Experiences in Designing HCI Studies for Real-time Interaction across Distributed Crowds and Co-located Participants

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Abstract: This paper is a post-hoc reflective case study from the point of view of the research investigators. The authors share the experience of designing and deploying four studies that involve real-time interaction between distributed crowds and co-located participants. We first recount the challenges that these uncommon, yet increasingly necessary, HCI research contexts afford. We then present the learning outcomes from 1) the 'designing', 2) the setting up, 3) the real-time dynamics and 4) the interaction between distributed and co-located participants. From this we deduce the impact for the four stakeholders in these contexts 1) the distributed crowd, 2) the co-located participants, 3) the system owners and 4) the researchers. This meta-research approach is motivated by our struggle to find more 'Researcher-experience' cases during the early stages of the studies. This contribution in experience sharing is intended to help HCI researchers who are planning studies in this field.

1 INTRODUCTION

This work presents the experience as a post-hoc reflective case study after a five-year timeframe of conducting HCI studies with real-time distributed interaction of online crowds. In this paper, we aggregate the insights from four studies in a sports context. Through the lens of the researchers, we share the challenges that these HCI settings afford. These studies required the development of a series of custom applications that allow distributed crowds to communicate their emotional support to athletes in real-time. Through four in-the-wild deployments we then broadcast sensor-data from athletes to globally distributed spectators in custom-designed data visualisations. These visuals help spectators build an understanding of the athletes' remote performance. Concurrently, supporters were prompted to externalise their support in the form of remote cheering Across the studies we were interested in investigating four central questions to 1) understand the experience of the data-sharing athletes while receiving remote support, 2) identify factors that influence remote spectators' behaviour during live events, 3) identify motivations for using real-time spectator support systems, and 4) provide guidelines for researchers and designers that seeks to facilitate support from remote spectators during sports events. In this paper, we aggregate the learning from these individual studies and use the experience to share the challenges faced by researchers when planning and conducting complex but increasingly necessary HCI research that involves real-time interaction across distributed participants. This is intended to guide other researchers who are planning studies in this exciting research area.

2 BACKGROUND

This work was composed of four phases as follows.

1. We first conducted a feasibility study to assess the viability of investigating real-time support from remote crowds in a sporting context, identify any

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ethical issues that may arise from the study and gather preliminary insights on how to design systems for remote spectator support. This feasibility study was composed of desktop research and two in-the-wild deployments during two sporting events (Curmi, 2013).

2. With the insights gained in Phase 1, we then designed and build BioShare, a customizable research tool that facilitates sharing live data over social networks and allows remote spectators to send instant feedback (Curmi, 2014).
3. With BioShare, we than developed and deployed HeartLink, in an ad-hoc in-the-wild 5k event with 5 athletes and 140 remote spectators. HeartLink is an application that allows athletes and spectators to interact in real-time during events (Curmi, 2015).
4. Finally, we conducted a fourth in-the-wild deployment during a 24-hour 170-mile relay race with 13 athletes and 261 spectators (Curmi, 2017).

The next sections briefly describe each of these individual studies. We present the methods used together with an overview of the learning outcomes from each of these phases.

2.1 Phase 1: Feasibility Study Consisting in Desktop Research, a Pilot Study and a User Study

Phase 1 (Curmi, 2013), assessed the viability of investigating remote crowd support. It gathered insights on possible ethical issues that should be taken into consideration when deploying events in-the-wild within this context and captured requirements for system design.

Through desktop research we first reviewed existing commercial mobile phone applications that were designed for sports activities. We found that applications at the time of conducting the study, did not allow spectators to communicate with athletes during events. We also identified that academic research on sports applications is very limited particularly when it comes to the sharing of live personal data. In this light, before conducting in-the-wild deployments, through a survey, we assessed the readiness of participants from a university setting to share personal data while conducting sports activities.

A pilot study and a user study were then conducted. These investigated the technical issues involved when athletes share data in the wild. These also gathered primary data on the athletes' and the spectators' experience. A pilot study took place during a triathlon in the Lake District and focused primarily on validating the technology. A user study was then conducted during a charity run in Lancaster, UK. This focused primarily on capturing the participants' experience. Analysis of the data that was captured through observations, server-interaction logs, interviews and content analysis of online discussions during the events, indicated that research in remote-crowd support is worth pursuing.

However, the use of third-party communication applications that were used to share athletes' data within an in-the-wild research context, presented several challenges that included a lack of control on data integrity and reliability. These also limited the ability to measure user experience and behaviour thus motivated the development of a bespoke data sharing system for researching remote spectator support: BioShare.

In summary, the contributions of this phase 1) confirmed that further research in remote crowd support is worth pursuing, 2) provided preliminary insights on how to build crowd support systems around athletes and spectators, and 3) highlighted the need to create dedicated tools for researchers working in this area.

2.2 Phase 2: System Design and Development

In Phase 2 (Curmi, 2014) we designed and developed BioShare. The requirements capturing for developing Bioshare involved three stages.

We first reanalyze the data collected in Phase 1 and identified key system requirements.

We were interested in making Bioshare relevant for other researchers working in this area. Consequently, to validate whether the insights gained from our experience in deploying two in-the-wild studies matches the requirements of researchers who developed closely related systems, we then compared and contrasted our insights with those of closely related systems that are referenced in literature.

We found that systems that are referenced in literature lack details on how these systems were developed and details on issues that emerged during their development, if any. Thus, we further investigate past systems' development by interviewing HCI researchers who created closely related data sharing systems for research applications.

The developed prototype consisted in a native mobile application that broadcasts users' locative and physiological data over mobile networks and received feedback from online crowds. A web interface together with a dedicated backend allowed distributed crowds to follow and communicate with the data-sharing users. BioShare is open-source and is designed such that it can be configured for different study requirements.

In addition to contributing BioShare as a tool for researchers, this phase also contributed a set of requirements for spectator support systems in the presented context. These include ethical considerations, design for adaptability and a framework to empower the user over the shared data.

2.3 Phase 3: Deployment in an 5k-road Race

A customised version of BioShare, HeartLink, was then deployed in a 5k-road race with 5 athletes and 140 remote spectators. In this deployment, we 1) captured the experience of athletes when sharing data and receiving remote support in real-time and 2) identified key influencers to the supporters' behaviour during a live sport event. Pilot studies suggested that spectator engagement is influenced by both the data that is presented (e.g. the effort that the athlete is exerting) as well as the social relation between the athlete and the supporter. To validate this, we recruited two spectator groups. One spectator group was recruited through the athletes' own social networks. Thus, the spectators in this group knew the athletes. A second spectator group was recruited from a crowdsourcing platform and thus these spectators had no social connection with the athletes. Additionally, to compare whether different data types, particularly heart rate data, influences the spectators' engagement, all the spectators were randomly assigned to one of two conditions. One group was presented with locative data while a second group was presented with both locative data and heart rate data of the athletes. The results indicated that having a social tie with the athletes increases engagement when supporting the athletes. These spectators cheered the athletes more and spent more time supporting. Spectators who were presented with the additional heart-rate data in their interface also cheer significantly more. Additionally, through a focus group, the athletes suggested that the motivation for athletes to use remote spectator-support systems is dependent on the effort that the task entails and the degree of loneliness that the event presents. To further investigate this, we then conducted a fourth in-the-wild deployment during a 24-hour 170-mile long relay race across the UK.

In summary, Phase 3 (Curmi, 2015) contributed the following:

Through quantitative data, the work highlighted differences in spectator behaviour across spectators who are presented with different visuals, and spectators who have different social relationships with the athletes. For example, we found that spectators who are presented with additional information about the heart rate of remote participants are likely to feel more emotional and consequently cheer more.

Through qualitative data, the study identified key motivations for using live remote cheering systems. For example, we identified that spectators' behaviour depended on their understanding of why the athletes are conducting the task (e.g. the assumed athletes' egoistic vs. altruistic objectives in participating in an event). With regards to the athletes' motivation, we identify that the impact that the cheering has on the athletes is relative to their expectations. This and similar outcomes, are congruent with existing theories of expectations management (Boehm, 2000) and self-determination theory (Ryan and Deci, 2000).

2.4 Phase 4: Deployment in a 170-mile Relay Race

For this event, BioShare was customised and embedded in a running relay-baton form factor (Curmi, 2017). This baton works as an interface between the remote crowd and the athletes. The baton's form-factor also provides enough space to store the needed energy for the 24-hour long event. Following a co-design process with the athletes, the prototyped baton collects and broadcast data in real-time and vibrates whenever a remote supporter clicks a cheer button on the web interface. Additionally, the baton also calls out the name of the person who sent the 'cheer'. In this way, the athletes get an awareness of where the cheers came from.

Through these deployments, we further analysed and deduce user-motivations for using real-time crowd-support systems. Athletes reported motivation from: receiving remote support, building followship, having a proof of accomplishment, satisfying a social need to connect with others, democratising sport events and facilitating mindfulness about the event, among others.

Additionally, the data collected through these deployments provided insight on key factors that need to be taken into consideration when engineering real-time crowd support systems. These are presented in three categories:

1) Spectators' expressiveness i.e. the design of how spectators can externalize their support. This can range from a highly controlled form (e.g. simple binary 'Likes') to a more open approach such as user-generated communication (e.g. live audio streaming of aggregate cheers from spectators' microphones).

2) Context applicability i.e. we identify contexts where remote spectator support seems most pertinent. Findings indicate that these systems seem to be most valuable in challenging events and where the athletes feel lonely (e.g. participating in an unaccompanied setting at night-time). On the other hand, remote support appears less useful in competitive events.
3) The design of the data flows within the social network. Here designers need to consider how system users (athletes, spectators and organisers) communicate and design communication flows.

3 METHODOLOGICAL CONSIDERATIONS

A common element in these studies is the adoption of an in-the-wild approach. Unlike traditional experimental methods that take place within the lab (Johnson, 2012), the method go beyond observing existing practice and present opportunity to evaluate novel technology in the place where the technology is intended to be used (Morris, 2012; Marshall, 2011). Research in the wild is an old practice. Centuries-old inter-continent expeditions that inform ship design may classify within the definition. However, over the last decade, research in-the-wild became a common research practice in HCI. As in our study, HCI researchers often seek to explore new technology, test prototypes in the location in which they are intended for and understand how people interpret and appropriate the technology (Dahlbäck, 1993; Gaver 2013; Kittur, 2008, Rogers 2011).

Prototypes were deployed with participants in different cities, countryside pathways, cycle lanes, nature parks and inside a lake. For example, the final prototype deployment connects athletes running a 170-mile race, from coast to coast, across the UK. In this setting, research in-the-wild allowed compare and contrast the effect of mobile data connectivity on the proposed technology across different environments within the same deployment.

Evaluating technology in-the-wild poses a number of added challenges. These challenges go beyond the lack of comfort that out of the studio participants are presented with (Rogers, 2011). An in-the-wild study may suffer from lack of control that a lab facilitates (Laseki, 2013). Consequently, extrapolating specific effects becomes difficult and researchers need to interpret data that is influenced by several externalities and interdependencies (Rogstadius, 2011). Using multiple methods of data collection often compensates for this. Where possible, we triangulate findings across different data sources. Eight data collection methods were used throughout the study, namely, surveys, literature reviews, focus groups, semi-structured interviews with athletes, spectators and HCI researchers, content analysis of social network comments posted during deployments, quantitative data of online users' interaction that is collected by the data servers, observations, and research through designing four data telemetry prototypes and four online-crowd interfaces.

The challenges that research in-the-wild presents are widely documented in literature (Mueller, 2010; Fox, 2006; Rogers, 2011). However, over and above these challenges, this work faced additional unusual dynamics. Each of these augments the complexity of running the study (Figure 1). Namely, 1) the need for co-ordinating a group of co-located participants that are conducting a challenging task in-the-wild, 2) the need of co-ordinating a group of globally distributed participants and 3) the need for all activities to operate in real-time with synchronous interaction at a global scale. The latter does not afford the traditional lab recruitment approach where the researcher schedules participants at a time when it is most convenient for each participant. In such HCI studies, all the participants have to synchronise with the live event.

In this context, recruiting participants, particularly online spectators, requires rigorous planning. Online spectators may be less difficult to recruit than co-located athletes since much less effort is needed when participating in an online task than when participating in a physically challenging task such as a long-distance race. Additionally, there is typically no travelling involved. The participants do not feel they are being watched and they might do work in parallel to following and/or supporting the athletes. For example, Manson points out that participants might have coffee while engaging in an online event (Manson, 2012). Another important consideration is 'Attrition'. In a lab experiment, it is very unlikely that a participant walks out of an experiment due to unstated pressure from being in a face-to-face situation. This does not apply to an online environment where participants may easily leave the experiment at the click of a button. The participants may also be distracted by various other factors such as surfing other websites, making errands or experience technical system failure, to mention a few. To monitor this, we placed occasional prompts to monitor attention. The system then logs the time taken for each viewer to respond and this measure may then be compared to different participant groups and collected datasets.

Additionally, to mitigate complexity, we start with a small-scale deployment that has few participants, to then increment the scale of the deployment iteratively. This approach promises 1) incremental improvement, 2) contains any emergent ethical issues and 3) minimises risk of failure.

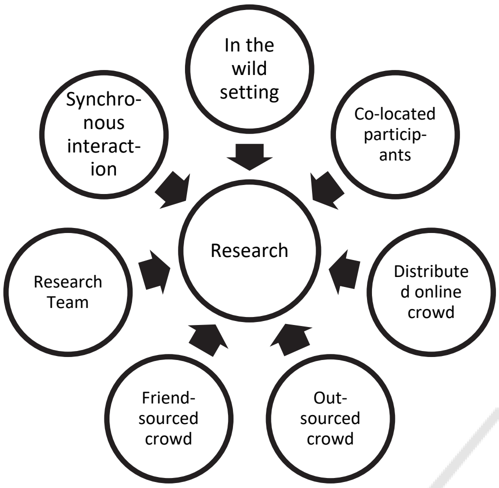

Figure 1: Methodological influencing contexts.

4 FINDINGS AND REFLECTION

4.1 Conducting RIW Deployments with Synchronous Interaction between Distributed Participants

As earlier stated, all the deployments were conducted in the wild. This made planning, organising and deploying extremely challenging. Moreover, each study involved multiple user groups that were not only in the wild but also distributed across different locations. Additionally, the interaction under investigation was synchronous. Thus, the participants needed to synchronize themselves to the study rather than the study synchronises to the participants. The need for participants to synchronise with the study limits the number of participants that can take part in the study as their participation is not only conditioned by their willingness and appropriateness to the sample group but also by their personal schedule. This restriction is particularly visible when the user group is friendsourced, that is, the participants have a social tie with the athletes. On the other hand, this is less restricting for outsourced participants, that is, where participants have no social connection with the athletes as the sample frame may be larger.

Outsourced participants were recruited from CrowdFlower, a crowdsourcing platform. Crowdsourcing platforms provide a large enough pool of participants (crowd workers) who are seeking work that matches their expected enjoyment and financial return. The enjoyment value is a major factor in the recruitment process. Many studies show that crowdsourced participants value the pleasantness of a given task (Rogstadius, 2011). This impact both the engagement of participants in the task and also the reputation on the platform (through post-task-completion feedback) of the researcher who issued the study.

4.2 Contrasting Real-time in the Wild vs Lab

Inversely should there was a lab variant of the studies, the challenges would have been very different. 1) The researchers would not have been bound with recruiting a large group of participants to perform at one specific global time. 2) The researchers would have had more control over the environment and confounding variables would have been limited. For example, weather conditions would have been minimally influential on the study, if any. Windows would have been closed and, say, a treadmill could be kept the same gradient for all participants such that all the participants would have been presented with an identical controlled experience. Similarly, cheers could have been computer generated from predefined patterns that would simulate remote cheering crowds. 3) Running such an experiment would have been easier because the researcher would be in the comfort of the well-known, tried and tested, “lab”. The researcher could have wired, handled and observed one participant at a time.

However, no matter how controlled this environment would have been, it would have never been anything close to the real thing; the in-the-wild environment with real crowds sending self-initiated cheers at that moment in time.

In hindsight, an in the wild deployment that involves distributed crowds, like the four deployments in this study, are more unforgiving then an in the lab approach where single participants sequentially conduct offline sessions. For example, if there is an issue with the system, such as what happened in the pilot study due to downtime on US Amazon Web Services, then the researcher needs to coordinate a crowd that is distributed. This is challenging, not only because the investigation involves a crowd but also because the data is live and distributed. In this case, the research event is likely to fail or at minimum, the research objectives would change. Moreover, a new event is likely to require coordinating a new crowd. Should that have been in the lab, a participant would have been ranked as an outlier or replaced with an additional lab session. Finally, in a lab variant, systems can be tested, and researchers can pose as dummies. In an in-the-wild version where crowds operate synchronously, systems are difficult to test comprehensively. For example, collecting enough participants to simulate a crowd to test a system in situ is often impractical. Furthermore, if the researcher does manage to do this, in most cases, the in-the-wild environment is likely to change over time. Hence, reliability across all variables is challenging at best. For example, data telemetry that is dependent on mobile network coverage (reception) may be influenced by the density of users that happen to be in that public area and of which the researchers have little or no control.

These challenges that research in the wild with real-time interaction brings to the table further highlight the differences of real-time in the wild over an in-lab study. These differences emphasise the distinct values that both approaches present the researcher with. Based on the above considerations, we recommend the following to researchers who intend conduct research on the lines of this work:

1. The researcher should seek to control any variable that can be controlled but plan contingencies for unexpected events.
2. Conducting meticulous planning minimizes the risks of unexpected outcomes.
3. In these contexts, observations during the event as part of the research method is highly important and details should be documented during or immediately after the event.
4. The researcher should have a communication channel with remote participants. This is essential for ad-hoc coordination should unplanned phenomena occur.

Roles for documenting events and coordinating events should be assigned to separate individuals. Due to the complexity that such tasks entail, we recommend that researchers build a research team where each member is assigned a pre-designed role. Different studies and conditions would necessitate different roles for supporting staff. In the case of the study in Phase 4, the 170-mile relay race, the recommended roles for the event such that the researchers can focus on core areas were as follows: 1) A researcher was assigned to coordinate the online crowd. This person would, for example, message the crowd should there be a need to do so during the live event and answer any queries that online participants may have. 2) A person needs to coordinate the co-located athletes. 3) An experienced researcher journals the event. 4) A videographer and/or photographer may provide grounded content for post-event analysis or in support of post-event publications.

4.3 Managing Interfaces with Multiple Stakeholders

The deployed interfaces were driven by two main sources: The athletes and the spectators. In their work, “Designing the Spectator Experience”, Reeves et al. classify these interfaces as public interfaces. These are public interfaces not because the interfaces are out in the wild but rather because of the “extent to which [the] performer’s manipulations of an interface and their resulting effects are hidden, partially revealed, fully revealed or even amplified for spectators.” (Reeves, 2005 p.741). In recent years, there have been numerous discussions within related communities, such as SIGCHI, on interfaces that are moving away from providing an individual dialogue but rather are *designed for a crowd* (Boulos 2011; Brady, 2014) and *driven by a crowd (Laseki, 2013)*. In most of these cases, as it is the case of the above studies, the crowd is distributed.

In a real-life cheering context, within an open sporting event, the human interaction is intended to be public. Spectators cheer from the sides of a racecourse or from the stands at a stadium. On the other hand, in the digital world, there is by far more human-human communication that is designed for a private setting rather than a public one. Public telephones for example are enclosed in boxes or photo kiosks (Rogers, 2011). There are also multiple levels of engagement. There are spectators who follow the data through the crowd-powered interface, hence they can follow the data of the athletes and the data that is driven by the crowd (i.e. the live cheering, the spectators live comments as the event unfolds and the number of spectators that join and leave the event, during the event). There are also the supporters, that is, those spectators who do not simply follow the data but also interact with the interface and the athletes by cheering and commenting, hence contributing to the live discussion. Finally, there are the athletes whose interaction is highly automated, both the sharing of data, and in receiving feedback from the crowd. In a way, the interface of the athletes is hidden and inexistent. It is an extension of the crowd’s interface. For example, the relay baton that was deployed in Phase 4, opens a channel to the crowd. The athletes do not interact with the baton, but the baton automates the communication from the athlete to the crowd. The baton captures the data and sends it to the crowd without any interaction from the user (the athlete). There are also the co-located spectators, who, although they might not interact with the cheering system or the online crowd, they may also influence the online environment through the athlete's environment. In this regard, Reeves et al. add another dimension to *public* vs. *private* dichotomy; *manipulations* and *effects,* where manipulations are the actions of the 'performer' (in our case these are the actions of the athlete). On the other hand, the effect is the impact of the manipulations; a click on a cheer button triggers a vibration (direct effect) and may make the athlete aware of the support being sent. The athlete may perform better and his or her exertion may influence the gradient of the chart representing the live heart rate (indirect effect).

The work of Reeves et al. helps us position the authors' interface within the spectrum of interfaces. Interface categories include 1) Magical, this refers to interfaces that hide the manipulations but the effects are revealed (e.g. wizard of oz interface (Reeves, 2005)), 2) Secretive, where both the effects and the manipulations are hidden (e.g. within a competitive game), 3) Suspenseful, where manipulations are hidden but the effects are revealed and finally 4) Expressive, where both the manipulations and the effects are revealed or amplified. Within this taxonomy, the proposed cheering system positions itself in the expressive quadrant. Spectators' actions are channelled to the athletes and amplified through haptic and sound synthesisers. The athletes' performance is sensed and amplified to all connected spectators within the spectators' interfaces.

The real-time cheering system associates another dimension to this. The interface is not only generated and interacted-with by the individual and displayed to the spectators as a crowd, but this crowd also drives the interface. In other words, the interface (including the cheers, the number of online spectators and the live comments that make up the interface) is generated from the crowd. These become, as Michael Bernstein coined, crowd-powered interfaces. Crowd-powered interfaces are "interfaces that rely on human activity traces or human computation to provide benefits to the end user." (Bernstein 2010 p.347). Undoubtedly, the cheering process is explicitly conducted for the benefit of an end user, the athlete. We argue that this process relies on both 'human activity traces' and 'human computation'. They rely on human activity traces as the distributed individuals trigger the cheers, and each has his or her intentions and motivations to cheer. The human computation component is highlighted in the user interviews. Upon interview, the spectators showed interest in maximising the positive impact that the cheers could have on the athlete. In this regard, spectators devised strategies such as leaving more cheers towards the end of the race, 'such that the cheered athletes do not get used to the cheering'. These strategies are reflected in the cumulative cheering plots.

4.4 Managing Multiple Communication Modalities

Across the studies, we looked at primarily two communication flows. Informing the online crowd (spectators) and informing the athletes. The athletes' awareness of spectators' behaviour and their support, can contribute to build a sense of 'liveness'(Mueller, 2010). However, it can also generate pressure on the athlete. The sense of 'being observed' that real-time remote support systems create, may make the athlete feel obliged to perform or feel embarrassed for mistakes since spectators are following the performance. The modality that is adopted to communicate the crowd's support to the athlete is an influential factor in the design of the athletes' experience. The deployments explored tactile and sound alerts to communicate the cheering crowd. Results showed that the effect of the communication modality is dependent on different externalities over and above the modality itself. These include the context (e.g. the background noise within the environment), the trustworthiness of the cheering crowd (e.g. whether there are spammers among the cheering crowd who might misuse the modality, say, send inappropriate messages) and the individual personalities of the athletes that the set modality is communicating with. For example, when the modalities where calibrated to generate the same intensity of tactile feedback for all participants, some athletes did not feel the set vibration. This seemed related to the athlete's body mass and athletes with larger arms were more likely not to feel the vibrations that were triggered by the telemetry device thus emphasising the need for personalisation.

5 CONCLUSION

We believe that these findings are just the beginning of this research area and we trust that other studies will follow. What is presented here may provide the preliminary groundwork for real-time remote crowd support. Our findings suggest that this research domain promises high impact in many research fields, including social network theory, crowd psychology and commercial applications in sports.

Finally, a more challenging but equally interesting area is that of studying how these systems could be personalized for individual needs and expectations. Results indicated that different athletes react differently to cheering. Through a psychological framework, further work could reveal which traits determine the relevance or otherwise of remote cheering for individual personalities.

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