

# Watching the Footwork: Second-Screen Interaction at a Dance and Music Performance

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## ABSTRACT

Interactive mobile technologies have become part of audience experiences of live performances in terms of both general media sharing and specific (sometimes official) extra content. At the same time, high bandwidth affords streaming of live events to mobile devices. We take advantage of these technologies in our high resolution, panoramic image video stream and study a scenario of audience members viewing the very same live event they are watching on a tablet. The video stream on the tablet is navigational and enables audience members to pan and zoom in the real-time video feed. We studied audience interaction and impressions in three performances of a dance and music show and found distinct uses of the second-screen video stream. We emphasize that despite initial reluctance, the observed utilization of the technology opened up for new potential practices. Our study shows how working with perceived conflict in technology can still open up design space for interactive technologies.

## Author Keywords

Interactive television, second-screen interaction, mobile entertainment.

## ACM Classification Keywords

H.5.1. Information interfaces and presentation (e.g., HCI):  
Multimedia Information Systems: video.

## INTRODUCTION

New interactive technologies provide intriguing possibilities for augmenting live music and theater performances. Opportunities are plentiful, and several strands of productions and research address, for example, social content for audience interaction [2, 14, 18], technology-facilitated experiences [6, 26] and interactive drama [29]. Today, spectators at live events increasingly use mobile technology to capture, share and interact with content; clips of theater performances are being recorded and shared online, and the personal background of a

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particular sports player is looked up online after she scores a goal. This increased use of mobile technology has been viewed as a distraction — but also as enhancing the live experience with new creative and social possibilities [33]. As devices and mobile networks become more powerful, the amount of content available to spectators will only increase, both in terms of venue- and performance-specific content, and as open interaction between audience members through other channels. This poses a challenge for technology and performance design in terms of developing services and interaction tools that add to the live experience rather than divert attention away from it.

From the perspective of recording and broadcasting live events, high bandwidth and more powerful computing devices have recently made possible real-time streaming of live performances to personal and mobile devices. Technology prototypes focus particularly on the spectator as “being their own director” in that the video stream can be selectively watched using several video feeds [19, 27]. Such an opportunity presents many possible scenarios in terms of personalized viewing of live events and complimentary viewing of an event. Yet, these live events are being broadcast to devices *outside* the sphere of the live event and are often tested with recorded content in laboratory conditions. In this paper we explore the novel scenario of users having access to the live stream in a high resolution, panoramic format, with the possibility to pan and zoom within the video stream, *as they are watching* the live performance. In essence we are extending the concept of “second-screen” interaction to include a stream of the live performance for close-up and navigational viewing. The “second-screen” is then a second image source in the hands of the spectator, complementing the view of the live event rather than a television screen.

In this study we take advantage of a state-of-the-art recording studio setup to capture and broadcast a live dance and music performance to explore how audience members use and interact with an optional screen. We observed the audience as well as the interaction on the tablets at three performances and interviewed a select set of audience members immediately after the performance to gain insights into their motivations and impressions of the experience. Our analysis focuses on audience members’

subjective experiences and their actual interactions with the live video feed.

The results of our inquiries and observations inform detailed descriptions of possible applications of secondary screens. We emphasize how this technology can be advantageous despite initial skepticism, but also how the audience members' added sense of control kept them focused on the performance. Our study contributes a further understanding of how streaming technologies can be used at live performance events, but also, more broadly, how deploying non-obvious functionality in real situations allows the researcher or designer to uncover new possibilities for interactive technologies.

### RELATED LITERATURE

Several strands of research are relevant to our setup and study. Although we are focusing on a live event, most existing interactive media systems have been studied or tested as part of watching television or prerecorded content. Similarly, second-screen interaction has mainly been explored in a large-screen context rather than within live event situations, which is why most related literature is related to interactive television technologies.

#### Interacting with Video Content

Many systems are developed to provide viewers with a live video streamed event with the option to choose their own viewpoint and angle. Olsen et al., for example, describe an interactive TV sports event broadcast where an application prototype gives viewers the option to choose the view and to control replays [25]; experiments with the prototype showed that sport viewers made use of functions such as changing between cameras and "moving in time" rather than passively watching the broadcast. In contrast, Patriakakis et al. pointed to users' potential annoyance when receiving continuous annotations and recommendations for channel switching in a similar interactive video stream [27]. Many different types of interactions have been addressed in terms of video, but the spread of tablet computers and their established interaction paradigm (of pinching to zoom and moving the picture to pan) has made them a modern intuitive way to interact with image media on touch screens. Yet, few video browsers are capable of this type of interaction within video content. Some prototypes have been designed to facilitate, for example, scrolling visually through a video on a tablet [17] or using gestures to browse videos on smart phones [15]. Other researchers have developed direct manipulations techniques with objects in video [20] and simple zoom and pan interaction [36].

#### Second-Screen Technology and Interaction

Although interaction with other objects during television watching is perhaps as old as the television itself, the distinct behavior of dual screen use, actively using another device or technology, is only as new as portable technology. Most research into dual attention of media technologies — so-called *second-screen interaction* — is recent, and made possible through the emergence of smart

phones and tablets. Courtouis and D'heer, for example, surveyed 260 tablet owners in terms of tablets' ability as second-screen media for television watching and concluded that there is an untapped potential since a majority of the respondents reported combining a range of media technologies in actual use [9]. The same authors conducted a qualitative study of media technology use in the home and point out that the television is as often used as secondary to computers and tablets as vice versa [11]. Another approach to second-screen companions to television or video content is a customized information feed related to the television content. One example is FanFeeds, a social media application that provides social, contextualized information about television content. The authors report how FanFeed enabled socializing around television shows, even when time-shifted, due to the flexible availability of the commentary content [4, 5].

When taking the second screen out of the living room and into live events, literature focus particularly on sporting experiences where the screen facilitates extra information (e.g. about the players), essentially attempting to augment the event with technology-enabled content [23].

#### Meditated Live Events

Live events, and live performance in particular, is often described as having inherent qualities of authenticity that can only be experienced in the moment and that are lost when that event is mediated, e.g. through television [1]. The idea that mediating technologies is somehow detrimental to the "essence" of a live performance has recently returned to the public discourse, with performers and artists banning the use of camera phones at concerts. More positive accounts identify the characteristics of mediated "liveness" as being immediacy, intimacy, anticipation, participation and engagement, among others [13, 31, 34]. Dayan and Katz go so far as to say that a mediated live event is in better focus and that a home audience sees more of the event, because the performance is combined with an interpretation or narrative structure [10]. In research, live mediation is also closely tied to the concept of presence, as seen in a range of application areas from video conferencing, media spaces and virtual reality to iTV. Lombard et. al. [22] identify similar characteristics of presence, including immersion, realism and social richness. HCI research has proposed numerous means for engaging with live performances in new ways using mobile media technology [12, 21, 35]. However, in both research and commercial products, there has been a natural focus on mediating events to remote audiences or participants. With the concept of viewing a mediated live event *while attending*, some of the values of mediation, e.g. conveying a sense of immediacy and intimacy, are less relevant to an audience that is present and able to see the actual event as it unfolds. Instead, the potential value of a second video image in the event context itself speaks to characteristics of engagement, participation and a visually enriched live experience [10, 13, 22].



Figure 1: Panorama view of the performance

### PERFORMANCE AND TECHNOLOGY

The live event studied was a dance and music performance, serving as the center of a larger showcase of technologies for broadcasting ultra high definition (UHD) panoramic television from live events [30]. The performance was 22 minutes long and included two dancers, two singers and five musicians (see figure 1). It was the inaugural show by a modern composer, and performers were a mix of professionals and performing arts students. The dancers were at the center of the performance, moving around using the whole stage but regularly returning to the center. The two singers moved only occasionally from their positions on either side of the stage. The musicians were fixed in position apart from a midway intermezzo where all performers moved around and interacted physically with one another in a carefully choreographed fashion. At the end of the show, all performers left the stage (and the studio), leaving just one of the singers performing the final part a cappella. The audience members' fixed seated perspective meant that each performer was likely to, at one point or another, be outside the view of one or more individual audience members. The show was recorded and broadcast real-time to tablets where users could navigate the video stream by zooming and panning. See figure 2 for view of tablets with different views.



Figure 2: The view of the nine tablets with individual streams

### SYSTEM ARCHITECTURE

The panoramic, ultra high resolution video is captured by an omnidirectional camera (see figure 3). This camera

consists of five individual cameras whose images are stitched in real time to form a panoramic scene covering 180 degrees at 5K x 2K resolution. The system transmitting the image, with support for interactive navigation, is a fully implemented end-to-end broadcast system comprising a complex chain of stitching, scripting and delivery engines, control nodes and relays connected by 20Gbps Infiniband lines and 10Gbps-Ethernet. For practical reasons, the architecture presented here is simplified, and focuses on the interchange of interactive commands and rendered video between the tablet end user clients and their access point to the larger system, the Rendering Proxy.

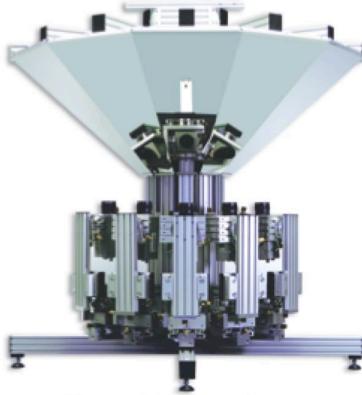
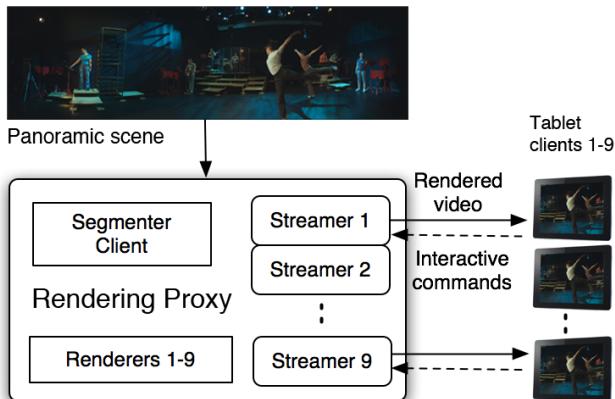


Figure 3: The omnidirectional camera

The Rendering Proxy [24] (see Figure 4) receives the entire panoramic image in the form of 64 high-resolution segments or "tiles". The Rendering Proxy then recreates the image and performs GPU-based rendering of the panorama for each of the end-user clients. The image is encoded using low-latency H.264 encoding and transmitted over TCP/IP. The Tablet Client supports real-time interactive navigation in the panoramic video by means of pan, tilt (swipe) and zoom (pinch) gestures. The video served to these terminals is processed in parallel Streamer instances on a single desktop machine, equipped with a single AMD GPU card. Each Streamer client in the Rendering Proxy listens to interactive commands from their respective tablet device over a TCP port, and operates an OpenGL virtual camera according to the received navigation gestures.



**Figure 4: Rendering Proxy and Tablet Clients**

In the instance of the system used in this study, nine end-user clients running on tablets were supported, with an end-to-end delay (from the camera to each tablet) of 2 to 3 seconds, due to the massive amount of data to be ingested by the video delivery system (around 3Gbps before compression). The round-trip delay between the rendering proxy and a tablet was well below a second, leading to a sufficiently responsive handling of the user interactions (zooming and panning). Note that these latency values are very low compared to many live IP-based video delivery systems. As an example, HTTP-based delivery on the web, typically leads to 10 seconds (or more) of end-to-end delay. For more details on the Rendering Proxy used in this study and the underlying optimizations for panoramic video delivery, we refer the reader to [24, 28].

## METHOD

We wanted to explore audience members' experience and interaction with the real time navigational video stream during the live performance. Although the streaming system was not developed for this specific use, but was provided here as part of a larger technology showcase, we found the opportunity to investigate this initially contrary setup intriguing. Streaming high-definition real-time video might be technically impressive, but our question was how the audience would actually use this navigational video stream in a real setting.

The event we leveraged to study the tablet interaction was performed in total six times; three rehearsals and three regular performances with invited outside viewers. Due to technical limitations, material from audience interaction was recorded from just three performances: one rehearsal and two regular performances. For each performance we collected two video recordings for analysis: One of the audience watching the show while interacting with the tablets, and one with all the actual tablet interaction in a split-screen view (see figure 2 for a composite of the tablets). For the three performances altogether 16 audience members were using tablets.

## Interviews

Thirteen audience members were interviewed after the performances about their experiences (three of the 16 audience members using tablets did not have time or declined to be interviewed after the show). We asked questions in relation to how the secondary video content influenced their experience and what they used it for while watching the performance. Participants were not affiliated with the project but all had a relation to the performance or the location of the showcase, either being relatives of the performers, employees of the local media industry or people affiliated with the university where the performance took place, such as students and teachers. Eight of the participants reported they had a personal interest in dance and music; for example, two of interviewees were dance students and two were professional musicians and music teachers. The interviewees were between 25 and 60 years old with a median age of 32 (seven people were 30 and under and five people were 45 and over). Five were female and the remaining eight were male. Pseudonyms have been used to protect anonymity. Interviews were semi-structured and lasted between ten and 20 minutes. They were recorded and transcribed right after the showcase day.

## Analysis

The overall analysis was based primarily on interviews with audience members. Analysis of video recordings complement these, and were used to uncover viewing and interaction patterns beyond participants' self-reports, though not at the level of a transcribed interaction analysis.

The video content was analyzed by noting each time an audience member looked down at the tablet, when they interacted with the content, and if they zoomed or panned. This was made possible through a synchronized composite screen of the two camera feeds: one of the audience from the side (the audience sat in a soft semi-circle) and one of the screen with each of the tablet feeds running (see figure 5). Thus we could see exactly what the audience members did on each tablet. This enabled quantitative analysis of interaction instances in addition to qualitative analysis.

Before coding the composite video feed it was timestamped with 0 as the start of the performance. Owing to the setup, audience members' faces were occasionally obscured behind other people or because someone walked in front of our camera. Whereas a laboratory setup (e.g. using eye tracking equipment) can measure gaze and interaction in more detail, maintaining a natural environment was more valuable for the purposes of this study. The coding was done in a coarse-grained manner, with short glances down defined as one second and with blocks of time describing zooming and panning, but without detailing the precise targets. The coding was done individually by one author, with another one spot-checking key moments in the videos.



Figure 5: Composite of the video recordings for analysis of observations

The interviews were transcribed and analyzed through qualitative methods using constant comparison to draw out themes and categories. We also compared the audience member's expressed interactions with actual interactions recorded through the two video streams. This allowed us to interpret the audience members' own view of what 'little interaction' or 'a lot of interaction' meant.

Interviewees were informed that we were not directly involved in the development of this technology and that we wanted their honest and critical opinion. However, as previous research has pointed out, there will always be a participant bias, and this small set of interviews evidenced this overly positive response [7], possibly due to participants' initial impression of the technology.

#### AUDIENCE EXPERIENCES WITH TABLET INTERACTION

The responses to the concept and technology of the zoomable second screen were mixed. Several participants were dismissive, saying that it did not work with a live performance like the one they were attending, mainly owing to its modest size given that several activities going on at the stage at the time. If anything, they felt it would work with a smaller-scale performance in a more intimate setting, or in a larger performance such as a rock concert. Rebecca expressed: "I didn't see a big advantage to using a device to look at [the performance] while I was also at the event, just because I didn't think that it could do as good a job as my eye, just following what I wanted to watch without thinking about it". Yet other participants were more positive, highlighting what they felt the second screen was good for: "I wanted to see the 180 degrees so I could watch everything at once, which you can't do when you just turn your head side to side. So that was really good" [Sally]. Three audience members admitted that they had been hesitant and skeptical at first but enjoyed the actual experience. One explains: "To be totally honest, at first I thought it's not going to be that useful because if anything it's going to distract from the actual performance from being there but I found that you can actually interact in a way that you couldn't otherwise." [Malcolm]

While we did not expect everyone to embrace the second-screen interaction with equal enthusiasm, it was interesting to us that some of the participants were initially highly critical of the concept of having another device while

experiencing a live show. This might be a factor of the nature of the particular show chosen, as it was a performance designed for intensive viewing, as opposed to, for example, team sports events, but it might also reflect skepticism borne of inexperience at being presented with a parallel media stream: Why would I want to look at a video of the same performance that I am attending? Several participants expressed this view, or said that they had at least wondered about that before the show. Interestingly, however, almost all users found creative ways to use the extra media stream, often due to the stream being just slightly different from what the viewer could see as real-life audience of the performance. We now review three distinct uses that audience members explored.

#### Viewing Strategies

We found three distinct ways in which users took advantage of the navigational video feed: to get around obstacles and see viewing angles they were otherwise not able to, to look at something related to a special interest of theirs, and to go back in time.

#### *Viewing Inaccessible Parts of the Performance*

Five of the 13 participants specifically explained that they used the second screen during the performance to view parts of the scene that were not visible from their viewpoint in the audience. This included views that were obstructed (e.g. by the camera) or views that were at a very different angle than the audience member's own. Gautier for example said: "I looked at the two ladies that were singing [...], because they were really at the extreme of the landscapes. So it was very interesting to see the [dancer] that I couldn't see with the tablet. [...] I saw a completely different viewpoint". Rebecca also expressed how she used the tablet to see inaccessible parts: "I had quite a good view of the center of the drummer [...], and when the dancers are in the middle, but not of the far right. I couldn't really see sort of that side, I used the tablet to look at it". Ben tied his low expectations but surprisingly positive experience to the fact that he could view these inaccessible parts of the scene: "[First] I was thinking, if I'm in a live performance, I wouldn't be using a tablet. I'd be enjoying the live performance. Then, where I was sitting in the back row, and the camera and the other equipment in the way, so, actually, yeah, it was quite interesting to see what was going on beyond".

The fact that several participants, independently of each other, reported that they found a useful way of ‘seeing around’ the obstacles, illustrates a commonly encountered challenge in live performances such as theater and concerts: for most spectators, there are occasional blind spots due to infrastructure such as columns, angle of viewing and, in filmed live experiences, cameras. Although attendees may not consider this before a performance — or perhaps even consciously after if they have had an overall positive experience — when they are actually experiencing the performance, these obstacles become real and the tablet video feed becomes an easy method of seeing the otherwise hidden object of interest.

#### *Special Interest*

Another way audience members used the secondary screen was to pursue their personal interests. Four participants were performing artists themselves, two dancers and two musicians. Three of these people reported that they used the tablet to zoom in and follow their ‘special interest’ person. Rachel, who recently finished her bachelor degree in dance as performing art, was particularly interested in the moves of the female dancer. She was able to look at the details of the body moving with the music through the secondary screen: “I try to [...] get all the movement in without ... you can lose really nice moments while trying to move about, so I try to keep [the tablet view] quite open like that in dance pieces”. She did not zoom all the way in on the dancer but kept ‘an open view’ so she could follow her closely on the screen as well as in her view of the stage. Both our observations of her in the audience and her media stream confirmed this claim.

Stephen, on the other hand, who was a musician himself, was not as enthusiastic about the technology because he worried it would take away from the experience. He did zoom in on the musicians in the beginning though but then addressed most of his attention to the live performance. He mused around the technology’s potential: “[this tool ...] would be quite cool, because you could have that advantage. Let’s say it was a regular gig and an arena gig, [...] being a musician as well, you have your own things that you might want to look at, so it would be good in that situation. [...] [Y]ou do occasionally get the situation where something’s happening that might quite interest you”.

The special-interest viewing pattern was particularly facilitated by the video zoom function, in that it enabled close-ups of the performers. This highlights the advantages of being able to pan and zoom rather than just streaming a produced video of the performance to second screens.

#### *Automated Rewind Through Time Delay*

Due to network latency the tablet feed had a fixed delay of 2-3 seconds during the performances. Most participants were able to abstract from this but for some, it was a deal breaker. Most participants were fully aware of the technology’s prototype stage and reassured us that this did not color their opinion much since they knew it would be

‘fixed’ in a real implementation. However, this does highlight a serious problem with many state-of-the-art systems consisting of new components: It takes a lot of work to have a fully working prototype, and often small aspects of infrastructure affect the quality in unpredictable ways. At earlier technical testing we had not experienced this delay; it was a surprise at final rehearsals where all the technologies came together. It is important to note that with a system as sophisticated as this, there might always be a ‘missing piece’ from a fully and flawlessly working system.

What we witnessed though was an ability on the part of a few of the audience members to turn this bug into a feature. Two audience members reported specifically that they used the tablet to see parts of the performance that they had missed two seconds before. Rachel, for example, would quickly shift her view down to the tablet if she saw an interesting piece of footwork, in order to see it in detail again. Sarah was also a dancer and explains: “... if I saw something I liked, because of the latency on it, I could go back and have a look and like see things... [...] Like if someone would ... If one of the dancers did a move I quite liked [I thought] ‘Oh, I’ll go and have a look at that again’”.

This is a good example of technology appropriation, where users find an alternative way of using a technology, a way that fits the needs at hand better [4]. In essence, audience members were turning a disadvantage into an advantage and this case points to the value of having more than one temporality. These three viewing strategies led to the experience of control that can emerge from having an interactive second-screen stream.

#### **Obtaining a Sense of Control and Active Production**

The audience members who were most positive towards the concept of an interactive secondary video stream reported that they enjoyed the control that the tablet interaction provided to them. “I thought it was really good fun because then I get to chose how I view it”, was one common comment. Others also found it difficult to follow the elements of the show, particularly the dancers who moved faster than the audience members could sometimes pan: “The end space would jump a bit [...] when I was zooming in or out, which made it hard to follow if I was trying to follow the dancers, [...] They suddenly went out of shot because they’re quite unpredictable. I couldn’t follow them very easily just because I didn’t feel I had complete control over it”. The control of the view on the tablet was not necessarily the same as control over where to look at the stage. To counteract the lack of performer predictability, some audience members kept a wide view on the tablet.

While this increased control over how and what parts of the performance to see worked well for some audience members, others expressed a ‘lazy’ preference for having directors creating the view for them: “If I were watching it on Screen, I would prefer to have a directed view from a director in a traditional television coverage where the camera focuses on what’s of interest” [Ben]. This opinion

echoes a common criticism of interactive television: that viewers most often want to lean back while watching a show and interact only occasionally with the content. On the other hand, control over the view enabled the different viewing strategies described above, in essence creating the experience. It is important not to interpret what participants say they would prefer as actual design guidelines.

### **Being in the performance**

One characteristic of experiencing live performances is the experience of presence in terms of being part of a live event. This sense of presence and immersion in the show contributes to the popularity of live performances and is the difference in perception from, for example, televised shows. Some audience members rightly expected the secondary screen interaction to take away from this experience of presence but several participants had additional insights. Malcolm explained: “[...] even if you are the most interesting performers, at some point your eyes are going to wander around and lose concentration for a few minutes. That lack of concentration was then passed on to the tablet”. Admitting that it is not always possible to focus a hundred percent on the show without his attention drifting, this participant used the secondary screen to retain focus on at least the same content, if not the live part of it. Another participants felt it was okay to follow the live performance and the tablet screen at the same time. It was not easy to follow singers, dancers and the band simultaneously anyway, so the tablet provided an extra viewpoint that could be utilized for the overall experience. Other research using eye-tracking equipment for determining focus between television screen and a secondary screen (tablet) also showed that 5-10 % of the time, the participants were in fact looking away from both screens, meaning their attention drifted from the interactive content [16].

### **OBSERVATIONS OF TABLET INTERACTION**

Where possible, we scrutinized the observational videos to confirm the interaction practices reported by the interviewees. This made clear, for example, that Rachel specifically followed the dancers but also kept her view fairly wide (as she explained), and we were able to determine that a craned neck followed by a glance down at the tablet was an attempt to view an otherwise obscured angle.

Our observational analysis of interaction also illustrated specific unarticulated uses. One common behavior was to use the tablet to pan around quite a bit during the first 3-5 minutes of the show. Then, as the audience member became familiar with the zoom and pan options, they used it less but still regularly throughout the show. One participant, Stephen, on the other hand, only interacted with the tablet in the beginning, then put it aside and watched the show normally. Others kept sporadically glancing down briefly at the screen, even without interacting with the content.

All in all, out of the 22 minute performance, audience members interacted between four and six-and-a-half

minutes with the tablets, meaning looking down at them and/or panning or zooming. The average was five minutes and 24 seconds. We found that users mostly used the panning function, with about one third of the instances of panning also including zooming. At the most, one instance per person per show was an activity of zooming *without* panning, illustrating how the object of interest was most often not in the center of view. The panning sessions<sup>1</sup> were between one second and almost two minutes with averages for each audience member ranging between six and 18 seconds. The overall average of panning sessions was ten seconds. Considering the total length of active interaction during the performance, audience members panned and/or zoomed for four minutes and 41 seconds on average. They would obviously be looking down while panning or zooming, but they also often just glanced down at the screen without interacting: on average 24 times with glances lasting between less than a second and 32 seconds.

All in all the audience members were using the tablets in a fairly predictable way and to a level compatible with still taking part in the live performance. The main difference between audience members was not how much they panned and zoomed but how often they glanced down at the tablet without touching it; this corresponds well with the diverse expressions of the system's appropriateness we found in the interviews.

The ratio of panning to zooming that we observed underscores and adds to our observational findings regarding two primary viewing behaviors. Panning was dominant in both finding better viewing angles and locating points of interest, and was more intuitive as an interaction technique. Zooming was valuable for added detail, but focusing on a point of interest was observably more difficult for viewers and involved the risk of losing the overview. Still, the frequent use of combined pan-zooms, actions (moving quickly between the two), a fairly complex navigation technique, indicates that both these navigation modes for “content interaction” [see e.g. 20, 36] on tablet devices are feasible and familiar enough to be used with confidence by participants without prior training in this particular interface.

From these observations we infer that the initial, more intense interaction is due to familiarizing oneself with the interface and to its novelty value. The following more mixed attention, although likely affected by the trial situation, suggests a more realistic range of use patterns.

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<sup>1</sup> A panning session is defined as the time between the audience member looking down and starting to pan until they looked up again. Their fingers were not necessarily touching the tablet the whole time, but as with all interaction with touch screens, fingers would be lifted, paused, and sometimes taken to the side.

Importantly, the interface supported these different levels of engagement equally well.

## DISCUSSION

Introducing mobile media technology into a live event setting is not uncontroversial, and may even seem to be at odds with the live experience the spectators seek. Yet, the way mobile devices have entered and changed this space is unmistakable. In particular, the use of camera-phones for taking pictures and filming at events has been both hugely popular and hotly debated. As an alternative to trying to reverse this development, we see an opportunity for designers and developers to produce interactive media technology that enhances experiences rather than disrupting them. The tablet system presented in this study contains a novel set of features that allow spectators to interactively navigate an ultra high resolution panoramic video of the event they are attending in real time as the event is unfolding.

Several participants in this study were initially skeptical when presented with a second screen for viewing and interacting with the live performance content. As described in the analysis their skepticism largely had to do with whether the video on the screen would give them anything they would not otherwise get from the performance itself, or just be a distraction. After trying out the application, a few remained dubious, stating that they did not see themselves using an additional live video device, no matter the functionalities offered. Still, the majority of participants, skeptics and enthusiasts alike, discovered specific ways of using the live video panorama that complemented their experience of viewing the live event. The following section draws on these behaviors to propose situations where an interactive second-screen application could enhance the live event experience and features to explore further in design.

### Advantages of Second-Screen Video Stream

There are several situations and manners in which such live video stream is useful, as evidenced from our observations and audience inquiries; we here explore four core advantages:

Firstly, the fact that most spectators do not have ideal viewing positions in the audience implies an obvious advantage of being able to choose a better viewpoint. Any performance or show that is televised will have both equipment and personnel between the audience and the stage, and even traditional theater experiences have seats with limited view due to columns and other building infrastructure. Premium seats still have one set vantage point, while the actors might be positioned in a different side of the stage. The camera used for the second-screen stream will typically be placed at the best position available since its view is presented to the larger (sometimes remote) audience.

Second, and related, the viewing angle in our system is 180 degrees, which provides a more detailed view to the

audience. Our participants noticed the extra viewing angles compared to their own view, where a focused 180-degree view required turning their head. Taking advantage of the panoramic possibilities in video content can provide a condensed overview over the activities on stage and inform spectators where the attention should be directed.

A third valuable use of a secondary screen is apparent when considering larger events. Although our event was a small studio-based show with only nine performers, a larger audience would have placed some spectators even further from the stage, with consequences for detailed watching. Large-scale performances such as stadium concerts potentially benefit from viewers being able to zoom in and find detailed parts, illustrated by the now-common placing of large screens on the side of the stage. These large screens most often show a directed video stream of the performer with additional camera angles and occasional replays, which was one of the specific preferences from a few of our interviewees. Yet, it is not clear if the stated preference for a directed stream came from an established standard of practice or an actual lived preference.

Fourth and finally, even at engaging live events, there are times when spectators' eyes wander or the spectator needs a visual break. At these times, a second screen may provide variation, and actually make event attendees *more* engaged with the performance at points when they otherwise would turn away from the event. As we described, many of the audience members were observed looking down at the tables on multiple occasions throughout the performance, often for just a few seconds, without interacting with the stream.

These findings are relevant to a current interest in HCI research in providing tools for participation and content creation at live events [18, 21, 32]. Where this prior work has proposed means of creating, sharing and saving content to be viewed afterwards, our work presents an alternative route that provides the visitor with additional content to engage with in the moment. Combining the two approaches by adding basic broadcasting and recording functions would allow visitors to share and save their experiences as memorabilia.

### Broader Lessons for Design

From the experiences with a panoramic, navigational stream of a live event, we now broaden our findings and examine implications for interactive media technology at live events. We found, despite our initial doubts, that this type of technology has the potential to enhance the live experience rather than detract from it.

On a broader level we found that flaws or 'seams' [8] in the technology worked to our advantage and illustrated a potential use: the "replay" functionality caused by the video delay, although not intentional, was in some cases valued. It became clear that the secondary screen video stream would benefit from just such a function. This does not need to be a

replay in the production sense (manually produced), but simply the ability to play back material, for example a fixed number of seconds back. A full rewind functionality might not be necessary but a simple way of moving a couple of seconds back in time, then forward to synchronous time again, might be valuable for some spectators.

Secondly, audience members' sense of control in terms of attention is a relevant issue to consider. A live performance is often a more focused experience than a televised (even if live) show and attention is more likely to be on the performance for a higher proportion of the time. But even so, attention occasionally diverges, particularly to other media devices and perhaps other audience members. As we pointed out, the system afforded a feeling of control, and the second screen not only provided them with a place to turn, but also content that was still part of the performance. In addition, this illustrates the room for media sharing in terms of both 'in the moment' and after the event. Instead of having the spectators record the event themselves, such a secondary stream will have the benefit of being readily available for sharing through mobile devices.

Finally, we want to highlight that it is important to work *with* the conflict in technology adoption and appropriation, extracting potential practices from real-life situations, rather than avoiding interactive technology deployment because of assumptions that it will not add much. The FascinatE high-resolution panoramic video system was not designed *just* to support a second-screen stream, but for many other purposes, such as automatized editing and directing of a large live event and to record a panoramic scale video of a live event. The possibilities for streaming this content live to tablets came later in the development process, and let us examine this a real-life situation. This provided us with a unique opportunity to see how potential users approach such a tool.

## CONCLUSION

We have described how audience members interact with a secondary navigational video stream of a live event while being present at the event itself. Despite audience members' initial skepticism, our observations and inquiries uncovered and elucidated several unique uses. Many participants were themselves surprised to find the second video stream appropriate and not necessarily in the way of their real-life experience of the performance. Our study showed that audience members were able to keep control over their viewing experiences through the second-screen video feed while maintaining a presence in the live performance.

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