# Performing Thrill: Designing Telemetry Systems and Spectator Interfaces for Amusement Rides


**Holger Schnädelbach [1], Stefan Rennick Egglestone [1], Stuart Reeves [1], Steve Benford [1], Brendan Walker [2] and Michael Wright [1]**

[1] Mixed Reality Laboratory
University of Nottingham
Computer Science
Wollaton Road, Nottingham, NG8 1BB, UK
{hms,sre,str,sdb,maw}@cs.nott.ac.uk

[2] Aerial
42 Murchison Road
London
E10 6NB, UK
info@aerial.fm



## ABSTRACT
Fairground: Thrill Laboratory was a series of live events that augmented the experience of amusement rides. A wearable telemetry system captured video, audio, heart-rate and acceleration data, streaming them live to spectator interfaces and a watching audience. In this paper, we present a study of this event, which draws on video recordings and post-event interviews, and which highlights the experiences of riders, spectators and ride operators. Our study shows how the telemetry system transformed riders into performers, spectators into an audience, and how the role of ride operator began to include aspects of orchestration, with the relationship between all three roles also transformed. Critically, the introduction of a telemetry system seems to have had the potential to re-connect riders/performers back to operators/orchestrators and spectators/audience, re-introducing a closer relationship that used to be available with smaller rides. Introducing telemetry to a real-world situation also creates significant complexity, which we illustrate by focussing on a moment of perceived crisis.



### Author Keywords
Performance, theme-park, amusement, fairground, telemetry, biosensing, spectator interface, wearable computing, heart rate, orchestration.

### ACM Classification Keywords
H1.2 User/Machine Systems; H5. Information Interfaces and Presentation.


### INTRODUCTION
The amusement park, spanning the theme park and the fairground, is an historic form of entertainment that has driven the development of entertainment technologies for many years, from the first manually operated roundabouts or 'dobbies', to today's virtual reality simulations and extreme roller coasters [15]. Computers are now routinely used to design amusement rides, control their operation [18], enable a rider's interaction and immersion [12], and increasingly to document their experience by automatically producing still images or even videos as souvenirs.

One of the most challenging problems facing modern amusement parks today is that of spectators: accompanying visitors, often the adults in a party, who are unable or unwilling to go on the rides, but who nevertheless have to spend a day at the park. These visitors are often left 'holding the bags'. Given that they are often also the ones who hold the purse strings, it is important to consider how their experience might be improved. Inspired in part by the increasing use of telemetry in sports such as motor racing [5], our approach to this problem is to use a personal wearable telemetry system to capture a rider's experience and broadcast it to spectators so that they can get a greater sense of what it might be like to ride and can more closely share in the reactions of friends and family. Such a system also has the potential to extend the images (and in some places videos) that are now being sold as ride souvenirs.

HCI research has also begun to focus on the spectator. As interfaces have moved into public settings such as museums, galleries, clubs, performances and the city streets, it has become increasingly important to consider how interaction with computers operates as a public affair. Inspired by ethnographic studies of interaction in such settings [6,7,8,16], researchers have proposed new approaches to designing interaction with spectators in mind, for example choosing to reveal or hide the manipulations of an interface and their consequent effects [13], or by considering how to frame interaction in the public arena [2]. This paper reports on a deliberate attempt to create such a spectator interface and our study is therefore relevant to this emerging discussion in HCI as we address later on.

Our approach has involved the rapid development and public deployment of a wearable telemetry system along with a qualitative study – involving video recordings and follow up interviews – in which we have developed an understanding of how this technology is understood by the public. As a first prototype we staged a sequence of live experiments which played a principal role in a series of major science museum events based around the study of amusement rides. We therefore begin by describing this performance event and our telemetry system before turning to our study.

## OVERVIEW OF FAIRGROUND: THRILL LABORATORY

Our study is of an event called Fairground: Thrill Laboratory, henceforth referred to as F:TL. This was a series of six theatrical events that were staged at the Dana Centre (Science Museum, London) in three weeks of autumn 2006. Full technical details of the design of the events and technology can be found in [17], as these are only briefly summarised in this paper. The events were designed to explore the nature of thrill through a combination of science and entertainment, involving talks by experts (for example, in biometrics and theme park ride engineering), live telemetry streamed from a selection of theme park rides, and the opportunity to go on the ride at the end of the evening. After a set of introductory talks, the audience was presented with a visualisation of live telemetry streamed directly from the ride. Firstly a member of the production team rode, providing a live commentary of his experience. Secondly, a lottery was used to select an audience member whose telemetry would be transmitted next. During the final stage of F:TL, all other audience members were free to ride, with volunteers using the telemetry equipment as often as the technical and organisational infrastructure could support.

**Figure 1 Booster** **Figure 2 Rider position**

Each week featured a different amusement ride that was set up outside so that it was visible from the various spaces used within the venue. Here we draw on the experience surrounding the last and most extreme of the three, the Booster, a pure white-knuckle ride that relies mainly upon fear and on extreme accelerations to elicit a sense of thrill in the rider. It features a central tower supporting a 40m-long rotating arm, similar to a windmill. Freely rotating carriages are attached at either end of the arm and hold two pairs of riders seated back-to-back. The speed and direction of the rotating arm can be controlled, with riders experiencing accelerations reaching up to 4G. We have chosen this ride because the event structure and technology were at their most stable and well developed at this point.

A custom-built wearable telemetry system captured four sources of data from riders: video of their face, audio as a means of self-reporting, ECG and acceleration. This equipment was integrated into a jacket as shown in Figure 3. This had to meet several design challenges, including fitting the passenger restraint system of each of the rides, being comfortable to wear and remaining easily serviceable. The design also had to address the physical strain of wearing head-mounted equipment at high G-forces.

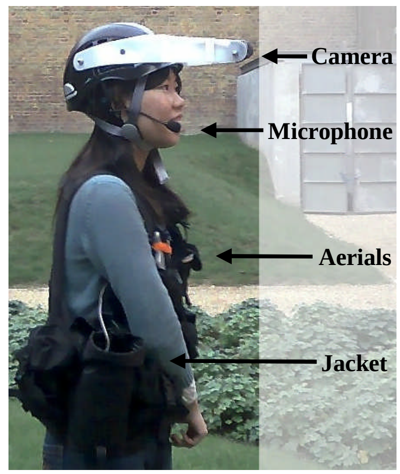


**Figure 3 Wearable telemetry technology**

The audience experience of the telemetry data was supported by the ‘expert’ visualisation, shown in Figure 4, projected in the main auditorium. Other, less detailed visualisations were projected into the bar and onto the side of an opposing building as ambient display for the benefit of any participants who were in a position to observe these locations.

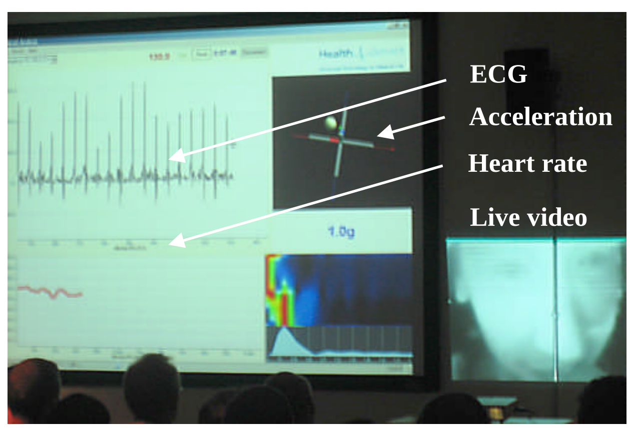


**Figure 4 Visualisation of telemetry data**

This visualisation included the ECG and heart rate trails, numerical heart rate data, a 3D visualisation of the G forces experienced by the rider and live video from the helmet camera in addition to the audio stream broadcast over speakers. During transmission, experts were at hand who introduced the data to help the audience make sense of it and 'calibrate' their expectations.

## EXPERIENCING THRILL

To explore the impact of introducing wearable telemetry technology on riders, spectators and ride operators, we concentrate on three vignettes drawn from a larger corpus of data. This data consists of: eighteen sets of telemetry data including video recordings captured by helmet mounted cameras worn by the riders, along with corresponding log files of accelerometer and heart rate data captured for each; approximately fifteen hours of video recordings by a handheld camera following participants and team members; and supporting design documents and notes. These vignettes have emerged from an analysis process which involved the transcription and discussion of multiple fragments in a series of 'data sessions', during which our key themes emerged. These themes were also followed-up through five semi-structured phone interviews with riders. Two further semi-structured interviews with ride operators at the events were also conducted. Ultimately, we selected these three vignettes as being representative of the most compelling issues that we uncovered. Some appreciation of the spatial and organisational set-up of spectators, operators and riders and their lines of communication is critical for understanding the vignettes. The following therefore provides a brief overview. Overall the event was staged across multiple spaces inside and outside the venue, while we concentrate here on those spaces that are directly necessary for our discussion.

**The main auditorium (2nd floor)**. Here, data transmitted from a single rider sitting on the ride outside was visualised and discussed. This process was guided by a number of event hosts, who ensured that each group of roughly 90 spectators had good access to this information. In addition, the main telemetry control room was set up on one side in the same space, physically overlooking the ride outside. From here, technical operators ensured the availability of the live data streams at the right times during the event.

**On the ride.** On the ride, set up outside approximately 40m away from the auditorium, riders went through the roughly two minute long ride program. As part of the telemetry equipment, the rider had a one-way audio link to the control room, which was sometimes (but not always) broadcast to the audience in the auditorium. This audio stream was controlled by event staff, who responded to requests from event hosts.

**Outside in front of the ride (ground floor).** From here, the ride operator controlled the speed, direction and duration of the ride, as instructed by a telemetry operator, who was in two-way radio contact with the control room upstairs. At the right times during the event, the telemetry data, operation of the ride and verbal commentary by the rider were coordinated via this link.

The following three vignettes, taken from the final event, highlight the experiences of different kinds of participant in the event. The first follows a 'professional rider', a member of the production team who gave an initial public demonstration at the start of the event. The second follows the relatively routine experience of Sam, a member of the public audience who became a rider by virtue of winning the ticket-lottery. In contrast, the third focuses on the activities of the technical operators as they decide how to deal with a moment of crisis in which a public rider appears to be in difficulty.

### Vignette 1: Alan – the professional rider

Our opening sequence begins with Alan[1], our professional rider, waiting on the ride outside having already been presented to the audience downstairs. The audience is getting seated in the main auditorium. Two of the operators are outside on the main platform of the Booster ride. Two more operators are in the control area in the auditorium and are in radio contact with one of the operators on the ground. As the audience settles, a host at the front of the room provides a very brief introduction for the audience, introducing Trevor, an expert in the sensing technology whose role it is to explain its operation and the nature of the visualisations.

{1} Host: Come and sit down. Mentally fasten your seatbelts [...] we're gonna go straight to Trevor [gestures towards main projection, which at this point switches to the visualisation]. Telemetry, what is it? [Faces Trevor who enters] Trevor. [Host claps][Audience claps]

Once standing by the projection, Trevor goes on to describe the individual components of the visualization.

{2} Trevor: [...] On the ECG [pointing at the ECG display again] we see the peak [flattens hand and raises further into air] when the heart is beat, we analyse it and calculate [points at heart rate display at bottom] the heart rate. We see Alan is still... [moves hand horizontally] sitting there and waiting so his heart rate is not big [inaudible] 70 or [inaudible] we see it changes all the time [waves left hand along the heart rate line] it's very variable. [...]

Trevor's conduct at the projection highlights how variable the visualisation is and thus how to make sense of and 'read' what is a 'reasonable' or 'expected' level of variability in heart rate, ECG and so on. As his description comes to a close, Brian, another host, who is at the back of the room begins speaking.

{3} Brian: I think... we'll see we'll umm I'll cut to Alan now and see what he's got to say just before we started the ride. [Beeping radio sound, Brian talks into radio] Right Tim could you get Alan to start speaking please?

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[1] All names have been changed for anonymity

Alan is silent for approximately three seconds during which time the ride starts moving relatively slowly.

{4} Alan: Uhh okay I'm assuming you can hear me. And it's pretty cold out here [audience laughs]. […] it's going to be an interesting ride. And [inaudible] get spun around and it's actually quite a pleasant sensation. The view up here is phenomenal. And the ground comes rushing towards you pretty quickly here I'm not really going fast yet so…

It is notable that Alan mentions the ride's slowness. The ride was, in fact, intentionally run slowly at the beginning as experience had shown that this increased the reliability of wireless communications, providing stability during the moments when Brian 'hands over' to Alan. As a professional rider, Alan has already been on the ride many times, but each time he must describe his experience anew. Although he can talk to his audience he cannot see or hear them in return and so must broadcast himself to unseen-but-assumed audience.

Alan now continues his reportage. However, as the ride speeds up so his talk begins to feature more exclamation than description.

{5} Alan: And I've started to rotate oh here it goes and I'm upside-down ooohh! [Audience laughs]

Brian: Brian to Tim [an operator outside] can you go faster please?

[Audience laugh]

Alan: The ground's [inaudible] very quickly!

[Audience laugh]

Although it is in the planned schedule of events that the ride will indeed speed up after a short period, Brian theatrically highlights this moment to the audience. Brian's statement transforms what might normally be a private coordination between the crew into a public one.

At this point there is sudden silence as the video freezes and audio drops out. The audience laughs and starts talking amongst itself, with some audience members at the back looking out the small windows to the ride itself.

{6} Host: Have we lost him?

Brian: Are we… I think we've lost Alan [laughs]

[Video resumes and Alan can be heard laughing]

Host: No he's back

Brian: Oh no he's back

[Audience laugh]

Alan: Wohoo!

[Video and audio freeze again]

Brian: Ooh…

Brian and the host comment on what is observable to the audience, such as "losing" Alan (i.e., the audiovisual stream freezing), getting him "back" (i.e., resumption of the audiovisual stream) and finally "losing" him yet again. It is part of the performative work of Brian and the Host to weave Alan's broadcast into the ongoing trajectory of the performance, highlighting his comments, covering during disconnections, and fading him in and out as necessary.

{7} Brian: Okay I'll get him off the ride now I think he's had enough. Okay can we let err let Alan off please?

[Video and audio begin to work again]

Alan: I can't really talk [fades out]

As we saw earlier, Alan's more sober description became more interspersed with laughter and exclamation. Here Alan states as he is faded out that he is finding it difficult to talk. Even though Alan is a 'professional rider,' there are times when he may 'lose control' to some extent due to the extreme physical nature of the experience.

Finally, Trevor returns to briefly describe Alan's heart rate, explaining that he can "start to relax now", highlighting the decrease with his hand once again. Brian then closes the performance.

{8} Brian: Brilliant that was Alan on the Booster! [Claps] [Audience claps]

### Vignette 2: Sam – the public lottery winner

In our second vignette, a member of the public, Sam, has won an opportunity to ride the Booster in the public lottery. Her friend Anne joins her for the ride. Sam has been guided downstairs and towards the lawn in front of the ride in order to put on the necessary equipment (see Figure 1, bottom). Also present are operators H, J (filming), and operator F, who in this case is female so as to avoid potential embarrassment when fitting sensors to Sam's torso. Standing near the ride, and after a short moment of discussion about the cold and "nerves", Sam begins to don the equipment, the first element of which is the heart monitor.

{9} Operator F: We need we need to attach these [holding up patch] here and here on your skin so I'll do that over here

At this point Sam and operator F, who step away from the main group, creating a more private area in which Sam is facing away from the group as the sensors are placed on her torso. The setup procedure continues as operator H now helps Sam into the jacket and helmet.

{10} Operator H [Moves around to the side of Sam, holding the helmet's camera]: Is that relatively even? Does that fit? [Operator H moves round the back again]

Sam: Yeah yeah it's a bit it's a bit loose [moves helmet around with hands]

[…]

Operator H [moving round to side of Sam again]: We'll [inaudible] the strap as well

Sam: OK that'd be good

[…]

Operator H: Now we need to attach these to the sensors [to Operator F] you put those just here [places palms on side of his torso]

[…]

Operator H: [Stands up straight now, steps back from the jacket] Now let me see we've got everything

As the first part of the donning procedure comes to a close, operator H physically steps back to appraise the situation. The equipment must be 'just right' in preparedness for the ready signal, as well as being relatively comfortable for the rider. This takes a significant amount of time and operator H has at this point already spent several minutes getting to point at which it is possible perform the next task. This second phase of readying involves testing the various functions of the equipment. This takes a further few minutes.

{11} Operator H: [Walks back away from Sam and guides her into a position] Could you stand here for a second, and just stand this way exactly that way [...]

Operator H: [Speaking into radio, oriented towards main building] Hello err we've got everything switched on are you getting data? [...] You getting the video as well? Shall we test audio [...] [To Sam] So the err just count or something

{12} Sam: [Looking at Operator H] 1 2 3 4 5 6 7 I'm really scared at the moment I'm going to crap myself any minute now [...]

Operator H: Just count again

Sam: Okay 1 2 3 4 5 6 7

[Sam continues counting several times whilst Operator H talks with upstairs]

Operator H: Confirmed ok that's fine thanks [Turns towards Sam, nodding] S'alright

[Sam stops counting]

{13} Sam: Okay you're going to make me talk and stuff oh brilliant oh dear

The equipment is now designated as working. Sam, operator H and the others must wait in readiness for the signal to start the ride.

{14} Operator H: [to Sam] We've got about 10 minutes but yesterday it varied by a lot so I hope it will just be 10 minutes.

This sequence shows the considerable time and work required to get the rider and equipment to a state of readiness. The rider must stand at particular orientations so as to align aerials ("stand this way exactly") for lengthy periods conducting tests in concert with operator H. After further waiting, the signal is given to operator H who then suggests they "go on" the ride. The group climbs the steps onto the base of the Booster, with Sam and Anne coming to be seated on the ride itself. As Sam is seated, operator H has to carefully remove the helmet, pass it through the bulky seat harness and reattach it once again. Trailing wires, battery levels and so on then have to be checked again. Sam and Anne wait for the ride to begin, chatting.

{15} Sam: It's really cold isn't it. Brrr. [...] Is this all part of the thing to like proper heighten our senses or something so we're really screwed up before we go on it? Do you offer post-traumatic stress counselling sessions?

We can contrast Sam's experience with that of a normal rider. There are a number of practicalities which impact her: there is considerable waiting to be done, both on and off the ride; she feels the cold (in this instance); she must spend time donning and getting comfortable in the equipment, and taking part in testing it. The build-up to the ride here is greater and longer than usual, and is clearly seen by Sam as heightening her anticipation. We also note how the audio testing reinforces the idea that she is meant to commentate on her experience.

Finally the signal is given that the presentations upstairs have come to a close and that the audience is ready. Sam begins talking as the ride's steps retract, with the ground staff present on the lawn watching.

{16} Sam: Umm helloo um I'm sitting on the ride slightly scared but um really really excited so it should be cool. If I die, I love you all. [...] Shall I just keep talking? Oh. The ride's about to start! Ok we're currently going up oh this is so cool! [...] We're kinda hanging forwards and um we're coming down to the ground we're going quite slow at the moment. I'm absolutely fine at the moment. Okay yeah they're speeding up a bit now, this is absolutely brilliant. Um yeah quite high. Oooh! [high scream] Okay that was cool. Oh my good [...] Wow! [screams] Woohoo! Woohoo! Waa

[Video cuts out]

Sam: [shouting] Oh my gosh! This is so cool. Oh wow. This is the most amazing [inaudible] ever. [screams] woohoo woohoo! wooooooh! Oh wow this is fantastic mate. Ah you gotta come on this absolutely brilliant. Woo hoo! You alright Anne? Woo hoo hoo! This is absolutely wicked! Oh this is so good! ha ha ha woo hoo! I was afraid of heights not any more! Get in! [inaudible] Oh wow woo so far from the ground it's wicked! [...] Okay we're coming to a stop now. Like that one, yeah, you should give it a go. Woo! Can we go again?

After the ride comes to a stop, Sam and Anne are helped off by operator H. Like Alan in the previous vignette, Sam is broadcasting to the unseen-but-assumed audience. Similarly to Alan she also begins by providing a running-commentary of her experience until she breaks into less controlled screaming and exclaiming as the ride speeds up. After this, when the ride has slowed down somewhat, she encourages the audience to have a go on the ride.

### Vignette 3: Crisis in the control room

In our final vignette, we turn our focus to the control area in the main auditorium, during a time after both Alan and Sam have been on the Booster. The audience are now on the lawn in front of the ride, either queuing, on the ride itself, or spectating. Also on the lawn is operator H, helping a (female) rider who has volunteered herself from the queue to don the equipment. Operators A, S, T and J are in the control area.

{17} Operator S: Yeah I can hear audio

Operator A: We have err audio. Do we have ECG and accelerometer?

Operator S: No not yet

Operator A: Not even accelerometer cos I don't think he turned that off

[...]

Operator H: Hello there what's the reception like?

[...]

Operator A: Yeah the video's working fine and audio

Operator H: Okay so can we go on the next ride yeah?

Operator A: Having having said that video has just closed but I think once you oh it's back again... I think once you go on the ride it'll be okay

Operator H: Okay

Operator J: I think there's somebody somebody standing in front of her so probably she's blocking the transmission

This sequence exhibits the counterpart perspective to operator H's work in the previous vignette. Here we see the extensive work of the crew upstairs in getting the ECG, accelerometer and audiovisual streams functioning to such a degree that they are in a 'rideable' state. This includes reasoning about the causes of wireless drop outs.

Now that the system is in a readied state and the last ride has come to a stop, the rider and her co-rider are taken by Operator H to the front of the queue, where they walk onto the Booster platform together. Like Sam, operator H helps the rider into the seat and checks the equipment for trailing wires and so on. With the bottom carriage loaded, the ride operator spins the ride halfway round so that our rider and her colleague are waiting at the top while the next carriage is loaded. It is at this point that the rider attempts to contact the ground. In fact, her audio is not generally audible but is channelled into some headphones which operator S has in his hands. However, she probably does not know this.

{18} Rider: Scuse me can you hear me?

Operator S She's saying can we hear her

Operator A [to Operator H]: She's saying can we hear her... wave to her or something

Rider: Scuse me

{19} Operator H: Yeah I don't [inaudible] forward. She sounded quite scared

Rider: Are you sure Ned? [Ned is sitting next to her]

Operator A: [laughs] Excellent that's what we want to hear

Rider: Hello control?

Operator S: She thinks we can hear us

Rider: Control please

{20} Operator A: Her heart rate's gone down

a bit now

Rider: Okay... control room can we please turn it off for Ned?

Operator A: I can't quite see her eyes... but

Rider: He's really scared

Operator S: She said she's really scared

Rider: Please can you get the ride off?

Operator S: She said she's really scared can we take her down

Operator A [to Operator H]: Apparently apparently the [inaudible] on the top says she's really scared can we take her down

Operator H: Sorry?

{21} Operator S: I think we should I think we should pretend we haven't heard

Operator H: Sorry could you repeat

Operator T: Do you think it seriously or?

Operator A [to Operator H]: Apparently the girl on the top is really scared can we take her down

Rider: There's nothing to be scared... hey

Operator A: How how how scared do you think she is... she's not looking too...

Operator H: She really is saying that she wants down?

Rider: Hello control can you please hear me?

[Operator A looks at Operator S, who has the headphones to one ear during this]

Operator S: S'yee yeah [takes headphones away from ear] she keeps saying ... can she come down

Rider: Hello pleeease

Operator A: She does keep saying that I mean we might [inaudible] actually so maybe bring her down if you can

Rider: Hellooo

As the ride actually begins properly, what is a critical moment for the technical crew arrives.

{22} Rider: Ned Ned close your eyes

Operator A: Yeah... How how's she looking is she still

Rider: Stop... stop please stop please stop noo

Operator A [to Operator H]: She she keeps shouting out stop... go go and see the ride operators [inaudible]

{23} Operator T: Why, it's way to 160 her heart

At this point, operator H can be seen moving towards the booth in order to instruct the ride operator to slow or stop the ride. The main job of work for the crew in this episode, both on-the-ground and in the control area, is in determining the 'seriousness' of the situation, and then acting appropriately. Experiencing fear is a presumed possibility (if not expectation) with a ride like the Booster, and the technical crew must be sensitive to 'normal' or 'expected' levels of fear versus 'serious' fear. As the situation progresses, a variety of methods come into play in determining the seriousness of the unfolding situation: Operator H observes: "she sounded quite scared"; operator A considers her heart rate and facial expression ("how's she looking"); operator T explicitly introduces the issue of seriousness ("do you think it seriously or?"); and finally operator S reflects on her persistence ("she keeps saying", "she keeps shouting out stop").

At this point we must stress a couple of points. Firstly, the rider's companion reported being scared rather than the rider herself, and neither person was in any physical danger given that such rides are subject to strict safety checks and agreed operation procedures. Secondly, the operators in the control area were not in direct control of, nor directly responsible for, the ride's operation, and this is a point upon which operator work in determining seriousness revolves. Initially the rider's communication attempts are woven into a joke ("wave to her or something"), and the crew "pretend [they] haven't heard", relying on plausible deniability. This plausible deniability can only be sustained for so long, however, due to the determined level of seriousness, and as such the crew must begin to consider stopping the ride. This strategy, however, carries with it a number of significant overheads. Stopping the ride or slowing it down just for one person obviously disrupts the experience for co-riders and requires intervention by the operators. In the end, the ride is slowed down, but not stopped, which appears to resolve the crisis.

{24} Rider: Are you okay? Ned are you okay you okay you okay? Ned are you okay? Look look it's [inaudible] no… it's okay

Operator S: She she says it's okay she says it's okay

Operator A: Oh sorry Operator H she says it's okay now she says it's okay

Operator H: It's okay now?

Operator A: Yes yeah [inaudible]

## DISCUSSION: PERFORMING AMUSEMENT RIDES

We now reflect on our three vignettes, further illustrating them with quotes from post-event interviews, in order to reveal the ways in which our telemetry system transforms riding into a public performance and also to identify key challenges for the development of future systems.

### Previous research in performance interfaces

In order to ground this discussion and to enable us to draw out more general lessons for HCI, we relate our observations to previous accounts of interactive performances from the literature.

There is a longstanding interest in HCI in interaction in public settings such as museums, galleries, artistic performances and even the city streets. Ethnographic studies of interactives in museums and galleries have revealed the public nature of interactions and highlighted the roles of co-visitors and spectators [16]. Other studies of interactive performances have highlighted the importance of orchestration practices in shaping a live experience, including the ways in which technical crew monitor and intervene in an experience from behind the scenes [6, 8].

Studies such as these have inspired more general design frameworks for performance interfaces. In particular, [13] has discussed the relationship between the primary users of an interface, called performers, and nearby spectators, showing how different approaches to revealing or hiding performers' manipulations of an interface and their consequent effects might lead to experiences that can be considered to be 'expressive', 'secretive', 'magical' or 'suspenseful'. A second framework has considered how a performance is framed, further dividing spectators into two categories, audience members who are inside the performance frame and therefore aware of the nature of the performance versus bystanders who remain outside the frame and so may be unwitting observers [2]. Drawing on this existing body of work, we now consider how our F:TL performance can be described in terms of the relationships between the three roles of *performer*, *spectator* (who may be further subdivided into audience and bystanders) and *orchestrator* (spanning a diverse range of sub-roles).

### Reconnecting performers, spectators and orchestrators

In F:TL, the performers are the riders who wear the telemetry system, whereas the spectators are those who observe them. These spectators can indeed be divided into an audience who have purchased tickets for the event and who gather in the main auditorium to view the telemetry output, versus bystanders who may observe the ride outside but without seeing the telemetry. Finally, there is an extensive crew of orchestrators including the ride operator, the various technicians who manage the telemetry system, and the host and other 'front of house' staff. We now discuss how our telemetry system changes the nature of each role and perturbs the relationships between them.

**From spectator to audience**. As intended, our telemetry system transforms the experience of watching the ride, creating an audience who were observed to engage with the host and respond to events shown by the telemetry, for example by clapping and laughing (e.g., vignette fragments {1,2,5,8}). In post-event interviews, audience members reported enjoying riders' audio and video commentaries as this conveyed "how they behave and how they react" but also the telemetry data as this gave a glimpse into "what's happening within them". They noted that the telemetry system offered a level of detail that was not available when directly observing the ride due to its scale and speed:

> "when you're near the ride and watching it, you can't obviously see people's reactions. … You can only see that they're screaming, but, as there are four people on each car, you don't even know who's screaming … its just like there's a screaming seat, four seats, coming past, and you don't know who's screaming."

However, feedback also noted that the system could not replace the physicality of being next to the actual ride itself:

> "There's still the queue, there's the noise of the engine going, of the machine, which I remember from the first one made this incredible kind of noise, it sounded quite interesting, there's the queue, the lights … the experience"

In short the telemetry system can enhance, but not replace, the experience of observing the ride.

**From rider to performer.** The introduction of the telemetry system radically transformed the experience of riding. There was a clear, almost universal, tendency for riders to consciously perform, commentating on their experience for the benefit of the watching audience {4,5,16}. This urge to perform may be a natural tendency or may have been learned from the initial demonstration by the professional rider. It may also be a way of reducing anxiety for some riders as noted by one interviewee:

> "I think in a way it made me feel more comfortable … to be speaking to somebody all the time … you have somebody accompany you rather than feeling the dread alone".

It is interesting that they felt this way even though the communication was asymmetric, i.e., there was no reassuring direct feedback from the audience.

However, the most striking aspect of these performances was their bi-modal nature. Nearly everyone, including the seasoned professional, switched between providing a lucid commentary when the ride was moving slowly {4, 16} to displaying a distinct loss of control, shouting and screaming but being unable to commentate, at high intensity moments {6,16}). Interviewees commented on this:

> "There were certain periods were I just couldn't concentrate on anything else other than the ride, put it that way".

Riders also reported losing their awareness of being recorded and observed during these intense moments:

> "Maybe at the beginning I was controlling myself … later on, everything was gone … during the ride it all just faded away".

This reflects previous accounts of how 'pleasurable' experiences can lead to a 'flow state' in which people experience an altered awareness of their surroundings [4].

An interesting design implication of this bi-modal structure is a potential requirement to create ride-programs (human or computer controlled) that provide opportunities for both modes. While most rides tend to begin slowly and then speed up, it may be beneficial to exaggerate this or even build slower moments into the middle of rides to offer opportunities for more lucid commentary. Interestingly, our wireless communications also seem to have been more reliable at slower speeds, with most drop outs occurring during fast movements {6}, and so the technology may also benefit from carefully designed programs, for example, if we wish to avoid long drop outs in the telemetry.

The process of donning the technology also affected the rider's experience. We saw in sequences {9,10,11} that it took many minutes to don the system dealing with mundane but important details such as glasses, ponytails, the fit of the helmet and trailing wires. Such delays could heighten anticipation and anxiety as seen in {15}. Fitting the body worn sensors can also be invasive {9}, involving consideration of privacy and the gender of helpers. A further delay arose from the need to coordinate performers and audience, especially delaying the ride until the audience was in place, primed and warmed up for them {3,14}. Managing the coordination of performers and audience will be a significant challenge if telemetry systems are to be employed on a mass scale in high throughput situations such as theme parks. New mechanisms (e.g., involving mobile phones) may be required to coordinate individual riders with groups of family and friends who wish to observe them in particular. Of course, current rides already involve a degree of coordination between these two roles as family and friends may try to spot 'their riders' from a viewing gallery. However, the introduction of our telemetry system raises the stakes if the point is for spectators to be able to observe particular riders.

**From operator to orchestrator.** F:TL also significantly extended the ride operator role to include a variety of additional tasks concerned with the deployment of the telemetry system such as fitting, testing and monitoring as well as the coordination of ride start, speed and acceleration with the rest of the event. Our data has also demonstrated that in an actual fairground setting, ride operation might additionally involve provision of the 'professional rider' and the interpretation of the telemetry data {2}. In F:TL these various orchestration functions of ride operation were spread across multiple people and spaces, requiring new communication and coordination practices and technologies {17} and resulting in a complex control scenario.

Overall, our telemetry system not only transforms each role, but also serves to connect them in new ways. Perhaps the most interesting perturbation introduced by our system was to more directly connect riders to the orchestration team, as shown in our third vignette in which a rider uses the telemetry system to try to persuade the team to stop the ride on behalf of another rider. This vignette also shows how the team use the telemetry system as a resource to help them decide how to proceed, drawing on audio, video and even the heart rate data in assessing the state of play {19,20,23}. It is interesting to reflect on this in light of the history of amusement rides. Traditional fairground rides were (and still are) on a much smaller physical scale than today's extreme rides and so naturally afforded a close connection between riders, spectators and operators. For example, so-called 'gaff lads' (operators assistants) would ride the Waltzers, collecting money from 'punters' in the cars, showing off to the girls and giving some cars an extra spin depending on who was in them (see [11] for an account of showmanship and traditional fairgrounds). Modern theme park rides however have fractured this relationship due to their massive scale and also computer control. Perhaps telemetry systems such as ours can reconnect these fragmented roles and spaces, restoring an element of traditional showmanship? Indeed, one of our interviewees, an experienced showman, expressed an appreciation for the technology as being "back to the old school" in this regard.

### Selective disconnection

This said, providing a universal open channel between performers, spectators and orchestrators may be going too far. Returning to the bi-modal nature of performance on an extreme ride such as the Booster, on watching their videos afterwards several interviewees were surprised by their loss of control during intense moments and noted some potential for embarrassment, for example:

> "I was kind of slightly um worried that I would have done something stupid"

> "I was doing things that I was not aware of. I was swearing, for example, and um … I did it unconsciously, I don't remember doing it, you know".

A similar issue can be seen in our third vignette in which a rider pleads for the ride to be stopped over what is potentially a public channel. People are often scared on amusement rides (after all, this is part of the point of the experience to a degree) and may want the ride to stop. While operators do of course monitor for critical incidents and could stop the ride if necessary, the lack of a clear backchannel from riders gives them the latitude to choose not to so do if they judge based on their experience that the situation is normal, for example that a rider is 'routinely' scared and will probably soon improve, or that stopping or slowing the ride would make matters worse (as this could be a long process), would destroy the experience for others, or might ultimately embarrass the individual more through the public humiliation of being removed from the ride. In other words, there is a degree of ambiguity in the traditional set-up that allows operators to choose 'not to see' scared riders if they feel this would be beneficial. This is reminiscent of Aoki and Woodruff's discussion of the potentially useful role of ambiguity in 'saving face' in personal communications when using mobile phones [1].

Our telemetry system however, closes down this ambiguity, as riders are now aware that operators should be hearing them and may be more inclined to feel that they are being ignored. The situation is further complicated by the presence of spectators who may also be party to the rider's requests over a public channel (perhaps luckily in vignette 3 they were not as the public telemetry display did not broadcast audio during the later stages of the event). This has the potential to further embarrass riders, to make it even more difficult for operators to exercise their judgement, potentially facing a severe ethical dilemma, for example in the case of a real medical emergency on the ride. Finally, broadcasting this type of information might potentially reduce spectators' motivation to try the ride for themselves.

In short, our technology is perturbing what is a subtle balance of awareness and communication among the three roles of performer, spectator and orchestrator, potentially closing down some useful ambiguity in what is after all an edgy experience in which many people will feel scared for a while, but may ultimately feel relieved or even proud for having seen it through. This implies a degree of selection and editorial control over the use of the telemetry data. The big question here is how should this be done? Should both riders and orchestrators have the ability to switch off the public broadcast? Should users be able to vet and approve their videos after the event, but losing the element of liveness? Or should we further differentiate between spectators, for example transmitting the live telemetry only to the mobile phones of selected friends and family? These questions remain open for further exploration.

### Implications for research on spectator interfaces

More generally, our study speaks to recent design frameworks for spectator interfaces. Building on [2], we argue that interactive performance involves a balance between three broad roles: performers, spectators and orchestrators, each of which may be further specialised and subdivided. Our study is novel because it introduces a new performance technology into an established situation, highlighting the way in which an existing balance of relationships between these roles is perturbed. Our study also suggests that while it may be useful to reason about how spectators experience performers' interactions in terms of revealing or hiding manipulations and effects as proposed in [13], that this is not a complete view. Instead, we also need to consider how *orchestrators* experience performers' interactions and beyond this, consider more selective revealing or hiding or interactions at different times or to different classes of spectator. Finally, we observe that a degree of ambiguity about who can observe what may support the subtleties of orchestration and for saving face in difficult circumstances.

## CONCLUSION AND FUTURE WORK

In conclusion, we suggest that personal telemetry systems attached to spectator interfaces have the potential to significantly enhance amusement rides. We have seen that our prototype can provide an engaging experience for spectators, especially when compared to their traditional role of 'holding the bags'. Beyond this, our study suggests that telemetry systems can also enhance the experience of riding and even operating a ride, providing that they are sensitively designed and deployed to avoid embarrassment and leave sufficient latitude for operational control. Key to this is recognising and supporting the bi-modal nature of riders' performances, moving between moments of lucid commentary and less restrained flow, and also respecting some of the subtleties inherent in deciding when riders are 'normally' scared compared to when there is an unusual situation that requires action. If these challenges can be met then we believe that telemetry systems may help restore some of the traditional 'old school' ride showmanship that may have been lost in the scaling up to today's massive high-intensity rides. From an HCI point of view, our study adds to the growing corpus of literature on spectator and public interfaces, showing how designers need to consider the balance of relationships between performers, spectators and orchestrators, and how introducing a new interactive technology can perturb these in subtle ways. Key here is the requirement to selectively reveal aspects of a performer's experience to different kinds of spectator.

We conclude by noting some directions for future work. A major challenge lies in scaling up the approach to work within high-throughput environments such as theme parks which raises several questions. Should the technology (cameras, microphones, sensors and communications) be embedded into the ride in order to avoid delays in donning and removing equipment and improve reliability? Or should such systems remain wearable so that they can sense people before and after the ride experience and can easily transfer between other rides? Here we speculate that the medium term approach will be to embed them in rides, but that in the long term there may be advantages in integrating them with future wearable health monitoring, sports and leisure equipment. A second issue for scale concerns the spectator interface; should these be large public displays or might it be better to flexibly route different riders' data streams to smaller groups of mobile devices?

Beyond this, there may be greater potential to use biosensing data to drive different aspects of the experience, for example providing useful cues for identifying key moments of an experience as part of automatically editing souvenir videos, or perhaps even enabling new rides that directly adapt themselves to a rider's level of excitement. In spite of several early explorations of using biosensing to either evaluate or control entertainment and other applications within HCI (e.g., [3,9,10,14]), developing such applications requires a far deeper understanding of the nature of biosensing in relation to experience that we have at present – especially where humans are in a feedback loop involving extreme movements – providing a challenging but certainly intriguing direction for long-term research.

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