Embedding a Crowd inside a Relay Baton: A Case Study in a Non-Competitive Sporting Activity

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ABSTRACT

This paper presents a digital relay baton that connects long-distance runners with distributed online spectators. The baton broadcasts athletes' live locative data to a social network and communicates back remote-crowd support through haptic and audible cheers. Our work takes an exploratory design approach to bring new insights into the design of real-time techno-mediated social support. The prototype was deployed during a 170-mile charity relay race across the UK with 13 participants, 261 on-line supporters, and gathered a total of 3,153 'cheers'. We report on the insights collected during the design and deployment process and identify three fundamental design considerations: the degree of spectator expression that the design affords, the context applicability, and the data flow within the social network.

Author Keywords

Social Support; Social Networks; Sports; Spectators; Broadcast; Cheering; Relay Race; Relay Baton.

ACM Classification Keywords

H.5.m. [**Information interfaces and presentation**]: Miscellaneous; H.5.3 [**Group and organizational interfaces**]: Synchronous interaction; J.4 [**Social and behavioral science**]: Psychology

INTRODUCTION

Crowd support can contribute to the success of competing athletes during sporting events [3]. However, until recently, this was only possible if the athletes and the spectators were in the same location, such as at a stadium or along a race route. Currently, there are few design guidelines around interacting with spectators remotely during sporting events, even though, remote spectators often comprise a much larger user population than co-located spectators. Most of the existing technology that allows remote spectators to show their support was designed for post-race feedback, with little or no application during the performance.

Recently, several commercial mobile applications implemented simple cheering modalities, whereby online friends send digital 'cheers' to athletes during the sports activity itself. These cheers are typically sent as sounds, vibrations or audible messages on the athlete's device. However, although commercial implementations have rapidly progressed, these provide little insight on designing such systems. Remote crowd support remains an under-explored area of research within the HCI community, particularly with regards to design guidelines in different contexts. In fact, the context is rarely present or accounted for in the extant literature on remotely located crowds, especially because most deployments are typically artificially controlled.

The objective of this paper is to investigate the effects, if any, of such crowd support systems when applied to a collaborative sporting context. We then derive key design drivers for providing better real-time support in this context.

Our hypothesis following the deployment of a number of

Figure 1: The long-distance relay baton in use

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smaller crowd support systems, is that real-time remote support might be most effective during challenging sporting events, such as long-distance running, during which the athletes are most likely to feel isolated. To further investigate this, we designed a baton prototype (Figure 1) that is carried by athletes during long-distance relays. After a design process that included a series of in-the-lab and in-the-wild tests, we deployed the device in a 170-mile relay race across the UK with 13 athletes and 261 online spectators. Such an extreme event allowed us to observe different contexts and elements of loneliness in a real-life condition.

The baton broadcasts locative and performance-related data to online spectators through the mobile network. Remote spectators can then follow this live data through their browsers. By pressing a cheer button, spectators send a small vibration to the baton. Thus, the athlete becomes aware that spectators around the globe are following his or her performance live. The baton also calls out the name of the 'cheering' spectator so that the athlete builds an understanding of where the support originates. As we shall further elaborate upon, in total, the work is the result of 380 hours of product design and development in a co-design approach [23].

Through observations, a focus group, and server-collected data, we identify key aspects that give bearing to technology-mediated crowd support systems. From these, we then isolate three fundamental design considerations for real-time crowd support: (1) the degree of spectator expression, (2) the context applicability, and (3) the real-time data flow within the social network.

EXISTING WORK

The study of live distributed-crowd support is a relatively new area of research. However, applications whose function is based on 'crowd processing' and which operates in real or near real-time have existed for quite some time. Most closely related is Bernstein et al.'s Soylent. [2]. Soylent is a word processor that summarises documents on demand by harnessing the collective intelligence of Amazon Mechanical Turk workers. Similarly, TimeWarp [18] (an evolution of Legion: Scribe [19]) lets users transcribe live speech by efficiently segmenting the narration into manageable chunks and assigning different segments to online distributed operatives. A more empathic-based objective is presented by Morris et al. in their attempt to crowdsource collective emotional intelligence [21]. In this work, distributed online participants contribute emotional support through 'cognitive reappraisal' of an individual's emotional state [12]. These cases show that remote crowds can have a positive effect on an individual's instant necessities, not only through harnessing mental calculations, but also through the (more challenging) gathering of social and emotional support. We are interested in investigating real-time crowd support in a sporting context.

A commonly cited related work in remote support during sports is 'Jogging Over a Distance' [22]. Mueller et al. explored the effect of having two distant athletes communicate during jogs to support each other. Although this work did not involve crowds, the research outcomes indicated that providing the athlete with real-time feedback from a remote other enhances the social experience of the participating athlete.

On the other hand, research involving multiple spectators focused on either 1) augmenting the experience of remote spectators by, for example, broadcasting additional personal data (e.g. see [1, 13, 17]), or 2) on connecting spectators during events (e.g. [14, 20]). For example, Hallberg's study [14] investigated the sharing of live telemetry data from athletes to remote online spectators. In this paper, we augment the experience of spectators that are following the event remotely by allowing these spectators not only to follow but also to interact with the athletes by sending live cheers through the custom-designed digital relay baton.

Recently, Curmi et al. conducted a series of studies in which remote spectators supported athletes participating in a triathlon, a charity run, and a competitive road race [8, 9]. They conclude that supporting athletes remotely can have a positive impact on athletes. 'Future work' suggested that remote-support might be most relevant when the task is challenging. Similar indications can be drawn from the work of Woźniak et al. [28], where a crowd feedback system was deployed during a 10-km public event. Woźniak captured feedback from a group of paid athletes who were asked to carry a cheering device while competing in a public city marathon. We extend this by seeking the transferability of lessons learned from competitive events to non-competitive ones, such as a collaborative charity event. The result is a comprehensive set of design considerations within the latter context. This differs from previous work as it 1) focuses on system designers and presents a set of motivations and design criteria captured in this setting, and 2) unlike earlier work, we investigate the crowd support system in an intense non-competitive event of long duration.

To maximise the effect that remote crowd support may have on the athletes, we deploy real-time crowd support in a long-distance relay race and custom designed a digital baton. Long-distance relay races are typically non-competitive sporting events and often present an environment that is challenging and where athletes may feel lonely, particularly during night-time hours. They range in duration from a few hours up to a number of days. Popular races are the annual Great Britain Relay Race, the Olympic Torch Relay or the Queen's Baton Relay in the Commonwealth games.

Digital batons are not new. At the University of Bath, a group of researchers developed a baton that periodically

Figure 2: The design process

records its position internally[1]. A more complex model is the Queen's Relay Baton[2]. In this case, the baton periodically logs its position and internally records a front facing and a rear facing video camera. Additionally, the baton broadcasts its position online such that spectators can follow its location.

We take the digital baton a step forward by designing a baton with synchronous two-way communication. In this way, the baton not only broadcasts data from the athletes to spectators but can also collect distributed-crowd support and communicate this support back to the athletes carrying the baton, in real-time, as the event unfolds.

As we shall further elaborate in the next section, unlike earlier work, we study a charity event that was externally organised around the technology under investigation. This approach allowed us to study a real-life event comprehensively, in context, and where the participants were not paid but intrinsically motivated to participate.

DESIGN PROCESS

Figure 2 shows the key stages in the co-design process of the relay baton. This culminated in the 170-mile deployment. As earlier stated, the authors were attracted to this event because it presents the athletes with a challenge both in terms of the mental effort (e.g. loneliness) and physical endurance. These factors were sought on the hypotheses that they are relevant constructs. Moreover, conducting research 'in the wild' in an extreme 170-mile activity promised to reveal design issues that were unlikely to emerge in conventional lab context [24].

Participants

A running club leader approached us with an interest in trying out our technology, which he knew of from earlier work. This presented a fantastic research opportunity in which the participants are intrinsically motivated to co-design and use the technology. Having participants with an innate interest in the design promises a closer to real-life investigation. The event was entirely and independently planned by the club, hence the researchers had no control on the event nor on the participants' selection. As for the spectators, the event was advertised through the club's social network and student union official website, as is standard procedure for the sports club.

The event

The relay race was a charity event organised by a University running club. Before committing themselves to taking the event to open public roads, the organisers considered conducting it as a 170-mile relay race around campus. However, this choice was discarded as it was deemed '*far too boring'*, even with the promise of a larger co-located cheering crowd. "*We wanted the real thing [outside University], but then we realised that we would not have anyone able to support us in such long distance*" [event organiser].

The event was then organised as a coast-to-coast race along a historic route known as 'The Way of the Roses'. The route starts from Morecambe in Lancashire and ends in Bridlington in East Yorkshire. The course had varying altitude ranging from sea level to 400m. The race started at 0900hrs and was expected to last approximately 24 hours. The actual duration was particularly dependent on the pace of the athletes but also on the weather conditions and the navigational ability of the athletes. 'The Way of the Roses' is a cycle route that is part of the national cycle network and which most people cycle over two to three days. It goes along roads and cycle paths and is well marked along the route. Athletes passed the baton at predefined handover checkpoints of 5-mile intervals. For health and safety reasons, a cyclist accompanied the athletes throughout the course. Additionally, a support vehicle transported the runners from the previous leg to the next relay leg, and so this vehicle was always waiting at the next handover checkpoint. Both athletes and organisers felt that night-time was going to be particularly challenging, as the countryside lanes would be dark and deserted.

The baton

The relay baton, the crowd-powered interface, and the interaction design was co-designed with the event organisers as the end-users. This process was user driven. The time from the initial meeting to deployment was three months. This co-design process was punctuated by key stages, as shown in Figure 2.

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[1] http://www.theiet.org/students/you-and-iet/on-campus/2012/gps-enabled-baton.cfm

[2] http://www.thecgf.com/qbr/

First, an initial preliminary meeting with the organisers defined the scope of the event and the preliminary system desires. At this stage, we considered using broadcast devices other than a relay baton, such as smartwatches and phones. This would have simplified implementation. However, this approach would have lacked the emotional value of ‘carrying’ and ‘handing over’ the (traditional) baton. The form factor of a baton provided a continuation of the traditional plus an additional crowd-connection. Hence the baton design was upheld. Second, three relay baton prototypes were iteratively developed (Figure 3a–3c) along with the real-time data handling server and the crowd’s online interface. The organisers were engaged throughout this process and provided a regular contribution to the design decisions through face-to-face meetings. This prototyping process lasted one month.

This was followed by another month of ‘in-the-lab’ and ‘in-the-wild’ testing by the researchers. The objectives included reliability testing, user interaction evaluations, and energy consumption testing in both city and rural conditions. A key concern when designing telemetry for extreme conditions is the ability of the baton to handle reliably mobile disconnections and reconnections in the wild while seamlessly transfer data to and from the crowd. Thus, the testing included transporting the baton in rural areas at the edge of mobile coverage and beyond. One month before the 170-mile event, the baton was handed over to the running club, and a training session was conducted. This session included guidelines on correct handling, on how the system works, information on the spectators’ recruitment process and a presentation of the spectators’ interface. As part of the briefing, the athletes were also informed that they were free to adapt the prototype in whatever way they felt

Figure 3: (a) early design sketches, (b) internal energy storage, (c) the relay baton

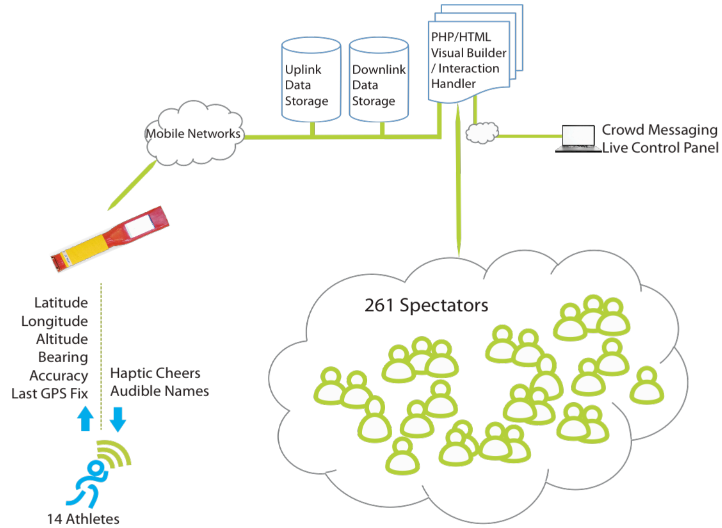

Figure 4: System design

appropriate. For example, they might have wanted to attach straps to make it easier to carry the device over long distances. Finally, the athletes further tested the prototype during eight training races. Any feedback collected was later implemented in the prototype. This feedback involved minor software changes regarding simplification of the spectators’ logging-in process and aesthetical enhancements.

The baton’s outer shell (Figure 3c) was made of Polyvinyl Chloride (PVC). The 24-mm-radius handgrip of the spray-painted baton was covered with tennis racket grip tape. This decreased the likeliness of the baton slipping during handovers. The soft grip tape also made the baton more comfortable to carry over long distances. Other design considerations included design for rainy and sunny conditions (i.e. the interface needed to be appropriately visible during daytime), night-time visibility, energy autonomy, data updates (i.e. updates should be fast enough to give a real-time feel to the spectator) and aesthetic look and feel.

In line with the rapid prototyping approach adopted, an Android device was used as the main processing and display unit. This approach shortened the design cycles in contrast with developing a custom interface and telemetry hardware. A modified off-the-shelf power-bank was embedded within the device to provide enough energy for a continuous broadcast capacity of 96 hours (Figure 3b).

Through a custom-built native app, the baton collected and broadcast telemetry data every 10 seconds to a remote server. This process was managed as an asynchronous background thread in an Android OS. When the mobile data network was available, this thread broadcast the data with a 4-second timeout and buffered the transmission data whenever the mobile data network dropped.

The athletes' and spectators' interface

Figure 4 shows the complete infrastructure. This infrastructure was based on BioShare [7], and the default configuration of BioShare was adapted to meet the needs of this investigation. BioShare is an open source tool that allows researchers to collect and share data over social networks in real-time. It also allows data viewers to send instant feedback to the data sharing users.

The baton's interface displayed the time, the current speed, the altitude and the total cheers that were received. When the baton is switched on, the native application presents a 'Start Broadcast' button. This button is disabled once the broadcast has started. This approach minimised the possibility of having athletes accidently turn off the broadcast during the event. Stopping the broadcast necessitated triggering a hard-to-press button inside the baton. The remote server collected and presented the data in a browser interface, as displayed in Figure 5 (overleaf). When loading their interface, spectators could either sign in with Facebook or manually type in their name.

The selection of the presented metrics in the spectators' interface was based on insight gathered from an earlier pilot study in which spectators attributed values to different visuals presented to them during a running event [8]. The metrics included 1) the total number of cheers that were submitted by the spectators, 2) the number of cheers submitted in the last hour, 3) the total number of spectators who followed the event for at least one minute, 4) the total messages posted to the site, 5) time since race start, 6) distance covered in the race, 7) average speed, 8) pace, 9) percentage of task completed, and 10) distance to race completion. Additionally, the interface included 11) a live map with the course and the position of the baton, and 12) a chart with the altitude. These two visuals were linked such that a marker was shown on the map when the mouse pointer was within the altitude chart. This allowed the spectators to investigate the altitude in relation to the position on the map. The metrics were updated every 5 seconds, thus giving a real-time feel to the spectators' experience. Finally, 13) an icon representing the weather condition at the location of the baton, and 14) a Facebook-like interface in which spectators could post comments, were also present.

Elements 1–4, 13 and 14 were intended to give the spectators a sense of the collective support. Elements 5–12 were intended to give the spectators an understanding of the athletes' performance and the context.

The crowd's interface also displayed whether the baton was online or offline, and the length of time since data was received from the baton. This was relevant, particularly when the baton lost mobile data connection in rural areas. The Facebook messaging frame was intended to build a community around the activity as the event was taking place. In this way, whenever the data broadcast from the baton was interrupted due to a loss of network coverage, the messaging interface provided a secondary source of engagement for the spectators and potentially alleviated any disconnection problem [5].

A system control panel allowed the organisers to send messages to the crowd in a fixed position on their screen. This manual message broadcast was intended for crowd coordination in any unexpected circumstances that a live event occasions. From experience, we noticed that a technical fault in the telemetry system could lead spectators to various conjectures; such as the system is not working, or the event has been stopped, or that there has been an accident. The "online/offline" indicator on the spectators' interface mitigates these potentially ambiguous situations. This information on mobile-awareness can also make the user value the effect of connectivity on the system [4] and appreciate the athlete's environment.

Finally, the presented interface had an always-visible "Cheer" button. Pressing the Cheer button triggered a small vibration of 400ms on the baton carried by an athlete. Hence, the athlete carrying the baton builds awareness that a crowd is following his/her performance. The baton also calls out the name of the person who sent the last cheer, so the athletes understand whether the live support is coming from known or unknown spectators. Both the athletes and the spectators were aware of these dynamics and their interaction effects.

FINDINGS

General observations

13 athletes with a mean age of 20.38 years (SD=1.5) participated in the 170-mile relay race, which lasted 23 hours 45 minutes. 261 spectators submitted 3,153 cheers. A major concern for such an extreme in-the-wild event was the mobile network coverage throughout the 170 miles (Figure 6). The assigned server received data from the baton live for 74% of the race (17 hours 34 minutes). In total, there were 12 live data drops. Of these 11 were due to blind spots in the mobile network across the course. In this count, a blind spot is true whenever the data connection interval between the server and the baton is greater than 60 seconds. Although the total number of drops may seem high, during the event, small drops (particularly during the first part of the event) did not appear to distract the spectators. Post submitted during the event suggested that blind spot of short duration might increase the spectators' curiosity and their interest in knowing what is happening. These positive effects stemming from data disconnection could be attributed to the connectivity feedback that the users were presented with [6].

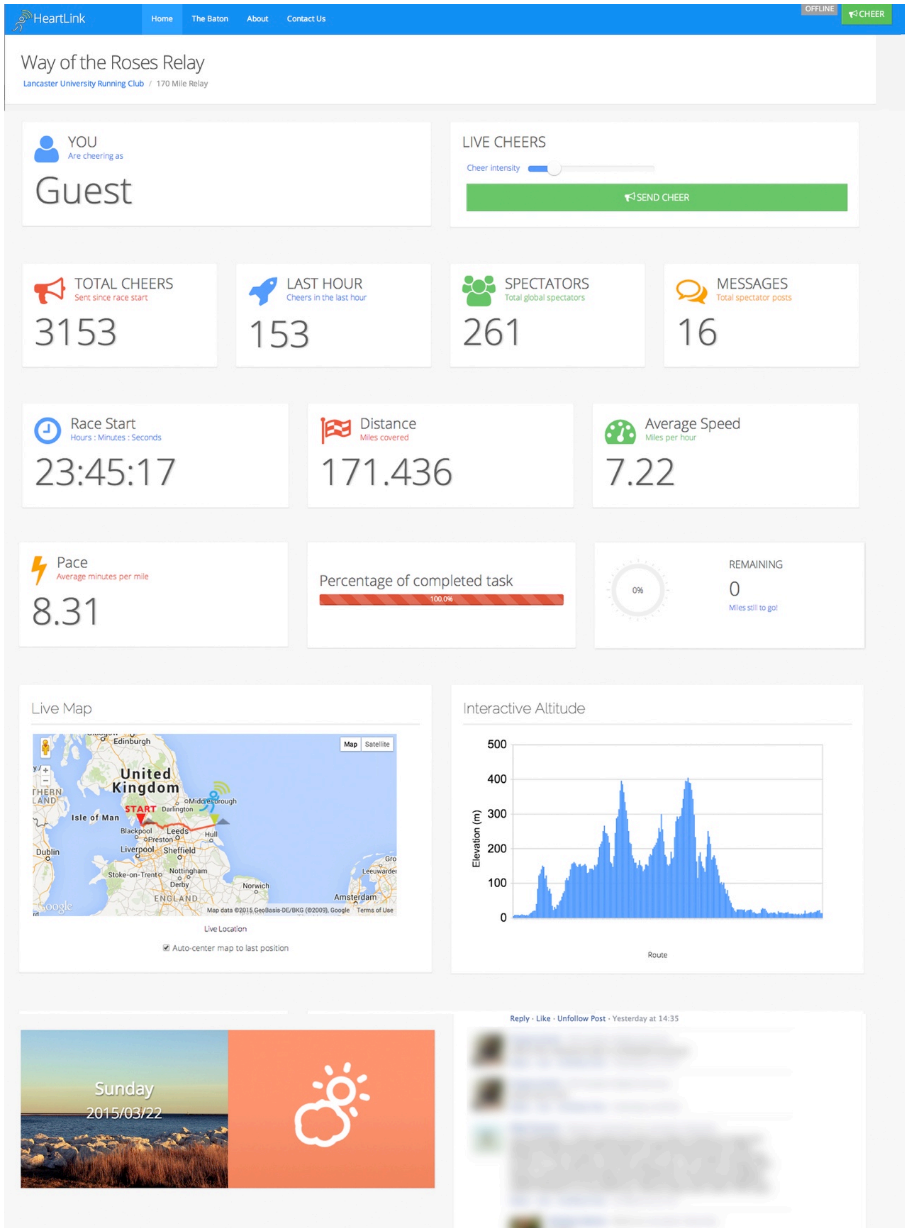

Figure 5: Spectators' interface

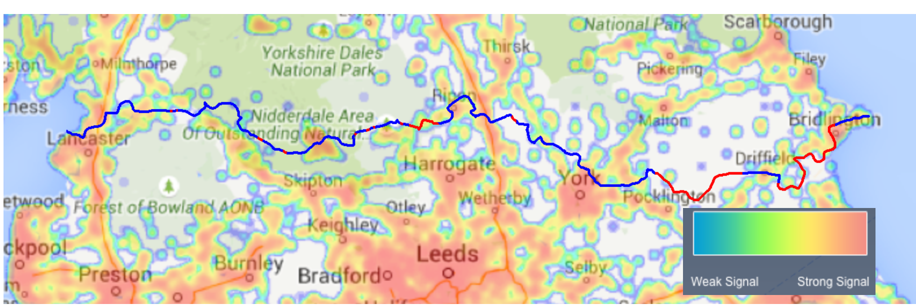

Figure 6: 2G and 3G-cell OpenSignal coverage map as predicted on the day before the 170-mile event. The blue path represents the actual data connections and the red path represents data disconnections.

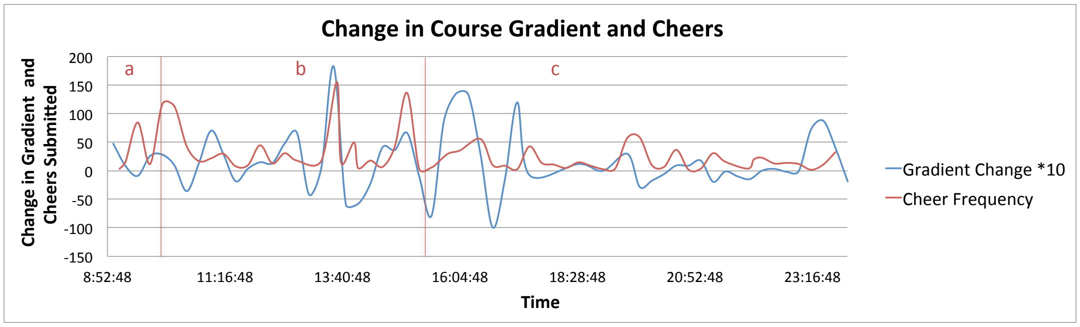

Figure 7: Change in gradient and cheer quantity. The gradient before the first marker has a negative relationship to the cheer rate (r=-0.773, p<0.003, n=13). Phase B has a weak to moderate positive relationship (r=0.484, p=0.033, n=148) while there is no significant relationship in phase C (p=0.454)

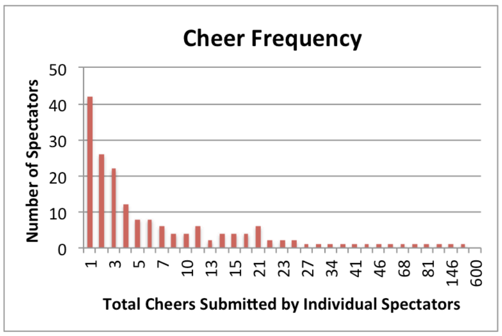

Figure 8: Frequency of total cheers submitted by each spectator

Figure 8 shows the frequency of 'total cheers' submitted by the cheering spectators. This results in a long tail distribution that is characteristic in contexts that involve crowd-engagement [16, 26]. Figure 7 plots the change in gradient (of altitude) and the cheers submitted. The changes are sampled as an average of 15-minute intervals for the first 15 hours of the event. We truncate the last part of the event to avoid the influence of the two largest mobile network disconnects within this part. The plot highlights three key crowd behaviour patterns. In the early stages of the race (section a) we find a spike of cheers that has an inverse relation to the course altitude. The course altitude was constructed on the spectators' interface as the event unfolded. Following this phase, the data indicates that the crowd seems influenced by the changes in the displayed altitude (section b). As time progresses (section c), the spectators' expectations of effort as interpreted from the altitude seems to become normalised, and changes in cheers become less influenced by the presented data. In other words, the spectators' expectation of effort is reframed by past changes. The data from this event also shows a periodic cheering oscillation with a time interval of one hour on average. We believe that this is due to spectators checking the interface at periodic intervals. In aggregate, these intervals are more likely to be on (or close to) the hour across all time zones.

Analysis of system's value

We evaluated user motivations for using real-time crowd-support systems in this context. We are particularly interested in bringing up factors that influence the value that remote crowd support may have. These will later help in framing design recommendations that seek to augment such product value. In addition to the server-collected data on user behaviour and our observations, we transcribed the athletes' statements during the event and a post-event focus group. This qualitative data was analysed through a grounded approach. The data was reviewed and repeated ideas were clustered in themes around system values. In the next section we briefly review each theme.

1) Receiving live support

The need of having a live supportive audience results as the most expected motivation for using such systems. The results highlight numerous cases where the athletes become aware that others are sending their support. For example A1 excitedly comments: *"... we got frantic text messages from someone else in the running club, who said, oh you just disappeared on the map. We said, 'it's fine, still alive, it's all good.' You definitely got the sense that people were tracking it for long periods" [A1].*

The data identifies that the awareness for which real-time support may be effective can be split in two distinct ways. The first is in mitigating loneliness. This was particularly highlighted in such an extreme lonely event. For example, A6 reports that *"In this sort of event, where it is a very lonely event because it is just you and the cyclist, it [remote support] is helpful. In a [competitive] race cheering does not massively help me" [A6].* A second identification is that of mitigating fatigue, particularly in a context where "*You have done so many miles, and you may be really struggling and that is just what you need" [A3].*

2) Build followers

Sharing data provided a sense of prominence. In our investigation, we separately took into account the data sharing and the crowd's feedback. During the event, the athletes were mindful both of having their effort followed (data sharing) and of receiving support from remote spectators (cheering). Interviewed athletes also distinctly commented on both the sharing of data such that spectators can follow the event and also on receiving live support: *"…it is the mixture of the two… people had the data to know where we are, and they followed it… I know that my mum followed it for a lot of the time because she was cheering so it was like 'oh I am cheering them on!'" [A6].*

In addition to initiating engagement, the broadcasting of live data from athletes to the spectators opened up communication over secondary channels such as traditional SMS texting: *"When this person [y] from the running club was watching, he would texts us [standby athletes] and we all cheer and we go 'ye this is another cheer to us'. It may be midnight and he probably should be in bed, but no he sat up there following and cheering us"[A1].*

3) Using live telemetry as a proof of accomplishment

One of the most surprising findings is the use of live telemetry as a proof of accomplishment. The athletes report that the telemetry provides evidence of task completion. This supports literature in other HCI contexts [8, 9, 25] where the real-time sensor-captured data broadcast is reported to give the data viewer an increased perception of truthfulness than what otherwise may be considered as curated content. In this light, the live telemetry provides curiosity, suspense, and expectation.

4) Triggering support mindfulness

The athletes report perceiving an association between the altitude and the support they were receiving. Data shows that spectators cheered at different intensities across the event (M=4.86, SD=3.7). This suggests that spectators are interested in externalizing varying degrees of support. It also indicates that spectators do not cheer randomly but are influenced by the data and the context such as the current altitude or the perceived exertion effort, as shown in Figure 8 earlier. This relationship is also reflected in the athletes' comments:

"We started the hill and at the top of the hill we got so many more cheers. It was quite remarkable" [A6].

"In the first hill, they went up by about 500. Joe had a very hilly section" [A7].

These results show that spectators are keen in building clear images of the context through data [15, 25, 27]. We recommend that designers seek ways to augment the spectators' emotional experience of the remote environment and the effort exerted by the athletes. We shall get back to this later.

5) Transpose social network edges

After the event, the athletes commented positively about the feature that informed them of who was supporting them. For example: '*knowing who was supporting you [during the event] was really nice… '[A6].* "*I really like being able to hear who it is who is cheering, especially if they know it is your section, so they are cheering you" [A4].*

The data indicates that the most effective live remote support seems to be that of acquaintances. For example, *"…people I know best are effective, however, if you had someone who is around the other side of the world supporting you, [excited] they must have logged on especially to help, it is not something that I feel I was duty bound to do, so that is quite nice " [A6].*

6) Satisfy a social need to connect just-in-time

Spectators could log in through either Facebook or by manually inputting their name. The spectators' awareness that the baton synthesised the login name, prompted three of the spectators to re-log into the system and insert complex messages in their name field. In this way, they could send customised messages, such as *"go Mike",* to the athlete carrying the baton. This highlighted the spectators' interest in communicating with the athlete during the event with more expressive tools than simple binary or predefined cheers. On the other hand, such openness brings ethical issues that emerge from the lack of anonymization. For example, a spectator (who was a close friend to the active athlete) messages: 'We hate Pete!' Such cases can be minimized by forcing spectators to log in through existing social media accounts such as Facebook, as a filtering process. This would be done at the expense of anonymization. Worth noting is that most of the cheers (69.8%) were sent by spectators who logged in as 'Guests' (i.e. opted to remain anonymous or did not have a Facebook account).

7) Reach a new audience

For the event organisers, the proposed cheering system facilitated reaching a new audience that was otherwise not connected with the event during the event. This 'audience' is likely to be different and in addition to the spectators who would be on the course cheering. After the race, the organiser highlights, through reflection, key engagement values:

"We used the system primarily to let people know how we were going because we knew that people would not be able to come and see it [the race] very easily as we went past. So we wanted people to be still involved" [organiser].

We observe that remote cheering gives the audience a feeling of contribution. This may be true irrespective of whether the cheering has any effect on the athletes or otherwise. This engagement channel can be used to increase event awareness and web traffic to the charity page. Both of these are important marketing affordances. Additionally, for the club, having a new system where spectators could interact with the athletes live was quite unusual. This facilitated event advertising through social networks.

8) Tracking and event control for organisers

Finally, worth mentioning is an unintended consequence of carrying the baton; the ability for the organiser to track the athletes and detect wrong turns. On two occasions, this helped in guiding athletes (via the cyclist) back on the course. Additionally, through live telemetry, the spectators present on the course could know when the athletes are coming towards them and (where and) when they should be ready to cheer.

DESIGN CONSIDERATIONS IN REMOTE CROWD SUPPORT

The results encourage the design of smart devices that facilitate real-time remote crowd support in collaborative contexts. However, these social support systems bring in a unique arrangement of design decisions. Based on the above findings, Figure 9 lists 14 design variables across seven dimensions that designers may draw upon. We cluster these in three sets that will be elaborated upon in the next section: spectator expressiveness, context applicability, and network configuration.

Spectator expressiveness

"I loved the cheer intensity…! Aaaa ok I am not going to cheer them very much!" [A5 - Laughing].

One key design consideration is the degree of expressiveness that spectators are allowed to show. This brings into play deliberations on the number of cheers that spectators are allowed to send, the cheering modality and whether spectators are allowed to generate customized cheering themselves (for example record their own messages) or use pre-defined modalities (for example having system sound effects).

A common question during the design process was, should spectators be allowed to cheer unlimitedly? In hindsight, an unlimited option as deployed in the presented case may better express human emotions. When this feature was discussed during design meetings, some athletes showed surprise in having unlimited cheers. Existing social networks deeply nurtured an expectation of one '*Like*' per actor per element. This approach may have been driven by a technical need of social network simplification at a time when online social networks emerged. However, in a real-life situation, there are no such restrictions and emotions are expressed in varying degrees by different users with diverse social ties.

This leads to a second design decision; deciding the explicitness of the cheers, ranging from very subtle feedback to explicit feedback. At the end of the scale, explicit feedback may consist of audible cheers that are loud enough for nearby athletes to hear. The latter would be closer to what typically happens in traditional crowd cheering where cheers are heard by nearby athletes and spectators.

A third design decision is the degree of openness for cheer expressiveness. In this case, at one end we may have predefined cheers such as haptic cheers. At the other end, one could allow spectators to send self-generated support. For example, spectators may be permitted to stream live voice comments to the selected athlete while the spectator's spacebar is pressed. The latter more open approaches are

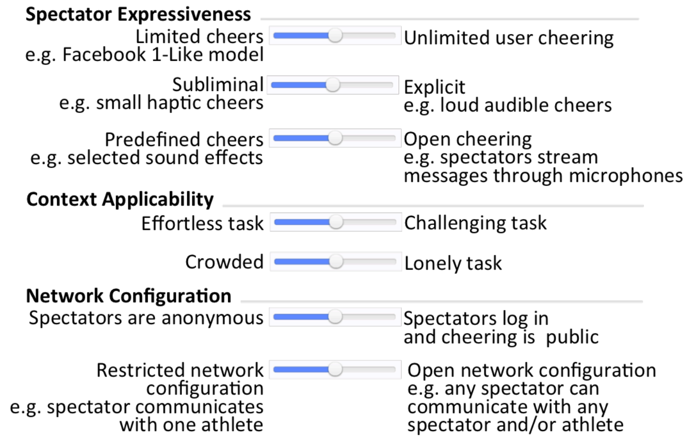

Figure 9: Design considerations

likely to increase spectator expressiveness but are also expected to increase ethical and security concerns.

Context applicability

In which conditions are the cheers most effective? By amalgamating the insights from related work conducted by Woźniak et al. [28], we bringing forward two key factors that influence the effectiveness of remote support: 1) the challenge-intensity that is provided by the task, and 2) the degree of loneliness for the athletes during the event. This is depicted in Figure 10. Earlier work suggested that support is most effective during a 'challenging' task. However, upon comparing the loneliness arising from this long-distance relay event with the authors' earlier related work, we clearly observe that the awareness of remote crowd-following is most relevant when the athlete is feeling lonely rather than in contexts where the athlete has a crowd of cheering spectators along the course. This promises most relevance in sporting contexts such as fell running, long-distance cycling or ultra-marathons.

Network configuration

The above design considerations operate within a set network configuration that may connect some or all of the

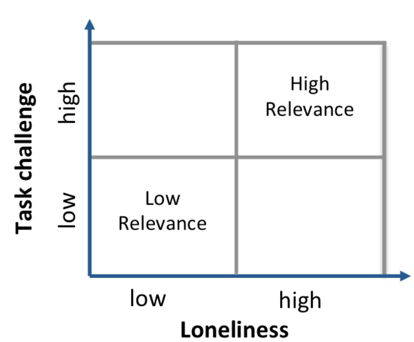

Figure 10: Relevance of real-time remote crowd support in relation to observed constructs of Task Challenge and Loneliness

athletes, spectators and organisers; through unidirectional, bidirectional or omnidirectional communication. For example, designers may support communication between spectators or limit communication to between the individual spectators and single athletes. Our recommendation in this decision-making process is that designers seek to integrate the requirements of all the stakeholders. Unlike traditional broadcasting, online crowd support during sports events creates an ecosystem with multiple stakeholders in which the action or lack of action of one actor influences the other actors. For example, athlete's performance may influence the spectators' engagement, (e.g. spectators send more cheers when the going gets tough, as shown in Figure 8) and this change in support may influence the athlete's performance (e.g. this may motivate athletes to perform harder). As such, researchers should seek to analyse these systems both at a micro level (e.g. analyse spectators' reactions to different visuals) but more importantly at a macro level (i.e. as complete ecosystems).

Future work should continue to find ways of decreasing the obtrusiveness of the data capturing and broadcast devices by looking into increasingly small and lightweight devices. We expect that as technology moves in this direction, attention will shift further from the distractions that physical devices create and allow athletes to focus solely on the performance and social interaction. More importantly, in future work, interaction design should seek to 1) increase the emotional engagement of the spectators by sharing live data that best narrates the effort that is invested by the athlete, and 2) expand the cheering modalities to allow spectators to express their support with a variable degree of expressiveness.

CONCLUSION AND REFLECTIONS

In this paper, through a co-designed approach, we designed, deployed and evaluated a connected baton for long-distance relays. The baton keeps the social network informed on how the event unfolds by broadcasting sensor-captured data through mobile networks. Concurrently, remote spectators communicate their support through remote cheering.

One commonly cited drawback of a comprehensive co-designed approach is that the participants may be more willing to comment positively on the design. We will note this in the limitations section. On the other hand, one of the advantages of this co-design process is that the participants have a strong intrinsic motivation to improve the design since they will be using the proposed solutions themselves [10]. Additionally, the project is on-going and the participants are using the gained insights to develop another iteration for their next event. Hence their intrinsic motivation for unbiased feedback was also present in the post-event data contribution.

Systems that are designed to facilitate real-time feedback from remote crowds have not been widely developed. The reason may be due to the social barriers (e.g. the pressure that such systems place on the social network actors to support the event in sync), as well as technical challenges. A technical challenge, particularly in such a large-scale in-the-wild event, is the perceived unreliability of the mobile network connectivity. Upon deployment, however, short network disconnections seemed to interfere little with spectators' engagement.

We observed that this is particularly true for close social network ties, thus suggesting that social capital compensates for lack of precision or technical failure. This advocates for reframing our focus on technical perfection when designing such socio-dependent support systems. In the last century, the broadcast industry exposed viewers to a constant increase of visual and technical perfection. That is, we expect that broadcasted content is perfect, stable, with exceptional lighting and excellent picture composition. However, viral video sharing on social networks introduced an inverse perspective to this [11]. Similarly, in our case, small dropouts in data updates had little influence on spectator engagement, particularly when spectators were in some way socially related to the athletes.

Following this study, we are now designing a new self-adaptive filtering mechanism to minimise interaction while conveying the same emotional intensity. We encourage designers to explore diverse support modalities. For example, in preliminary spectator interface designs, we considered live video broadcasts from forward-facing cameras strapped to the athletes' chests. At the time, this design track was rejected as tests indicated that shots would be 'too' shaky for spectators, who are typically accustomed to centralised broadcasts from leading broadcasters. However, after having now deployed four trials, we observe that crowd-support systems provide additional motivators that compensate for a loss in what traditionally may be regarded as being below the minimum acceptable quality threshold. In a situation where athletes are running alone, spectators with a social tie are keen to see a live picture and get a glimpse of what the environment looks like. Is it raining? Is it dark? Is the terrain rough? How does the breathing sound? This may have content value, irrespective of whether the media is jittery or compressed. In this regard, designers may want to consider balancing resources, not only in designing for technical perfection, but to factor in the value of 'designing for real-time social dynamics'. In this light, we hope that this work also contributes to bringing to discussion the making of more humane social networks. In this case, the focus is not in making affective machines (though useful), but perhaps of equal importance is in making machines that facilitate collective human support.

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REFERENCES

1. Louise Barkhuus and Tobias Jørgensen. 2008. Engaging the crowd: studies of audience-performer interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '08), 2925–2930. http://doi.org/10.1145/1358628.1358785
2. Michael S. Bernstein, Greg Little, Robert C. Miller, et al. 2010. Soylent: A Word Processor with a Crowd Inside. In *Proceedings of the 23nd annual ACM symposium on User interface software and technology* (UIST '10), 313=322. http://doi.org/10.1145/1866029.1866078
3. Charles, F. Bond, & Linda, J. Titus, (1983). Social facilitation: A meta-analysis of 241 studies. *Psychological Bulletin*, *94*(2), 265–292. http://doi.org/10.1037/0033-2909.94.2.265
4. Keith Cheverst, Nigel Davies, and Adrian Friday. 1998. Supporting collaboration in mobile-aware groupware. *Workshop on Handheld CSCW at CSCW'98*.
5. Keith Cheverst, Nigel Davies, Keith Mitchell, and Adrian Friday. 2000. Developing a context-aware electronic tourist guide. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '00), 17–24. http://dx.doi.org/10.1145/332040.332047
6. Keith Cheverst, Nigel Davies, Keith Mitchell, and Adrian Friday 2000. Experiences of developing and deploying a context-aware tourist guide: the GUIDE project. In *Proceedings of the 6th annual international conference on Mobile computing and networking* (MobiCom '00), 20-31. http://dx.doi.org/10.1145/345910.345916
7. Franco Curmi, Maria Angela Ferrario, and Jon Whittle. 2014. Sharing real-time biometric data across social networks: requirements for research experiments. In *Proceedings of the 2014 conference on Designing interactive systems* (DIS '14), 657–666. http://doi.org/10.1145/2598510.2598515
8. Franco Curmi, Maria Angela Ferrario, Jen Southern, and Jon Whittle. 2013. HeartLink: open broadcast of live biometric data to social networks. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '13), 1749–1758. http://doi.org/10.1145/2470654.2466231
9. Franco Curmi, Maria Angela Ferrario, Jon Whittle, and Florian Floyd' Mueller. 2015. Crowdsourcing Synchronous Spectator Support: (go on, go on, you're the best)$^{n-1}$. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '15), 757–766. http://doi.org/10.1145/2702123.2702338
10. Leon Cruickshank, Gemma Couupe, Dee Hennessy. 2016. Co-Design: Fundamental Issues and Guidelines for Designers: Beyond the Castle. *Swedish Design Research Journal* 9, 2: 46-57. http://doi.org/10.3384/svid.2000-964X.13248
11. Thang N. Dinh, Dung T. Nguyen, and My T. Thai. 2012. Cheap, easy, and massively effective viral marketing in social networks: truth or fiction? In *Proceedings of the 23rd ACM conference on Hypertext and social media* (HT '12), 165–174. http://doi.org/10.1145/2309996.2310024
12. James J. Gross. 1998. Antecedent-and response-focused emotion regulation: divergent consequences for experience, expression, and physiology. *Journal of personality and social psychology* 74, 1: 224–237. http://doi.org/10.1037/0022-3514.74.1.224
13. Joseph Hallberg, Sara Svensson, Ake Östmark, Per Lindgren, and Kâre Synnes. 2004. Enriched media-experience of sport events. *Sixth IEEE Workshop on Mobile Computing Systems and Applications* (WMCSA '04), http://doi.org/10.1109/MCSA.2004.12
14. Giulio Jacucci, Antti Oulasvirta, Antti Salovaara, and Risto Sarvas. 2005. Supporting the shared experience of spectators through mobile group media. In *Proceedings of the 2005 international ACM SIGGROUP conference on Supporting group work* (GROUP '05), 207–216. http://doi.org/10.1145/1099203.1099241
15. Kristina Knaving, Paweł Woźniak, Morten Fjeld, and Staffan Björk. 2015. Flow is Not Enough: Understanding the Needs of Advanced Amateur Runners to Design Motivation Technology. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '15), 2013–2022. http://doi.org/10.1145/2702123.2702542
16. Svetlana Kordumova, Jan C. van Gemert, and Cees G. M. Snoek. 2016. Exploring the Long Tail of Social Media Tags. In *Proceedings of the 22nd International Conference on Multimedia Modeling* (MMM '16), 51-62. http://doi.org/110.1007/978-3-319-27671-7_5
17. Esko Kurvinen, Mia Lähteenmäki, Antti Salovaara, and Fabiola Lopez. 2007. Are You Alive? Sensor data as a resource for social interaction. *Knowledge, Technology & Policy* 20, 1: 39–49. http://doi.org/10.1007/s12130-007-9003-y
18. Walter S. Lasecki, Christopher D. Miller, and Jeffrey P. Bigham. 2013. Warping time for more effective real-time crowdsourcing. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '13), 2033-2036. http://doi.org/10.1145/2470654.2466269
19. Walter Lasecki, Christopher Miller, Adam Sadilek, et al. 2012. Real-time captioning by groups of non-experts. In *Proceedings of the 25th annual ACM symposium on User interface software and technology* (UIST '12), 23-24

http://doi.org/10.1145/2380116.2380122

20. Martin Ludvigsen and Rune Veerasawmy. 2010. Designing technology for active spectator experiences at sporting events. In *Proceedings of the 22nd Conference of the Computer-Human Interaction Special Interest Group of Australia on Computer-Human Interaction* (OZCHI '10), 96-103. http://doi.org/10.1145/1952222.1952243
21. Robert R. Morris and Rosalind Picard. 2012. Crowdsourcing Collective Emotional Intelligence. In *Proceedings of Collective Intelligence Conference* (CI '12). *arXiv.org :1204.3481*
22. Florian Mueller, Frank Vetere, Martin R. Gibbs, Darren Edge, Stefan Agamanolis, and Jennifer G. Sheridan. 2010. Jogging over a distance between Europe and Australia. 2010. In *Proceedings of the 23rd annual ACM symposium on User interface software and technology* (UIST '10) 189–198. http://doi.org/10.1145/1866029.1866062
23. Elizabeth B. N. Sanders and Peter J. Stappers. 2008. Co-creation and the new landscapes of design. *CoDesign: International Journal of CoCreation in Design and the Arts* 4, 1: 5–18. http://dx.doi.org/10.1080/15710880701875068
24. Will Simm, Maria Angela Ferrario, Adrian Friday, et al. 2015. Tiree Energy Pulse: Exploring Renewable Energy Forecasts on the Edge of the Grid. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '15), 1965–1974. http://doi.org/10.1145/2702123.2702285
25. Petr Slovák, Joris Janssen, and Geraldine Fitzpatrick. 2012. Understanding heart rate sharing: towards unpacking physiosocial space. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '12), 859–868. http://dx.doi.org/10.1145/2207676.2208526
26. Piet Smet, Bart Dhoedt, and Pieter Simoens. 2016. On-demand provisioning of long-tail services in distributed clouds. In *Proceedings of* Network Operations and Management Symposium (*NOMS* '16), 1320-1323 http://dx.doi.org/10.1109/NOMS.2016.7503011
27. Jen Southern. 2012. Comobility: How Proximity and Distance Travel Together in Locative Media. *Canadian Journal of Communication* 37,1: 75–92.
28. Paweł Woźniak, Kristina Knaving, Staffan Björk, and Morten Fjeld. 2015. RUFUS: Remote Supporter Feedback for Long-Distance Runners. In *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services* (MobileHCI '15). 115–124. http://dx.doi.org/10.1145/2785830.2785893