and Page, S. J. (2019). *Event studies: Theory, research and policy for planned events*. Routledge. DOI: 10.4324/9780429023002.

Gomes, G., Conte, T., Castro, T., and Gadelha, B. (2023). Engagement, participation, and liveness: Understanding audience interaction in technology-based events. In *International Conference on Enterprise Information Systems (ICEIS) (2)*, pages 264–275. DOI: 10.5220/0011848600003467.

Gomes, G., Conte, T., and Gadelha, B. (2025a). Evaluating the impact of interaction technology on audience experience across event contexts: An empirical study. *International Journal of Human–Computer Interaction*, pages 1–18. DOI: 10.1080/10447318.2025.2482738.

Gomes, G., Nogueira, F., Kienen, J. G., Scarambone, B., Scarambone, D., Galvao, L., Lauschner, T., Steinmacher, I., Conte, T., and Gadelha, B. (2025b). Beyond applause: A collaborative and interactive experience in piano concerts. In *Simpósio Brasileiro de Sistemas Colaborativos (SBSC)*, pages 177–189. SBC. DOI: 10.5753/sbsc.2025.8661.

Haimson, O. L. and Tang, J. C. (2017). What makes live events engaging on facebook live, periscope, and snapchat. In *Proceedings of the 2017 CHI conference on human factors in computing systems*, pages 48–60. DOI: 10.1145/3025453.3025642.

Hödl, O. and Turchet, L. (2025). The tmap framework: describing the design space of technology-mediated audience participation in live music. *IEEE Access*. DOI: 10.1109/ACCESS.2025.3543064.

Jacucci, G., Oulasvirta, A., Ilmonen, T., Evans, J., and Salovaara, A. (2007). Comedia: Mobile group media for active spectatorship. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 1273–1282. DOI: 10.1145/1240624.1240817.

Jia, X., Kong, Z., Gao, H., and Wang, S. (2024). Intelligent concert light stick control system based on internet of things. In *2024 3rd International Conference on Electronics and Information Technology (EIT)*, pages 448–451. IEEE. DOI: 10.1109/EIT63098.2024.10762122.

Kim, S.-Y. (2017). Liveness: Performance of ideology and technology in the changing media environment. In *Oxford Research Encyclopedia of Literature*. DOI: 10.1093/acrefore/9780190201098.013.76.

Latulipe, C., Carroll, E. A., and Lottridge, D. (2011). Love,

hate, arousal and engagement: exploring audience responses to performing arts. In *Proceedings of the SIGCHI conference on human factors in computing systems*, pages 1845–1854. DOI: 10.1145/1978942.1979210.

Lee, S. W., Willette, A., Koutra, D., and Lasecki, W. S. (2019). The effect of social interaction on facilitating audience participation in a live music performance. In *Proceedings of the 2019 Conference on Creativity and Cognition*, pages 108–120. DOI: 10.1145/3325480.3325509.

Lo, W. H., Zollmann, S., and Regenbrecht, H. (2021). Xrspectator: Immersive, augmented sports spectating. In *Proceedings of the 27th ACM Symposium on Virtual Reality Software and Technology*, pages 1–2. DOI: 10.1145/3489849.3489930.

Mackellar, J. (2013). *Event audiences and expectations*. Routledge. DOI: 10.4324/9780203098080.

Martins, F., França, C., Paixão, P., Martinho, D. V., Campos, P., Gouveia, B., Lopes, H., Ihle, A., Marques, E., and Gouveia, É. R. (2023). Emerging technologies to promote fans interaction in football events: a systematic review. *Advances in Human-Computer Interaction*, 2023(1):6667260. DOI: 10.1155/2023/6667260.

Martins, G., Gomes, G., Conceição, J. L., Marques, L., da Silva, D., Castro, T., Gadelha, B., and de Freitas, R. (2021). Bumbometer digital crowd game: collaboration through competition in entertainment events. *Journal on Interactive Systems*, 12(1):294–307. DOI: 10.5753/jis.2021.1998.

McPherson, G. E. and Schubert, E. (2022). Enhancing music performance appraisal. *The Oxford handbook of music performance*, 2:103–134. DOI: 10.1093/oxfordhb/9780190058869.013.7.

Mueser, D. and Vlachos, P. (2018). Almost like being there? a conceptualisation of live-streaming theatre. *International Journal of Event and Festival Management*, 9(2):183–203. DOI: 10.1108/IJEFM-05-2018-0030.

Oliver Hödl, Christoph Bartmann, F. K. C. L. P. P. (2020). Large-scale audience participation in live music using smartphones. *Journal of New Music Research*, 49(2):192–207. DOI: 10.1080/09298215.2020.1722181.

O'Neill, S. and Sloboda, J. (2017). Responding to performers. *Musicians in the Making: Pathways to Creative Performance*, 1:322. DOI: 10.1093/acprof:oso/9780199346677.003.0023.

Otsu, K., Yuan, J., Fukuda, H., Kobayashi, Y., Kuno, Y., and Yamazaki, K. (2021). Enhancing multimodal interaction between performers and audience members during live music performances. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*, pages 1–6. DOI: 10.1145/3411763.3451584.

O'Brien, H. and Cairns, P. (2015). An empirical evaluation of the user engagement scale (ues) in online news environments. *Information Processing & Management*, 51(4):413–427. DOI: 10.1016/j.ipm.2015.03.003.

O'Brien, H. L., Cairns, P., and Hall, M. (2018). A practical approach to measuring user engagement with the refined user engagement scale (ues) and new ues short form. *International Journal of Human-Computer Studies*, 112:28–39. DOI: 10.1016/j.ijhcs.2018.01.004.

Pitts, S. E., Dobson, M. C., Gee, K., and Spencer, C. P. (2013). Views of an audience: Understanding the orchestral concert experience from player and listener perspectives. *Participations: Journal of Audience and Reception Studies*, 10(2):65–95. Available at:`https://www.participations.org/10-02-05-pitts.pdf`.

Radbourne, J., Glow, H., and Johanson, K. (2013). *The audience experience: A critical analysis of audiences in the performing arts*. Intellect. DOI: 10.2307/j.ctv36xvtc6.

Robinson, R. B., Rheeder, R., Klarkowski, M., and Mandryk, R. L. (2022). Chat has no chill: A novel physiological interaction for engaging live streaming audiences. In *CHI Conference on Human Factors in Computing Systems*, pages 1–18. DOI: 10.1145/3491102.3501934.

Salovaara, A., Nelimarkka, M., Kuikkaniemi, K., and Jacucci, G. (2021). Augmenting the performer–audience live participation in professional event productions. In *Proceedings of the 24th International Academic Mindtrek Conference*, pages 186–196. DOI: 10.1145/3464327.3464328.

Storvang, P., Mortensen, B., and Clarke, A. H. (2017). Using workshops in business research: A framework to diagnose, plan, facilitate and analyze workshops. In *Collaborative research design: Working with business for meaningful findings*, pages 155–174. Springer. DOI: 10.1007/978-981-10-5008-4_7.

Vasconcelos, V., Amazonas, M., Castro, T., Freitas, R., and Gadelha, B. (2018). Watch or immerse? redefining your role in big shows. In *Proceedings of the 17th Brazilian Symposium on Human Factors in Computing Systems*, pages 1–9. DOI: 10.1145/3274192.3274233.

Veerasawmy, R. and Iversen, O. S. (2012). Bannerbattle: introducing crowd experience to interaction design. In *Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making sense through design*, pages 228–237. ACM. DOI: 10.1145/2399016.2399052.

Veerasawmy, R. and McCarthy, J. (2014). When noise becomes voice: designing interactive technology for crowd experiences through imitation and invention. *Personal and ubiquitous computing*, 18:1601–1615. DOI: 10.1007/s00779-014-0761-8.

Wald-Fuhrmann, M., Egermann, H., Czepiel, A., O'Neill, K., Weining, C., Meier, D., Tschacher, W., Uhde, F., Toelle, J., and Tröndle, M. (2021). Music listening in classical concerts: Theory, literature review, and research program. *Frontiers in Psychology*, 12:638783. DOI: 10.3389/fpsyg.2021.638783.

Webb, A. M., Wang, C., Kerne, A., and Cesar, P. (2016). Distributed liveness: Understanding how new technologies transform performance experiences. In *Proceedings of the 19th ACM conference on computer-supported cooperative work & social computing*, pages 432–437. DOI: 10.1145/2818048.2819974.

Wu, Y., Zhang, L., Bryan-Kinns, N., and Barthet, M. (2017). Open symphony: Creative participation for audiences of live music performances. *IEEE MultiMedia*, 24(1):48–62. DOI: 10.1109/MMUL.2017.19.

Yin, R. K. (2009). *Case study research: Design and methods*, volume 5. sage. Available at:`https://iwansuharyanto.wordpress.com/wp-content/`

uploads/2013/04/robert_k-_yin_case_study_
research_design_and_mebookfi-org.pdf.