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Live Participation: Augmenting Events with Audience–Performer Interaction Systems

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ABSTRACT
Tools for supporting performer–audience interaction have been gaining increasing interest in HCI community recently. They encompass a wide range of systems from simple polls to live tweeting and backchannel chats. However, a lack of unifying conceptual framework hampers their efficient development and deployment in events. In this paper, we develop a notion of *live participation* and present a live participation system that aims to capture performer–audience interaction systems' salient design-relevant characteristics. With user studies, we identify central characteristics of live participation (RQ1) and explore the diversity of types of live participation situations (RQ2). The identified concepts—extended performance, integration work, and episodes—provide the groundwork for further design of live participation systems and more engaging audience interactions.

Author Keywords
live participation; co-located interaction; audience–performer interaction; events

ACM Classification Keywords
H.5.3 Information Interfaces and Presentation (e.g. HCI): Group and Organization Interfaces

General Terms
Human Factors; Design

INTRODUCTION
Many computer-augmented systems and tools have been developed and presented with a goal of supporting interaction between and among performers (e.g., presenters, teachers, event hosts, chairpersons etc.) and their audiences. These tools include, among others, question management systems [4, 18], audience response systems [21, 22], and backchannels [28, 45]. Also Twitter has been appropriated as a discussion board through live tweeting [9, 25, 29].

Together, these and other tools demonstrate a fertile application domain for human–computer interaction (HCI). However, to our knowledge, the possibilities of different performer–audience interactions in this application domain have remained unexplored comprehensively. We thus take the first steps to discuss the design opportunities and challenges in this domain that we call *live participation*. The term is a shorthand for computer-augmented performer–audience interactions where the emphasis is on audience members' concurrent involvement in the presentation or activity (i.e., "live") and their contributing role in it (i.e., "participation").

We are informed by research on *performance* as studied both in event studies (e.g., [14]) and in HCI (e.g. [19, 32, 44]). In a performance, one or many persons (i.e., performers) have a leading role in the orchestration of social interactions, and have something to show or offer to the rest of the people (i.e., audience) [35]. In particular, we focus on planned events where performers aim to disseminate information to an audience. Classes and presentations are prime examples of such contexts. Our work also focuses primarily on performers' needs (compared to, e.g., group support systems that aim for decision-making and problem solving purposes and where the performer's role is not as clear [31]).

For HCI and the design of interactive systems, live participation perspective opens new ways to explore computer-augmented social interactions. When audience–performer interaction in the real world is extended to a digital world, technology becomes the second venue for interaction—thus resulting in an *extended performance*. These two venues—mediated (extended performance) and non-mediated (on-stage performance)—are in interaction, leading to needs for performers to "bridge" the digital and physical performances, or *integrate* them.

We begin by outlining the existing research and by developing the concepts further. This provides a starting point for a conceptually informed empirical study on Presemo, a live participation system that contains a more comprehensive set of functions than other systems in the market or in academic

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research. In particular, we study, with a qualitative single-case study, *what characteristics are central in live participation* (RQ1). Endowed with this qualitative understanding, we continue by exploring the *diversity of types of live participation* (RQ2) with a multiple-case study of eight diverse contexts where the system has been used. The studies foregrounded new questions especially related to the social organization of live participation performances, and the range of opportunities for live participation.

PREVIOUS WORK

In this section, we review both the previous research on performance as well as the systems that fall under an umbrella of live participation.

Performances in Event Studies and HCI

Event studies—a sub-discipline of tourism research—have since early 1990s started to analyse the planning and execution of events (e.g., [13, 15, 16]). This research has covered a wide range of contexts from festivals to religious gatherings, and applies various perspectives to events. Among them is also the performance aspect that emphasizes that events are distinctly *socially framed and contextualised* [14]. For example, an academic conference has expected behaviour roles for presenters and the audience. These social roles define how they can engage in the event.

When technology is introduced to play a part in a performance, it has profound implications, as many HCI studies have already documented (e.g., [8, 32, 33, 37, 39]). Of interest have been the participants' different roles in performances, and what this implies to technological support for performance. 'Performers', 'audience', and 'bystanders' contribute to performances in different ways: Performers interact with the technology through publicly visible interactions. The audience members follow performers' interactions and are also themselves invited to interact with the technology. This makes them more performer-like [8, 32, 33, 37, 39]. Bystanders, in comparison, are those who do not focus on performers and do not engage in technology interaction either.

Based on systematic analyses on these situations, roles coincide with specific spatial locations in event performances. The centre-stage position, for example, is controlled by performers while the other staff can be found behind-the-scenes where they may manipulate technological equipment [32]. The performers' interactions may be visible (when they take place "centre-stage") or hidden (when they are in "backstage"). The interactions may be amplified with technology [33]. These works posit varying levels of importance for technology. Some researchers see technology in the core of the performance [37, 32] whereas others see it in a supplementary role [39].

Live Participation Systems

Live participation is an application domain where technology allows the audience to impact the direction of the event. Possible use contexts include teaching in classes [11, 17, 30] and conferences [18, 28]. Live participation can change the social set-up of an event [17, 30], transform users' roles [11], support the event flow by providing a non-interruptive channel for contributions [18, 28], lead to knowledge gains in peers' interaction [45], confuse participants due to cognitive challenges of following several information streams [28], and even lead to non-constructive commenting [6]. Therefore, researchers are familiar with these systems' audience-side implications, but less has been said about the implications on the performance and the performer, or the event as such.

To better understand these implications, we must further review the tools that have been developed and used in this application domain. We find it helpful to consider them along two categories: who *initiates* the interaction and who *controls* it. By initiation we refer to the actions that define when the first interactions take place and what their stimuli are for co-located participants' subsequent responses. Controlling, in turn, refers to the control and steering of the live participation process in the event context, and the unfolding of the computer-mediated interaction. We will organise our review of live participation technologies around three related categories.

Performer-Initiated & Performer-Controlled

Performer-initiated & performer-controlled technologies retain the control on audience engagement firmly in the performers' hands. For example, audience response systems ('clickers')—used most commonly in education—are tools with which teachers can present students with multiple-choice questions and quickly summarise the results. Based on the results, teachers may adapt their teaching and recap or elaborate concepts as needed—either for all the students or smaller groups [7, 12, 21, 22]. Work with these systems started in the 1960s, focusing on faster feedback loops between teachers and students. Later they came to serve also as discussion-starters [21]. The idea of a networked classroom in the 1990s also included audience response systems, as one of the means to improve the interactions (e.g., [24]). Even today, these systems's focus is on the interaction and its support through a mediated environment (e.g., [5, 24]).

The understanding of audience response systems and their impacts on learning and teaching is already mature, as has been shown in several reviews (e.g., [7, 12, 22]). Positive outcomes include increased engagement, interactivity, and enjoyment during the classes. These may lead to greater learning gains. Learning-enhancing practices include raising awareness and directing attention, improving cognitive processes, using the answers as part of (formative) evaluation, and pointing to questions to stimulate discussion [3].

Therefore, audience response systems emphasise the role of the performer who initiates and masters the interaction. They offer limited interaction methods; the current research, for instance, addresses predominantly multiple-choice responses. The audience has limited opportunities to express their views, usually from among a predefined set of options.

Audience-Controlled

In the other end of the spectrum are audience-controlled systems. Backchannels are an example of this category. Similarly to audience response systems, their purpose is to create

a complementary communication channel for a specific environment, such as a conference or a classroom [28, 34, 45]. Most commonly, backchannels are message boards or chats, but live tweeting through a particular hashtag in Twitter has recently become increasingly popular [25, 27, 29].

When compared with audience response systems, backchannels are more general-purpose and free-form in the interaction they afford. As we have seen, audience response systems mainly support a teacher asking questions from an audience. Backchannels, in contrast, can be used by the audience to ask questions or seek clarifications from one's peers [10, 28, 45] or to share thoughts with them [11]. Especially panel moderators might follow and engage with backchannels [28] during panel discussions to elicit questions from the audience.

Backchannels offer many potential benefits, such as peer learning and co-construction of knowledge [28, 45], increased sense of flow [28], and audience engagement as active contributors rather than passive listeners [11].

The primary focus with backchannels is on improving the interaction among peers in the audience. This is achieved by providing a free-form space for sharing ideas and comments and allowing the audience to direct the discussion to topics of shared interest. However, if the performers cannot be part of this interaction loop (e.g., if the backchannel is hidden from them, or if they have to direct all of their attention to this interaction), their opportunities do not realise for the performers, and subsequently the opportunities of live participation cannot be fully capitalized.

Performer-Initiated & Audience-Controlled

Audience response systems (focused on performers and their needs) and backchannels (focused on the audience and their needs) can be complemented with a third category: the interaction between the audience and the presenter(s) using two-way tools—something that happens only in a limited sense in the two preceding categories.

Confusingly, many papers label also these systems as backchannels. Backchan.nl [18] lets the audience rate questions during a panel discussion and panellists to answer the highest-ranking questions. Similarly, Fragmented Social Mirror [4] lets participants ask the lecturer specific questions, to which either the lecturer or an assistant can reply.

We re-label these systems as *question management systems*, to reflect the audience-initiated interactions with performers. Interaction may also involve peer interaction, such as voting on various questions' relevance [18]. These systems engage audience in the creation of the performance through two-way interaction, and thus transform them to be more active. They are thus highly relevant to more engaging performances.

LIVE PARTICIPATION

The above-presented heterogeneous collection of empirical work has pushed us to consider the systems in a common framework. Informed by concept-driven research [41], we move forward to examine *live participation* and develop an interactive artifact to explore its implications. Our focus is on planned events and their information sharing.

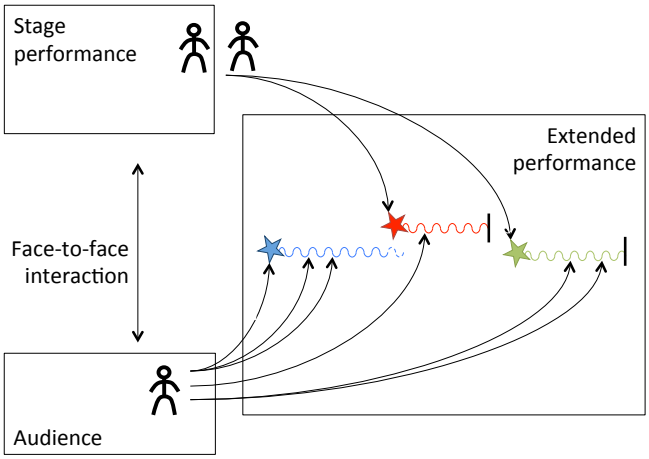


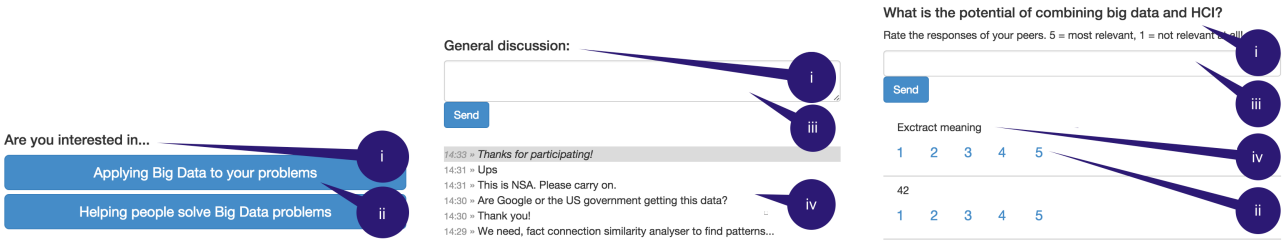
Figure 1: Live participation. The face-to-face stage performance is supported through a computer-mediated environment that allows audience-controlled, performer-initiated & performer-controlled, and performer-initiated & audience-controlled interaction episodes.

Live participation systems create a mediated space for interaction. Figure 1 presents live participation's three primary roles, building on performance literature[1] [8, 33, 32, 37, 39]: audience, on-stage performers and off-stage performers. We refer to the technology-augmented interactive elements of the performance as *extended performance*, to differentiate it from the physical performance ongoing on the stage.

Technology can amplify spectator experiences in artistic performances [33]. Similarly, in events, performers can use live participation systems to extend their performance to the mediated space as well. Therefore, the mediated space is not only another communication channel (as seen in group work, e.g., [26]), but in the best case becames also a part of the performance. Our choice to talk about "extended performance" rather than merely "extended communication channel", for example, reflects this ideal.

We observe that the extended performance requires *integration work* in order to become a natural part of the event and the performance. Integration work consists of any actions by performers that raise the audience's awareness of the mediated interaction space, encourage participation through it, and take the audience's contributions as part of the on-stage performance. Examples of integration work include framing and setting up the live participation activity, motivating the audience to use the live participation system, and reacting to audience contributions. The term's resemblance to articulation work—an important concept of computer-supported cooperative work—is not coincidental. Articulation work refers to efforts made to manage the distributed nature of cooperative work [36, 42]—in other words, the meta-work required to make the actual work possible. Similarly, integration work

[1]HCI community has had a liberal definition of "performance" (cf. [40]). We acknowledge that performances can take various forms. Our work may be generalizable to many situations, but we mostly consider presentations, classroom teaching, panels, and other contexts where the presenter-performers lead the interaction.



(a) Poll (b) Chat (c) Voting

Figure 2: Presemo's three interaction block types as they are seen in the audience members' devices. Blocks have a title (i) and can have performer-defined answer options (ii), an input field (iii) and user-generated content (iv).

addresses the efforts to establish a coherent performance both through the mediated and on-stage activities.

Accordingly, Figure 1 presents how audience follows two performances—on-stage and extended—and can contribute to the performance. In many live participation systems, this involves sending messages (e.g., [11, 28, 34]) or voting from predefined lists of possibilities (e.g., [3, 7]). Figure 1 visualizes the three different initiation–control interaction types with different colours. Those controlled by performers (red and green; e.g., polls and votes) have specific endings, while audience-controlled episodes (e.g., backchannel chats) have indefinite lengths.

If there are multiple on-stage performers, such as panellists (e.g. [18]), teachers (e.g. [3, 7, 11]) and presenters (e.g. [28]), they can share the responsibility of integration work. Events may also include off-stage staff who may support integration work by, for example, moderating audience members' messages [18, 4] and other contributions to the ongoing performance [28]. Figure 1 presents the on-stage and off-stage as separate actors that stand side by side.

Live participation relates to the previous frameworks in the following ways. Sheridan et al.'s [37] Performance Triad model posits the mediating technology in a central role in audience–performer interactions. Our model is more tuned to collocated settings where face-to-face interactions and mediated interactions may play equally important roles. Reeves et al.'s [33] spectator experience taxonomy orients to artistic performances where the technology is performer-controlled even when it is used in a shared manner with the audience. Finally, Spence et al. [39] presented systems where performers use media for storytelling. Also this approach gives precedence for performers who prepare the content beforehand and leave less control and agency for the audience. Live participation therefore differs also from this framework by being more oriented to the audience and its members' contributions of content.

These differences to existing frameworks arise from our attempt to focus on planned "live" events as an application domain for audience participation. For our use, "live" highlights the nature and the potential changes in the performance [2, 35]. For us, "participation", in turn, denotes the aspect of giving the audience a voice; either to influence the outcomes or to demonstrate their affect [23].

The desire to support performer–audience interaction has motivated use to develop Presemo—a system that supports live participation and integrates into a single system the various live participation functions that we reviewed above.

Presemo, an Integrated Live Participation System

Presemo's main design objective is to combine together the performer-initiated & performer-controlled, the audience-initiated & performer-controlled, and audience-controlled modes of live participation. In addition, Presemo also aims to support integration work and extension of the performance to the mediated environment. We have approached it through *episode-oriented* interaction design. Each usage of a live participation tool is part of a performer-defined episode. Such episodes can be, for instance, polling of answers for a question, a chat discussion, or a vote. We have aimed at making the initiation and closing of these episodes as flexible as possible for performers. One means for enabling this has been that the different episodes of an extended performance can be prepared in advance in Presemo. They are shown as "blocks" both in the composing mode as well as when they are active and interactable for the audience during a performance.

Each block offers the audience a single type of interaction opportunity. A plan for an event (i.e., the performance) may include multiple blocks, each one representing a different interaction session with the audience.

Presemo has the functionality for three types of interaction: polls (see Fig. 2a), chats wherein participants can send messages to everybody (see Fig. 2b), and voting, where the audience can first suggest options between which they then can vote (see Fig. 2c). These features map to the three modes of participation discussed above. The poll represents performer-initiated & performer-controlled audience interaction. The chat, depending on the performers' instruction, is audience-controlled and either audience-initiated or perfomer-initiated. The voting is performer-initiated & audience-controlled. We acknowledge that the design space for different blocks is not saturated with these three interactions. There remains room for considerable extension in future work.

New blocks can be both edited and created on the fly during a performance. In addition, performers can toggle the visibility and change the relative order of each block in real time both in a public screen and in the contents that audience members can

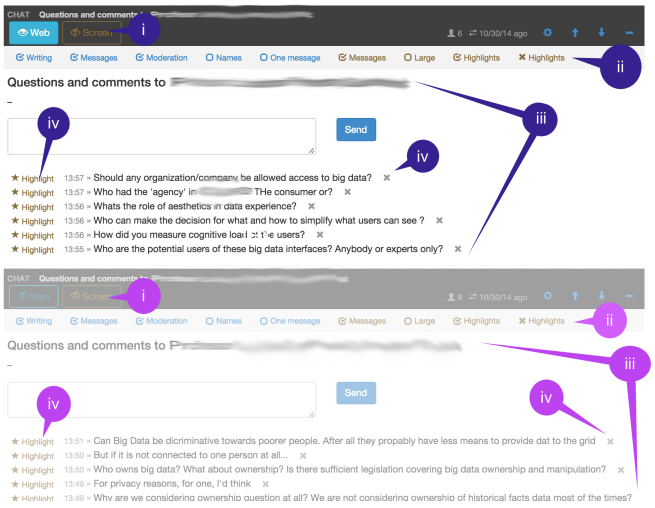


Figure 3: Presemo's full control interface for performers that allows for managing the blocks' visibility (i) and block-specific interaction mechanisms (ii). The interface shows the block's contents (iii) and allows content moderation (iv). In the figure, two voting blocks have been created.

see in their devices. This enables dynamically configurable presentations.

Audience members can use Presemo with any internet-equipped device. The system has been optimized for smartphone and tablet use, since these devices are usually most common in the audience. Using Presemo requires zero configuration: there are no logins or user accounts; instead, a simple URL is provided that the audience members can type in their web browsers.

To support performers' varying needs, we have developed two different control interfaces for managing Presemo. The full control interface (Fig. 3) allows for the performer to control the visibility of each block (i), configure block-specific options (ii), show user contributions (iii), and highlight or delete specific contributions (iv). The simplified control interface (Fig. 4) offers a narrowed-down set of functions, including only content showing (iii) and highlighting (iv). The need for two different control interfaces stems from our experience of actual Presemo use and facilitation that spans several years. We will discuss this further in the end of the work.

RQ1: CHARACTERISTICS OF LIVE PARTICIPATION

Having presented our instance of a live participation system—Presemo—we move to explore the characteristics (RQ1) and diversity (RQ2) of live participation. To study these aspects, we engaged in empirical case studies: a single-case study for the characteristics and a multiple-case study for the diversity (for more information about the cases, see Table 1 later in the paper). These cases demonstrate how live participation was taken into use in panels and discussion events (cases a, c, e, f), education (g, h) and conferences (b, d). They represent variety of audience sizes and organizers applying live participation and using Presemo. As Presemo

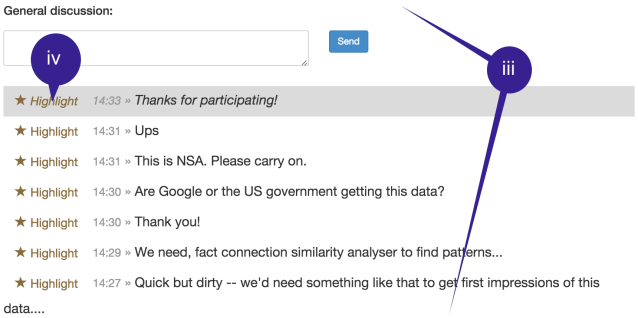


Figure 4: Presemo's simplified control interface. This interface shows the content (iii) and allows highlighting the content (iv).

has also been commercialized as an academic spinoff[2], these cases have been chosen from a series of in-the-wild studies.

We studied characteristics of live participation in an academic event, referred to as Case a in Table 1. It was a 1.5 hours panel where the panellists first presented their own work and then engaged in a discussion between themselves and their audience about the relationships of big data and HCI. The panellists sat next to public screens, facing the audience. The event also involved off-stage staff who sat in the front row in the audience (see Fig. 5) and managed Presemo's use via the full control interface.

We chose this case for a more detailed analysis because of several reasons. First, the large audience size made it comparable to the existing works in audience–performer interaction (e.g., [4, 11, 18, 28, 34]). Second, the case included two types of performances: the panellists' presentations and the discussion. Third, the audience consisted of mostly first-time users, which is the most common situation in live participation contexts. Finally, an academic panel allowed us to apply various data collection strategies, as the event was public and participants were supportive of research. We informed the audience about our study in the beginning of the panel, and no questions of our arrangements were raised.

We triangulated our analysis with video recordings, interviews, log data and a survey to analyse the interactions. We started the analysis from the video material and interviews where we applied the open-ended coding approach [38], first on the video material and later on the interview data. This way, the interview data analysis was informed by the video analysis and could be used to supplement the video-based observations [20]. In both of the datasets our coding focused on the performers' interactions with Presemo.

We carried out seven semi-structured interviews of 20 to 60 minutes each and rewarded interviewees with 25-euro (USD 30) gift cards. We inquired about event experiences and performer–spectator and spectator–spectator interactions. We continued with more detailed inquiries about the role of mediated and non-mediated communications in these interactions.

[2]See Screen.io, `http://www.screen.io`



Figure 5: Photograph from case study a, showing the public display (left), the panellists and of-stage staff (middle), and the audience (right).

Finally, we sent a questionnaire to all the conference participants, focusing on their experiences of the panel discussion. 24 participants—about one quarter of the panel audience—responded.[3] We probed for experiences about using Presemo, using a five-point Likert scale, to understand the experiences of the audience more broadly. The questionnaire items included both positive (e.g., 'Presemo was useful') and negative statements (e.g., 'Presemo was unnecessary'). We will consider the participants' responses descriptively in the analysis section.

We describe our findings on live participation through the following three characteristics.

Integration Work

The panel chair took the lead of integration work and used several methods to do this. He made verbal notes throughout the session regarding Presemo. He invited the audience to take part, framed the goal of participation during different stages of performance, and acknowledged audience's contributions and further presented them to the panellists. Also non-verbal actions, such as glancing at the public display, conveyed the notion of relevance of the content to those attending the panel discussion. Finally, he also highlighted audience's chat messages through Presemo and invited the panellists to discuss them. In an interview, one participant observed that

> I assume they [messages] kind of reflected the, again, the hive mind. So if the moderator [chairperson] selected those, it was because he was paying attention [Audience member, interview 3].

This indicates the perceived value this interviewee had towards the panel chair's attempt to use the content to lead the discussion. However, the panel chair was not the only on-stage actor conducting integration work. The panellists had monitors, which allowed them to see the content. We observed two cases wherein the panellists specially addressed a topic raised via Presemo in their on-stage discussion. One of the panellists engaging in this type of activity explained:

> [I] involved content from Presemo, to make it worthwhile for people to be interacting with it. So trying to address the comments that came through on it. So yeah, definitely a couple of times I explicitly referred to these comments. [Panellist, interview 5]

In this quote, we observe also the subtle ways of integrating the audience content without explicitly framing it as such.

Episodes

In this panel, a total of 11 blocks were used, seven of them ratings, three of voting and one of polling.

The panel started off with an introduction of Presemo and warm-up questions that aimed to familiarise the audience with its use. The chair presented the overall goal of the panel. During this time, the extended performance was mostly either performer-initiated & performer-controlled or audience-initiated & performer-controlled. This warm-up phase lasted roughly the first 25 minutes of the panel.

The second phase of the panel included customised chat blocks, each titled with "Questions and comments to N. N." Each block was shown during the respective panellist's opening statement. The panel chair used the content to ask questions after each presentation. Each block was then hidden from the audience. This represented a very typical pattern of audience-initiated & performer-controlled interaction. In total this took 35 minutes, and on average each extended performance episode lasted 8 minutes.

In the final phase, majority of blocks were freeform chats, and the chair involved its contents in summarizing statements about the panel. Here we saw audience-controlled interaction as well as audience-initiated & performer-controlled interaction. In total there were five blocks in this phase, shown and hidden in an alternating manner over a course of 35 minutes.

Extended Performance

The observed performer–audience interactions demonstrate Presemo's successful use in an extended performance. First, performers took content from Presemo and made it a part of performance (integration). Second, the blocks were shown and hidden based on the performance (episodes).

Also the off-stage staff's role in the creation of the extended performance was important. They commenced and closed episodes by hiding and showing respective interaction blocks as needed by the on-stage performers. To make sure that Presemo's use would be aligned with the event's different stages, planning had been necessary between the technical team, the panel chair and panellists before the performance.

However, as is typical in performances, the panel also involved improvisation. To facilitate further discussion, the technical staff opened an unplanned new block focused specifically on the privacy questions related to big data and HCI. This example demonstrates how the off-stage staff was involved in creating the extended performance beyond the original plans.

[3]We acknowledge that in our data-collection, response biases such as self-selection are clear; therefore, we use these statistical data to triangulate our other results and as an illustrative example.

Our survey indicated that live participation was overall successful, as more than 70% of the respondents agreed that 'Presemo influenced the overall flow of the sessions', and slightly more than 50% also agreed that Presemo allowed them to work with the panellists. These results mean that Presemo became an extended performance, instead of only a supplementary channel. Also, the audience considered its use meaningful instead and not an interruption. The performers enhanced the on-stage performance by making use of user-generated content. The system itself was changed based on the varying needs of the performance, also dynamically.

To sum up the answers to RQ1, we observed that integration work was distributed among several people, both on-stage and off-stage. We also observed how the panel chair, panellists and the off-stage staff were engaged in creation of the extended performance. Finally, we observed the episodic nature of the extended performance, where 11 different blocks provided a structure for the performance's different phases.

RQ2: THE DIVERSITY OF LIVE PARTICIPATION

To study the diversity of live participation, one needs to engage in studies in different cases and contexts. Thus we present a multiple-case study encompassing eight different contexts where Presemo was used, varying in terms of experience with Presemo (novel to experienced), audience size (20 to 400), audience members' familiarity with each other (from ad hoc groups to several years of collaboration), age of participants (from an elementary school class to working age), and use contexts (panels, education, conferences).

Although we have facilitated over a hundred Presemo sessions during the previous years, in the sampling of the cases for this paper we were limited to those ones where videotaping, logging and reporting of presentation contents was allowed. More details of the cases can be found from Table 1 where we describe the contexts, aims, and user roles from each case, as well as the number of blocks that were used in the events. We discovered diversity among several important dimensions, as presented in the following.

Aims and Means of Use

One of the most significant dimensions was the variance of goals why live participation was used (hereafter "aims") and the ways in which performers sought to reach the aims (hereafter "means"). Column "Aim" in Table 1 shows the purposes for which Presemo was used, as expressed by the performers. The aims can be categorized into four general categories: asking questions, activating audience, engaging the audience in knowledge co-creation and collecting information.

To analyse the means to reach these general aims, we analysed log data about blocks' titles (i.e., the textual prompts shown to the audience) across the eight cases. Our method followed the practices of qualitative thematic classification [43]. We asked two researchers *not* familiar with the cases, Presemo, or our own categorization, to group the block titles of each case (83 in total; the sum of blocks in Table 1) independently into categories. They then grouped the categories, discussed the results with us, and we developed the final grouping. We achieved reliable levels of inter-coder agreement of 87.8% and a Krippendorff's alpha of 0.855.

This process resulted in eight different means (see Table 2), some of which were used to serve several aims.[4] These eight means can be grouped into three conceptual categories following the distinctions between three types of initiation–control pairs that we already used to discuss existing live participation systems. We have highlighted the three categories with italicized sub-headings. Based on these analyses of aims and means, we find that Presemo afforded a wide variety of different ways of use, both ones giving agency to the performer and those giving it to the audience.

Audience Size

When we reviewed the literature on live participation systems, we found no previous papers that would have examined the scalability, in terms of number of participants, of different systems. Thus we do not know yet whether backchannels, Q&A systems and the like scale gracefully up or down from the typical range of 75–150 participants [11, 18].

Our eight case studies provide initial glimpses to the diversity of audience sizes to which the live participation concept can be generalized. Live participation seems usable at least with audience sizes ranging from 20 to 400. In most cases, the penetration rate among the participants who engaged in using Presemo varied between 40% to 100% (see column "Roles" in Table 1). In case e, we expect that the lower penetration was related to not having a public display to present the audience's contributions.

Although the benefits from using Presemo in these cases are difficult to measure, we received positive feedback from all the organizers. Therefore, we conclude that these cases may have not yet even reached the limits of scalability for live participation systems.

Performer Roles

We also observed various configurations of on-stage and off-stage performer roles (see column "Roles" in Table 1). Concerning the on-stage roles, we learned that not everyone on-stage is necessarily involved in live participation. Based on this, we have now developed a more detailed terminology for different live participation setups.

Chairpersons, for example, are on-stage performers who are actively using the system but mostly attend the other performers. However, they are often limited by their attentive capacity and therefore can at most show and hide blocks that are shown on screen. More demanding tasks such as reordering of the blocks or changing their contents may take too much attention from the face-to-face interactions.

Hosts are performers' "right hands" who especially in large events are in direct interaction both with the audience and the live participation, but interact less with the performers on stage. Unlike chairpersons or panel members, hosts do not

[4]The last means labelled as "event organization" is marked with "n/a", since it did not belong to the scope of live participation: performers only showed static content to the audience.

	Context	Aim	Roles	Blocks
(a)	An academic panel related to big data in HCI research. Panellists first presented their own work around the topic, after which audience and panellists discussed the opportunites and challenges together.	Ask questions from panellists and engage in knowledge co-construction.	Audience: 100 persons, of whom 40 used Presemo. On-stage: Five panellists seeing Presemo content and a panel chairperson with a simplified control interface. Off-stage: Two orchestrators who had full access to the control interface.	11
(b)	A marketing festival for sharing the latest news related to trends in information technology with corporations' representatives.	Activate the audience	Audience: 200 persons, of whom 100 used Presemo. On-stage: Five presenters and a host who had access to the simplified control interface. Off-stage: One assistant to the host, sitting next to the stage. Assistants providing technical support and managed the system via the control interface.	22
(c)	A strategy meeting discussing current and future trends in mobility with organisations' staff and external stakeholders, related to organization's strategy work	Ask questions and collect information for strategy work.	Audience: 400 persons, of whom 200 used Presemo. On-stage: Seven presenters and one host. Off-stage: An orchestrator, two moderators, and three technical support staff supporting the audience.	14
(d)	An state-of-the-art presentation and gathering of the industry where the latest information on industrial Internet development was shared and understand how various members of the relevant association apply industrial Internet thinking in their organisation. Presemo question was used much to collect factual information of participants, examined during the event and after it.	Collect information from participants and activate them.	Audience: 100 persons, most using Presemo. On-stage: Four presenters and one chairperson. The orchestrator was on-stage a few times to act as host of the event. Off-stage: An orchestrator and two moderators, both of whom pre-screened content.	20
(e)	An annual meeting of academic staff where the future of the research institute and university support services were presented. The first performer asked to be interrupred during his presentation, while the second and third presented preferred to go questions through in the end of his presentation.	Ask questions anonymously	Audience: 60 person, only few using Presemo. On-stage: three performers, none with direct access to Presemo content. Off-stage: two moderators, responsible of raising themes from Presemo to the stage.	3
(f)	A panel and discussion about the future of. Participants were a group of lead users. The performers asked questions and commented the results as their performance.	Collect information from the audience.	Audience: 150 persons, of whom 140 used Presemo. On-stage: Three panel members and two chairpersons, who had access to a simplified control interface. Off-stage: One orchestrator and two moderators.	9
(g)	A primary-school class for getting students engaged and to think about domestication of animals. The students answered two questions during 45 minutes class.	Activate the students	Audience: 20 students. On-stage: teacher, responsible both Presemo moderation and on-stage performance.	2
(h)	An university lecture focused on techniques for promoting good oral hygiene.	Activate the students	Audience: 50 students enrolled to lecture series. On-stage: teacher, responsible both Presemo moderation and on-stage activities	2

Table 1: Cases studied to examine diversity of live participation.

contribute to the main topic of the event, even if they are on stage.

Moderators and *orchestrators* work off-stage and help those on-stage to establish and maintain the extended performances. Moderators pre- and post-screen the content in the mediated interactions. Orchestrators, in turn, show and hide blocks in Presemo. Moderators were present in Cases a, c, d, and f, and orchestrators in Cases a–f. In cases g and h a single person was responsible for both the orchestration and content management, and was all the time on the stage.

The diversity of roles poses questions about live participation tools' interface design. If people in different roles have limitations in their attentive capacity, due to the contextual constraints, do they require different user interfaces? We will return to this question in the Discussion.

Episodes

Episodic extended performances were both our design goal in Presemo's development, and subsequently one of the characterising elements in the resulting live participation (see the section on RQ1). Episodicness makes it possible to be prepared for improvisation already before the event, through a pre-creation of interaction blocks.

To analyse the variation of episodes, we plotted, for each case, what means (as defined in Table 2) was used at any given time to advance the performance's aim. The results, shown in Figure 6, show how frequently the means was changed during each performance. These activity histograms allow us to discuss the episodes in these events.

First, in cases a, g, and h the performers switched the dominant interaction block during the course of the performance. These patterns are pointedly episodic as each moment is dominated by one type of means only.

In a more detailed analysis we confirmed that the episodic patterns were related to different stages of the event. For example, in the educational cases (g, h) the episodes coincided with first using Presemo for audience activation, and later for audience engagement. Even in cases where one means was dominant throughout the performance (such as in Cases c and

The means and its description	Example block titles	Supported aims*	Colour**
Performer-initiated & Performer-controlled			
Collection of precise information Collection of factual information from participants to assist with the presentation. The framing in terms of factual information indicates that each of the participants should know a single, correct answer.	"Your role in the company" (poll)	Collect	
Audience activation Closed-ended questions used during the performance and fully articulated and formulated by the performer team. These questions are often used as an input in the performance, thus as seeking various opinions and then discussing them.	"Evaluate the action (implementability)" (rating)	Collect	
Audience-initiated & Performer-controlled			
Audience engagement Open-ended questions used during the performance and contextualised as a part of the event. With audience engagement, there is a precisely defined, well-articulated aim for the interaction, presented in the framing of the activity.	"What are the problems in combining Big Data and HCI?" (rating)	Activate	
Interaction with performers Activities directed specifically to one particular performer on-stage, such as commenting on a presentation or asking questions of a certain performer.	"Questions and comments to [speaker name, organisation]" (chat)	Ask, Collect	
Audience-controlled			
General chat Allowing participants to discuss an open topic, without further elaboration on the purpose of the activity.	"General discussion" (chat)	Engage	
Specific chat Discussion of a topic that is related to the performance and has a special framing that contextualises the chat as part of the stage in question. However, this is open-ended and does not elaborate more precisely on the aim behind the interaction or the purpose of the chat activity.	"Talent on the Digital Frontier" (chat)	Activate	
Other			
Social lobby An 'anteroom' for the system, with activities familiarising the audience with live participation technology and examining how to use it before the event and performances start.	"How are you this morning?" (poll) "Welcome to [seminar name]" (chat)	Engage	
Event organisation Use of the live participation tool to support event set-up and organisation. This includes conveying information about event timetables, collecting feedback, and posting updates on the next stages of preparation for the event.	"11.20-12.05: Infoshots in Hall G, D and H" (chat) "Lunch Break 12.05-13.05" (chat)	n/a	

* The words refer to the aims presented in Table 1: Ask questions, Activate audience, Engage in knowledge co-construction, and Collect information.

** Used in Figure 6.

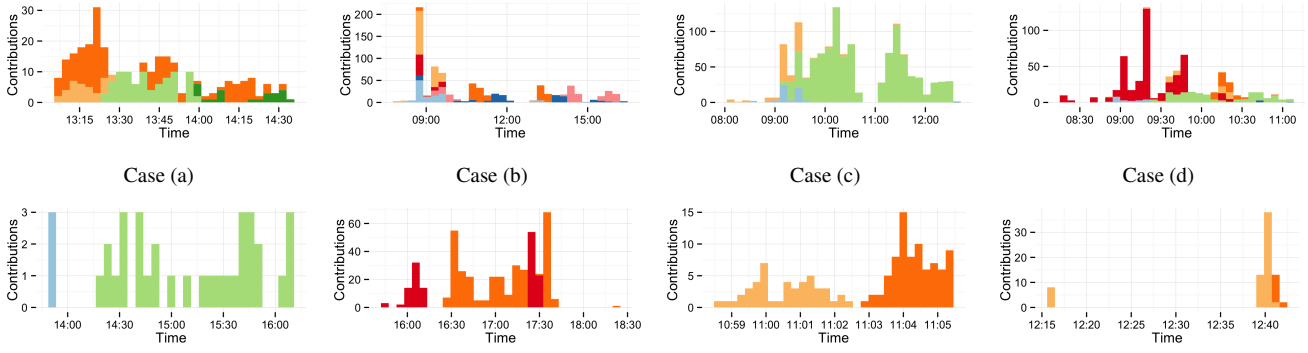
Table 2: The means by which blocks were used to support the aims of live participation.

e), different means had a lot of micro-level variation. While the graphs do not show it, Case c involved use of 14, and Case e use of 3 interaction blocks during the performance.

To summarize, while Presemo's design only included three different interaction block types, our analysis identified eight different ways (i.e., means) to use them to advance the performances' aims. Thus the same types of blocks, when considered as interactive episodes within a performance, were enacted by the performers in very different ways.

DISCUSSION

In this work, we have extended the previous research on performer–audience interaction by looking at various systems used for this target. Audience-response systems, question management systems and backchannels represent systems for a larger application domain that we have titled *live participation*. Furthermore, we presented Presemo, a tool whose design goes beyond those systems that have been designed with one prominent feature only. Our studies on Presemo explored live participation's crucial aspects (RQ1) and foregrounded a wide diversity of different uses (RQ2). With these studies and the conceptual work that we presented before the case studies we increased the understanding on performer–audience interaction on one hand, and tools with which it can be supported on the other.



* Timeline only reflects time when Presemo was in use

Figure 6: Presemo use at events. For the colours' meanings, see Table 2.

We introduced a novel concept—*extended performance*—suggesting that the mediated space created through live participation system can be a venue that performers can use to engage the audience in their performances. Our work involved three approaches that had not been previously considered together: We applied performance research to events, we considered concurrently occurring face-to-face and mediated performances, and we included the audience as an active contributor to the performance. We described the challenges of managing these simultaneous interactions through a concept of integration work.

Our empirical focus was on performers and the ways in which they take advantage of live participation. Performers appropriated Presemo's three functionalities—polls, chat and voting—for four different aims through eight different means (see Tables 1 and 2). Based on eight case studies as well as other settings where we have facilitated Presemo's use, we consider the system design a success and find that it clearly supports performer–audience interaction. Performers have generally been happy with the experience of using Presemo.

Supporting Integration Work

Successful appropriation of a live participation system, as said, requires additional effort from the performer. We referred to this as *integration work*, meaning acts by which performers "bridge" the digital and the on-stage activities. Performers engage in integration work, for example, by including the audience-generated content into the on-stage performance and by articulating what they expect the audience to contribute. Some cases of integration work are straightforward: A performer may ask the audience a question that needs to be answered in the mediated space, and takes the result into account in the subsequent unfolding of the performance. Other cases of integration work may be more effortful, especially if performers cannot follow the interactions in the live participation system. For example, backchannel discussions may take place in forums not directly accessible to the performer. Integrating such hidden interactions in the ongoing on-stage performance is next to impossible.

A significant problem in sustaining the extended performance is that integration work is labourious. When the audience really engages in live participation, performers become easily overwhelmed by the amount of input. Indeed, we observed activity spikes where within a short amount of time tens or hundreds of contributions were entered.

Despite potential hardships, based on our experience, integration work is in the heart of successful performance augmentation with live participation. Because verbal integration work is effortful, we find more potential in non-verbal integration work. Non-verbal interactions' benefit lies in their lightweightness. Live participation systems shoud allow performers acknowledge audience members' contributions with simple positive signals. For example, performers could mark audience contributions as "read", or indicate if they "queue" a contribution for later discussion. Receiving such feedback from the performer could encourage participants to increase the quality and volume of further interactions.

As we reported, audience engagement may be "bursty". To avoid overwhelming the performers, automatic content management could be considered. Chat contents and open-ended answers could be summarized with real-time tag and keyword clouds. With speech-to-text analysis, content in the mediated space could be highlighted based on what the performer is talking at a given time (e.g., [1]). Also if several audience members submit similar content in a short time period, this could be brought up more strongly, for example, by grouping and highlighting these contributions. Finally, content could be rated or otherwise further processed by the audience, such as in Presemo and backchann.el [18].

Supporting the Extended Performance

Successful extended performance requires that the performer has an active presence also in the mediated space. If this is not possible, additional performers may be needed to ensure a sufficient mediated engagement with the audience.

With multiple performers, roles may be allocated for different people. To support *different roles* (see "performer roles"; RQ2), dedicated role-specific live participation interfaces may be needed. Presemo provides currently two such interfaces. The simplified interface (Figure 4) seemed best suitable for hosts while chairpersons benefit more from the full control of Presemo's functions, including block initiation and content moderation.

In single-performer situations in smaller (e.g., classroom) events, the support for an extended performance needs a different approach, as one performer needs to manage both the face-to-face and mediated interactions. Based on our experience, a clearly alternating pattern has been useful. When extended performances become clearly distinguishable sessions, they need well-designed initiations and wrap-ups that bring structure to the performance. Close-ended polls whose results are graphically presented to the audience meet these requirements, but should not be the only means for augmenting performances. New interaction formats are therefore an important topic for future research.

CONCLUSION

Live participation systems are a fertile application domain in HCI. They are actively developed and taken into use in various performances. Our paper has gathered these systems—ranging from close-ended audience response systems to open-ended live tweeting systems and backchannels—together, under a shared conceptual framework. We have also increased, through empirical case studies, conceptual understanding on these systems' salient characteristics of use.

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