The Effect of Social Interaction on Facilitating Audience Participation in a Live Music Performance

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ABSTRACT
Facilitating audience participation in a music performance brings with it challenges in involving non-expert users in large-scale collaboration. A musical piece needs to be created live, over a short period of time, with limited communication channels. To address this challenge, we propose to incorporate social interaction through mobile music instruments that the audience is given to play with, and examine how this feature sustains and affects the audience involvement. We test this idea with an audience participation music system, Crowd in C. We realized a participation-based musical performance with the system and validated our approach by analyzing the interaction traces of the audience at a performance. The result indicates that the audience members were actively engaged throughout the performance, with multiple layers of social interaction available in the system. We also present how the social interactivity among the audience shaped their interaction in the music making process.

Author Keywords
Audience Participation, Mobile Music, Music Performances

CCS Concepts
•Applied computing → Sound and music computing; Performing arts; •Human-centered computing → Collaborative content creation;

INTRODUCTION
Audience participation in a public event is an effective way to engage large-scale audiences and create an artifact collaboratively [28, 13, 19, 42]. It is, however, challenging due to its instantaneous nature and the effort needed to coordinate audiences on that scale. In particular, researchers have explored audience participation performances in live concerts using audiences’ smartphones as musical instruments [33, 35]. Audience participation in a concert comes with a challenge of sustaining participants’ interest to continue participating, especially given that the outcome of the event relies heavily on the audience’s active participation. In addition, the duration of the designed participatory experience tends to be much shorter than other types of events (tens of minutes at most per piece, usually) and only non-verbal communication is allowed. Therefore, there exists a multitude of challenges for musicians in organizing audience participation in a concert: 1) lowering the barriers of involving a common audience in a highly interactive artistic practice, 2) engaging the audience in a participatory, collaborative creation, and 3) safeguarding the quality of the artifact (i.e., the musical piece). We explored these challenges in a recent audience participation...
We examine the effect of social interaction through an interactive music system, Crowd in C [33]. (Figure 1.) The system supports a hybrid event [41] in which audience members create an artifact (e.g., the sound of music) in a co-located setup while digitally connected over a social network provided by the system. In this paper, we particularly focus on the second challenge—engaging the audience in the participatory music-making.

We hypothesize that promoting social interactivity through computer-mediated communication channels in an interactive music system can effectively sustain audience engagement and help them be part of a large-scale participatory music performance. In addition, we are interested in understanding the effect of social interactivity on creative engagement with participatory music performance. Creative engagement is a concept for interactive art, which raises challenges like how to anticipate and define the user experience, and it has been mostly explored in the context of exhibitions/galleries [14].

We examine the effect of social interaction through an interactive music piece called, Crowd in C, in which audience members can interact with each other as in social media (e.g., browsing, endorsing, real-time interaction). Specific research questions that we seek to answer are as follows:

- **RQ1—Sustaining Audience Engagement:** Does incorporating social interaction among audience members in an interactive system sustain the participatory activity in a large-scale, participatory musical performance?

- **RQ2—Understanding the effect of social interactivity in the audience's creative engagement:** How does social interactivity influence and shape the ways in which the audience interacts with the interactive music system and participates in an interactive music performance?

We validate our approach by analyzing a recent performance of Crowd in C. We begin with a discussion of the background and related work in facilitating audience participation events in music and other domains. We then discuss how Crowd in C works, and we demonstrate how social interaction within the system is designed to help audience members participate in music-making. We then present the result of our data analysis of interaction traces from a recent performance to validate our approach. Lastly, we conclude the paper with further discussion on the study and future works. The findings from this study will contribute to the existing knowledge of audience experience research in informing artists and practitioners, and advancing our understanding in creative engagement particularly for interactive music performance [14, 3, 55].

**RELATED WORK**

This work builds on previous audience participation work in which audiences are engaged in a public event, in various settings. In the rest of this section, we introduce both general events and those in a musical setting.

**Audience Participation in Musical Performances**

Musicians and researchers have attempted to engage audiences by directly involving them in the music-making process at live performances. For example, We Will Rock You by British rock band Queen is famous for the repetition of a simple participatory rhythm—stomp, stomp, clap—which results in successful participation. It has been used frequently at sports events by fans supporting their teams.

One of the biggest challenges of enabling audience participation in live concerts concerns how one can reconcile the musicians’ desire to deliver a compelling piece of music while the audience directly influences the music. For example, if one decides to distribute traditional acoustic instruments (e.g., violins) and asks an audience to participate in performing a piece they have never heard of, it is likely that the audience would hesitate to participate in the performance; even if the audience does not hesitate, the sound is likely to interfere with the artifact that the organizing musicians wish to produce [32]. To that end, musicians develop devices that can facilitate audience participation from multiple angles—composition, pre-production, apparatus, and guiding gestures in live performance. In the example of We Will Rock You, the composers designed the participatory actions to be repetitive.
and simple for non-experts to perform. Through gestures and drum patterns, the band’s efforts coordinate the audience’s participation. In a contemporary musical piece, Moths by Jean Hasse, a conductor used a graphical, open-form score. By guiding people to read a drawing and interpret it as pitch over time, the audience is led to whistle in accordance with the conductor’s gestures [20]. Another example of this coordination can be found in Bobby McFerrin’s improvisation. During his talk at the World Science Festival 2009, McFerrin demonstrated audience participation, guiding his audience to sing the right note as he hopped around the stage. Some early examples included state-of-the-art technologies of their time (such as cassette tapes from The Flaming Lips’ The Parking Lot Experiments [11], or Maseda’s radios from [39]).

Computer-mediated audience participation can address the challenges inherent to participatory music performances. One approach is to allow the audience to take on the composer’s role, indirectly influencing the music without directly producing any sound. Glimmer exemplifies this approach well: audience members wave light sticks to influence the music, and the movement of the sticks is captured and analyzed with a computer vision algorithm [17]. The system generates real-time music notation based on this analysis for instrumental musicians who can sight-read—that is, they perform from the generated sheet music as they read it, in real time. This is similar to the approach of audience response systems—that is, audience voting—, the outcome of which is used to shape a performer’s play indirectly and dynamically [53, 57]. While musicians can safeguard the musical outcome, mediating the audience’s votes toward a pre-composed sonic outcome, the musical change effected by the audience may not be readily distinguishable, preventing the audience from understanding how their participation contributes to the music they hear [32].

The idea of using mobile phones to help broader populations participate in music-making have emerged with the development of smartphones [48, 52, 51, 9]. Particularly, the ubiquity of mobile phones can resolve this problem by allowing musicians to transfer musicianship to the audience, letting them literally play musical instruments using their smartphones in their palms [35, 33, 45, 8]. The main benefit of such an approach is that audience members’ engagement can directly contribute to the music and they can have a clear understanding of how individual sonic outcomes from their smartphone speakers add to the music. However, the risk of low participation can result in a complete lack of sound, which can be catastrophic for the musicians. To address this concern, musicians need to effectively sustain the audience’s interest in participating. In our work, we suggest that supporting social interactivity in an audience participation system would effectively engage the audience in a sustainable fashion, while letting musicians make music with the help of the audience.

Lastly, we draw ideas from crowdsourced content creation when an artifact can be collaboratively created with crowd participants. One such example is Scribe, a system that coordinates a crowd, potentially in a classroom or conference, to create real-time caption of speech for the people with hearing impairment [30, 31]. On the other hand, participants can build a physical artifact; in [28], the authors presented a networked system that can guide conference attendees to build a large-scale physical architecture with modular design. The online crowd can be incorporated in various creative practices from writing [25, 26] to animation [38]. Online crowdworkers can be recruited to support content creation in near real-time; one can hire crowd workers to design graphical user interfaces prototype [29], or to even augment the digital artifact by implementing interactive behaviors in it [37, 36]. This work addresses the similar challenges of facilitating instant and easy content creation for non-expert crowd in interactive music performance.

**CROWD IN C: DESIGN CONSIDERATIONS**

We realize the idea of social interactivity in a participatory musical performance in Crowd in C, an interactive musical system for large-scale audience involvement at a concert [33]. During a performance, each participating audience member uses a web-based, interactive musical instrument application, typically from their own smartphones. The aggregate sound outcome from all participants’ smartphone speakers creates a heterophonic texture, initially centered around a C major chord. The mobile phones that the audience members use are connected through the on-stage performer’s laptop via a cloud service (PubNub). More details regarding the musical motivation of the music piece can be found in [33]. The challenges of large-scale participatory music can be summarized as follows:

- **(C1) Lowering the barriers in instant participation for non-experts**
- **(C2) Sustaining an active level of participation and facilitating the collaborative creation for participants**
- **(C3) Shaping audience interactions into a coherent musical piece**

This paper focuses on assessing the system with respect to the second challenge (C2) in particular: that is, how the social interactivity provided in the system can effectively address this challenge. The challenge (C2) is relevant to sustaining attraction (sustainer) in creative engagement [14], expanding its context from exhibition to the live performance setting. The other two challenges and the piece’s musical aesthetic in relation to contemporary music are discussed more in depth in [33, 34]. To introduce how Crowd in C works, design considerations relevant to each challenge are discussed below.

**Democratized Music Generation**

The user interface for audience members in Crowd in C is designed primarily for ease of use. A simple and intuitive interface is essential to motivate people to immediately participate in the piece regardless of their musical backgrounds or lack thereof, especially given that they have little time to learn or prepare. In addition, thanks to the ubiquity of smartphones and the advancement of web audio, this performance requires minimal technical configuration for the audience—participants need only launch a web browser and type in a provided URL. This serves the goal of enabling an arbitrary audience to instantly participate in the performance with minimal effort.
whenever it reaches a musical note. The composed melody is patterned after an online dating application (e.g., Tinder).

The system provides a simple loop-based musical instrument that anybody can play. The location of the musical notes (presented as circles) determines the pitch and timbre of the notes. Once a melody is submitted in EDIT mode, a participant can BROWSE other audience members’ melodies and interact with them by sending a HEART or playing together in MINGLE mode.

The musical instrument provided to the audience for Crowd in C is designed to be extremely easy to use, which is advantageous in the context of large-scale audience participation. Using the musical instrument available at a specific URL, each participant simply defines a melody on the platform (i.e., instrument) by creating a spatial pattern with five musical notes (green circles in Figure 2 - EDIT). The location of a musical note in space determines its pitch (vertical axis), timbre (horizontal axis), and the intervals between notes (the length of lines that connect notes). There is a smaller yellow circle that moves at a constant speed, triggering sound generation whenever it reaches a musical note. The composed melody is looped while a user revises the melody. Thus, a participant does not need to produce a continuous sequence of “playing gestures” (e.g., striking keys on a piano) to generate sound. More importantly, musicians do not need to worry about the overall sound being too sparse due to low audience participation. While designing a creative tool to have a low floor and high ceiling is important [43, 54], we intentionally designed the instrument to have an extremely low floor and low ceiling, as it is a musical instrument that is designed to be used only for tens of minutes, without time spent learning how to use it. This design choice contributes to the challenge of sustaining participants’ interest (C2): if we give out a musical instrument that one can master in tens of seconds, how do we maintain users’ interest in using the instrument? We suggest that enabling social interaction using the music instrument is a resolution to this challenge.

Social Interaction through Musical Instruments

Most importantly, the system allows audience members to interact with each other. The instrument provides a sort of ad-hoc social network where participants can interact with each other by browsing and liking (sending HEARTs to) each other’s melodies. Social interaction in Crowd in C uses the metaphor of online dating; the social interaction available is patterned after an online dating application (e.g., Tinder). Each interactive component is described below:

- **EDIT**: A participant can compose (or revise) a melody like a personal profile in an online dating website. Initially, participants are asked to create a screen name and compose a melody when they launch the application. They can revise their melodies thereafter (Figure 2 - EDIT).

- **BROWSE**: Participants can browse melodies composed by others, as if they browsed people’s profiles in online dating websites. A participant can press a button labeled ‘NEXT’ to see the melody of the next participant in the queue. They can also choose to directly find a user based on their screen name using the SEARCH button (Figure 2 - BROWSE).

- **HEART**: A participant, say Jane, can endorse someone’s melody, say Danae’s, by sending a HEART. A recipient of a HEART will get a notification that reads ‘Jane liked your tune!’ with the sound effect of ⟨blip⟩, as shown in Figure 2 - HEART (3rd panel). If two users send each other HEARTs, both receive a notification like ‘It’s a match! Danae liked your tune, too’ with the sound effect of ⟨fairy wand sound⟩ on both devices.

- **MINGLE**: A participant can request a MINGLE session with another user. The user who received the request can accept or reject it. If the request is accepted, the melodies of two participants are overlaid on one screen and they can EDIT their own melodies in real time, as if chatting over a messenger or going out on a date. In this mode, one can make anticipatory revisions to match their partner’s melody either musically or visually—which brings musical intimacy, as in the example. See the upper left picture in Figure 1. The MINGLE mode terminates if either participant leaves the mode (Figure 2 - MINGLE).

Composing a profile, browsing, and endorsing online content are common interactions well-known to modern social media (e.g., Twitter, Facebook) users. We hypothesize that social interactivity will encourage participation and exchange creative ideas among the participants. We expect that the behaviors that emerge in this temporary social network help us gain insight into ways of increasing participation in large, live musical performances.

The Performer Performs with the Crowd

In Crowd in C, there is an on-stage musician performing the piece together with the audience members. Overall, the performer’s role is simply to perform a piece of music, explain some of the functions of the application both prior to and during the performance, and communicate with the audience. The stage performer serves as a sort of meta-performer, controlling the chord progression of the music by changing the scale to which the audience’s mobile instruments are tuned at any given moment. For example, the performer can alter the tuning of participants’ instruments from C major to E minor on the fly. The performer writes code from the stage to make these musical changes, sending JavaScript code to each connected mobile phone. The program evaluates the code it receives and makes the corresponding changes, altering the configuration (scale, key, volume, timbre) of the musical instrument. Repeating this process creates a chord progression. The performer thus does not generate any sound from the stage independently, instead controlling the high-level structure of the music by altering the configuration of the web-based musical instruments.
The performer’s laptop is mirrored in the concert space, and a view of the audience, the scoreboard adds a competitive aspect to the experience—for instance, it shows the screen name of the most “liked” person—the one who received the most HEARTs—and the most “crowded” person — the one whose melody is currently being played the most at the moment.

The goal of the interaction trace logger is to enable procedural analysis of each performance of Crowd In C. The density of user actions can be tracked over time for the whole audience or each individual. Using the collected interaction traces, we analyzed the audience activities and examined the effects of social interaction in the system. After collecting the raw data, we aggregated it into certain relevant categories. Examples of such categories are explained below.

- **EDIT**: Changing the location of a musical note; submitting a revised melody to the centralized system—the performer’s laptop. Everyone is supposed to compose a melody after they create their screen name (initial EDIT), and they can come back to revise their melody (noninitial EDIT)
- **BROWSE**: Browsing an audience member’s melody
- **HEART**: Sending a HEART to another audience member
Trend Analysis of Audience Activity. The temporal analysis of each audience action is aggregated into five different types: initial EDIT, noninitial EDIT, BROWSE, HEART, and MINGLE. The result suggests that the audience has been constantly active throughout the performance.

- **MINGLE**: Requesting a MINGLE session; accepting a MINGLE request; real-time interaction in a MINGLE session—moving musical notes within a MINGLE request in addition to the categories above, we differentiated initial EDIT, which was mandatory for all audience members, from noninitial EDIT. Noninitial EDIT activity is optional, and indicates that an audience member decided to revisit and revise their melody. The level of activity in revisiting helps us understand if audience members' intentions in interacting with the instrument are purely musical or social (e.g., a participant decided to revisit and revise a melody after seeing someone else's melody). In addition, we logged all textual messages and musical changes made by the performer with time stamps to see how the performer's intervention affects audience participation.

### RESULTS

We present the results of our analysis on the data collected from the performance.

**Sustaining Audience Engagement**

In this section, we analyze the interaction log of the audience at the performance to assess the effects of social interaction in sustaining audience engagement.

**Trend Analysis of Audience Activity**

The result of trend analysis indicates that the audience was actively engaged with the participatory system over the duration of the performance. The overall activity level of the whole audience was stable throughout the performance. We present the number of activities per category in Figure 4, aggregating data points into 10-second bins. The average number of interactions per audience member was 1.43 interactions per 10 seconds. The total number of activities for the whole audience was not linearly correlated with time ($R^2 = 0.01$).

The primary means of maintaining overall activity over time was the social elements of the system. In Figure 4, activity of types EDIT, BROWSE, HEART, and MINGLE is displayed as a stacked area chart. It is notable that initially, the entire audience started with initial EDIT activity, which was how the system was designed for all users. Once they submitted their melodies, the audience began to focus more on the social aspects of the system—BROWSE, HEART, and MINGLE—than on modifying their own patterns—initial EDIT and noninitial EDIT, which are the two light-gray regions on the bottom in Figure 4. The trend analysis indicates that the social interactivity of the system—BROWSE, HEART, MINGLE—was a primary factor in encouraging the audience to sustain their interest in participation. While social interaction was the primary vehicle for engaging the audience with their mobile phones (BROWSE + HEART + MINGLE in Figure 4), the audience continuously revised their melodies even after their first submission (initial EDIT). The active level of non-initial EDIT showed weak linear correlation with time ($R^2 = 0.03$), which suggests that the overall level of motivation for modifying existing melodies was constant throughout the performance.

**The Performer’s Intervention**

Further evidence that the audience was actively engaged with the performance system comes from the trace of audience responses to the performer’s intervention. Using the notification system, the performer sent multiple messages to explain the system during the performance and to ask the audience to make certain changes. For example, at 210 seconds, the performer sent a message reminding the audience of the MINGLE function, through which they can interact with other audience members in real time. The graph result shows a local increase in MINGLE activity immediately after the message was sent. Additionally, the performer asked the audience at 415 seconds to send HEARTs to many patterns upon receiving a binary question at 431 seconds, generating a large number of HEARTs and matching sounds at once with a slight slowdown after the binary question at 431 seconds. Receiving HEARTs, and mutual HEARTs (match) creates short sound effects of ⟨blip⟩ and ⟨fairy magic wand sound⟩, respectively. In the recording of the actual performance, both sound effects were frequently audible after the performer’s instruction. The performer’s ability to make audible changes in the music by sending textual messages to the audience suggests that the audience was actively participating in the performance.
While the standard deviation for receiving HEART is small, was more focused on musical interaction with the application. The diversity of individual strategies present in the graph suggests no linear correlation ($R^2 = 0.05$).

To better understand how individuals behave differently, we plotted each audience member in Figure 5, based on how socially active they were ($x$-axis: HEARTs sent + MINGLE), and how musically active (or socially passive) they were ($y$-axis: EDIT + BROWSE). The diameter of each circle represents how musically active (or socially passive) they were ($y$-axis: EDIT + BROWSE). The melodies of the users marked A-E appear in Figure 6.

**Emergence of Varying Social and Musical Behaviors**

There were varying behaviors from one individual to the next in social interaction. For example, the HEART functionality is a basic way to endorse someone in the system. On average, audience members sent (or received) HEARTs 8.21 times. While the standard deviation for receiving HEART is small ($\sigma = 3.48$, MAX = 17), sending HEARTs was driven by a small portion of people (for which $\sigma = 11.02$, MAX = 67)—that is, the top 20% of participants sent 62.2% of all HEARTs sent. However, the number of HEARTs sent and received showed no linear correlation ($R^2 = 0.05$).

At the top left corner—that were not particularly engaged with the performance system (alternatively, they may have refreshed their page and created new screen names). The diversity of individual strategies present in the graph suggests that even though the social interactivity provided by the platform may seem overly simplistic, individuals can take various approaches to participating in the system. It is important that *Crowd in C* can accommodate broader audiences with variance in extroversion and musical expertise compared to other types of participatory models, in which audiences are asked to participate in a uniform manner. For example, in many popular music examples, audience members are often asked to clap to the beat, which can be challenging to those who have no sense of rhythm. Or, in [8], the audience was asked to tweet using a specific hashtag and some members of the audience expressed concerns that tweet messages “that make no sense outside the context of the performance” may annoy their followers, while some others did not have Twitter accounts, which limited their participation.

**The Effect of Social Interactivity on Creative Engagement**

In this section, we investigate the effects of social interactivity in creative engagement of the audience with the interactive music performance.

**Who earns the HEARTs?**

Given the intentionally limited design of the instrument, it might have been frustrating for the audience, regardless of musical background, to use the instrument in a musically meaningful way on an individual level. Therefore, people may not have been engaged with the performance in a musical sense, and instead left the sound outcome to the performer and simply focused on social interactivity. However, it seems that participants who received many HEARTs gained popularity by composing a melody in an interesting way, given the overly simplified loop-based instrument with only five notes. We musically and visually inspected the melodies of the popular group—those who are within top 20% of the audience in terms of the number of HEARTs received (received 12 or more HEARTs, $n = 16$)—and plotted as green striped circles in Figure 5. One group of participants used the instrument to create a visually meaningful pattern—readable symbols such as a letter, a shape, or the university logo (VT) created with five musical notes (Figure 6- A, B, and C, which correspond to the green circles in Figure 5-A,B, and C). One participant drew the university’s logo, which is meaningful to the local community, and thus earned 12 HEARTs (image excluded for anonymity). Another group of participants created a pattern that is musically meaningful. For example, a few participants placed five notes close to each other, or placed them in one region to play one note of a scale, so that the melody can generate more dense and unified patterns with single pitches (Figure 6-D and E, which correspond to the green circles in Figure 5-D and E). It seems that audience members clearly sent HEARTs to those who used the instrument in unexpected ways, when they could find visual or musical meaning in the limited instrument. Note that participants C and D in Figure 5 were very passive in terms of social interaction, located at the bottom of the figure. Even with the low social activity, their constant musical actions in editing their melodies elicited positive responses—(HEARTs)—from other participants.

A few people used the strategy of being highly socially active—sending many HEARTs to people. For example, the audience member who received the most HEARTs among the whole
Those Who are Popular Influence Others

Next, we investigate whether audience members musically inspired other members to edit their melodies. Towards that end, we counted how many times each melody led to a non-initial EDIT to the melody of another audience member who browsed it, which we call the number of EDIT triggers. For instance, the number of EDIT triggers for a participant we will call John is $N$ if $N$ audience members decided to revise their melodies after browsing John’s melody. Our assumption was that if someone received many HEARTs, their melodies may be perceived as inspiring by other audience members (as shown in Figure 6 (A-E)), and a participant who saw such a melody would immediately revise their own melody. We divide the whole audience into three different groups—the Popular group, composed of those who received 12 or more HEARTs ($n = 16$); the Intermediate group, composed of those who received more than 5 HEARTs but fewer than 12 HEARTs ($n = 63$); and the Unpopular group, composed of those who received 5 HEARTs or fewer ($n = 19$)—and compared the average number of EDIT triggers between groups. The numbers of HEARTs (12, 5) that separate the audience into three groups are determined by segmenting the group by the top 20%, middle group, and the bottom 20% in terms of the number of HEARTs received. We found that the average number of EDIT triggers for the Popular group ($\mu = 2.19, \sigma = 1.38$) was higher than those of the Intermediate group ($\mu = 1.40, \sigma = 1.20, p < 0.05$) and the Unpopular group ($\mu = 1.16, \sigma = 1.34, p < 0.05$): a two-tailed $t$-test (two-sample unequal variance) was statistically significant (Figure 7). The difference between the Unpopular group and the Intermediate group was not statistically significant. This strongly suggests that browsing popular melodies by others—which is relevant to the uniqueness of the pattern, as seen earlier—prompted audience members to edit their own melodies. This observation supports the idea that the social element of the system (being able to browse what others did) facilitated the audience’s further musical exploration.

Musical Collaboration in MINGLE sessions

While it was used relatively less than other social elements (such as HEART and BROWSE), the MINGLE mode effectively engaged a portion of the audience in real-time creative collaboration sessions during the performance. The number of MINGLE sessions was 44, and more than half of the audience ($n = 51$) participated in one or more MINGLE sessions.

We further investigated how participants were engaged in a MINGLE session by inspecting the revision history of MINGLE sessions. Figure 8 shows selected examples that demonstrate MINGLE sessions we find interesting. For the first example (Figure 8-1), it is observed that two participants gradually made their melodies’ shapes resemble each other, whereas in the second example (Figure 8-2), two participants seemed to split the canvas into two parts and spread their melodies to the sides. In the third example, two patterns started in drastically different states before taking on a harmonious appearance,
Figure 8. Curated examples of MINGLE session histories. In MINGLE sessions, participants can overlay two patterns on the screen and edit their own melodies in response to a partner’s melody and interaction.

with parallel lines and balanced placements of musical notes. The last two examples (Figure 8-4) clearly demonstrate a case of how a participant can be inspired by another audience member’s interesting approach to use the instrument. A user (Red) in example 4 saw another user making a star-shaped melody (Green). Then, the user (Red from Example 4) borrowed the same idea of making a star-shaped melody in another MINGLE session. In this case, the original user, who used Green dots in Figure 8-4, took on the role of an “influencer,” affecting their followers’ behavior. As seen above, MINGLE sessions enabled more intimate social interaction than that produced by other types of social interactions introduced in the system, positively impacting the collaborative creation process.

DISCUSSION AND LIMITATIONS

In this paper, our goal was two-fold: (RQ1) to examine how effective allowing social interaction can be in sustaining audience engagement, and (RQ2) to understand how the social interaction shapes the audience’s creative engagement with the system in a large-scale, participatory musical performance. The idea of involving social interaction is tested in Crowd in C, a participatory musical performance system which enables multiple layers of social interaction—performer–audience collaboration, social media-like interaction, and live collaboration. We found that the audience was generally engaged with the participatory experience: 1) the sustained social activity trend, 2) successfully coordinated musical changes with a performer’s intervention, and 3) the emergence of diverse patterns of participation.

A variety of social behaviors and strategies manifested themselves during the performance, similar to various types of users in today’s social media (e.g., influencers, followers, lurkers, loners). The platform’s accommodation of diverse participatory strategies—as opposed to the imposition of a monotonous strategy (e.g., voting from the beginning to the end), or an approach tuned to extroverts/musical experts (e.g. singing in public)—helps broader audiences feel engaged and connected to the participatory experience. Furthermore, this suggests that enabling social interaction in a participatory system will benefit from an audience’s understanding of existing social computing systems.

The second question we set out to answer concerns how the social interactivity shapes the audience’s creative engagement. The participatory system successfully helped audience members constantly be involved in various collaborative music making activities—composing a melody, self-expression through instruments, endorsing others’ creations, being inspired by others, and live collaborative creation.

One of the limitations of this study is that we did not match the data-driven findings with audience perception that we could learn from a follow-up study or target group interview with the participants. Other similar studies that explored participatory artworks in public settings (exhibitions, live performance) can provide methodological improvements that can be explored as a future work [14, 1, 8]. As this performance was carried out “in the wild” and was a piece of a bigger concert, we did not conduct a follow-up survey or interview with the participants for logistical reasons. Another limitation of this work is that we did not validate how the system addresses two other challenges (C1, C3), which can be improved with a similar follow-up investigation with participants.

Another aspect that we overlooked in this study is the audience’s perception of the participatory experience in relation to the performed piece of music. To shape the aggregated sonic outcome as a coherent musical piece, some intervention from the performer was inevitable, which could have distracted the audience’s social interaction with others. For example, changing the chord and the scale of the instrument (e.g., from C major to E minor) may have made the audience feel interrupted, disengaging them from their control over the instrument. Multitasking and cognitive overload in participatory systems has been studied [56], and it remains questionable how two different levels of interactions (peer-to-peer vs. large-scale participatory music) coincide and conflict with each other in the context of live content creation. Artists’ intentions can vary depending on their choice of musical aesthetic; some may be fine with any sound, as long as the audience can have an engaging musical experience; others may simply use the audience as an array of speakers [49]. Given the performance, we believe a separate study is necessary to understand the audience’s perception of the tension between audience participation as a participant and as a consumer of the artifact. We believe that a combination of qualitative research methods,
including a follow-up survey and target group interviews, will be preferable.

Future work will leverage network analysis to further explore audience engagement, and discover the effects of moderation and intervention in the social network evolution. For instance, tasks of interest include characterizing the user similarities based on their activity trends or sequences [44], and comparing the social networks that are based on different user activities (e.g., HEART and BROWSE) or before/after intervention from the on-stage performer [27, 21]. Moreover, capturing user influence [47], modeling the participants’ behaviors and preferences, and identifying “outlier” participants in the social network [23] (i.e., participants whose interactions are significantly different than those of the other participants) may give insights into personalized interventions from the on-stage performer to sustain audience engagement and promote collective creativity.

CONCLUSION
In this work, we sought to understand the effects of social interactivity in facilitating participatory musical performances from two specific angles: sustaining audience engagement and understanding the ways in which social interactivity influenced the audience interaction with the instrument. We tested the idea in an interactive musical performance and system, Crowd in C. We found that the simple, ad-hoc social network realized through the musical instruments involved the audience throughout the performance, while accommodating diverse participatory patterns and supporting various social and musical interactions among audience members. The design of including social elements in the system and its results are relevant to inform other designs that aim to facilitate participatory performances and events. We believe that our study findings will help future work better understand the design considerations of incorporating computer-mediated social interactivity for future participatory systems.

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