User-Centred Design for Team Sports Wearable Display

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Abstract

This paper describes the user-centred design and development of a new wearable display system for team sports, named *TeamAwear*. Wearable display is a class of display that is worn on the body and is able to communicate information about the wearer. The application of such a technology within a team sport context has the potential to enhance the game-play experience. To identify and overcome difficulties during the development process, a user-based design approach was adopted. This included evaluative ethnography, creative brainstorming and group-based discussions involving the identified stakeholders, including athletes, coaches, referees and spectators. This research describes how the active participation of users during the development process significantly influenced the design outcomes.

Keywords: wearable computing, display, sports, HCI

1 Introduction

Team sports are a fundamental part of our society today. Several applications and technologies have been introduced within this domain for various purposes, targeting one or more of the stakeholders involved. While visualization systems already have demonstrated success in this area (Page and Vande Moere, 2006), more recently the use of wearable-based technologies has started to gain momentum, with applications in a wide spectrum of sports, such as martial arts (Chi, 2005), skiing (Michahelles and Schiele, 2005), and Australian football (Wisbey and Montgomery, 2005). Unfortunately, the acceptance of such technologies has been littered with controversy (Loland, 2002), and as a result, a number of these applications have been discarded by the athletes or game officials. This research aims to overcome most acceptance issues surrounding a new ubiquitous sports technology, by applying a typical Human Computer Interaction (HCI) perspective, which includes the involvement of users during the design process.

User-based design is a well-known approach in HCI research. It has already been used during the development of several ubiquitous systems, which have reported to be successful within their target context, including: a mobile computer for divers (Macdonald, 2005), a wearable display for increasing social awareness (Williams et al., 2006), a stress reliever device for healthcare purposes (Fabricant, 2005), as well as devices for fitness and sports (Stevens et al., 2005).

Similarly, this research examines the development process of an alternative practical application: a wearable display system for team sports, termed *TeamAwear*, which specifically focuses on basketball. By following a user-centred approach, this system has been adapted to several unexpected user concerns, and is expected to receive a higher acceptance from potential users.

2 The TeamAwear System

TeamAwear (so named for "team sports awareness wearable display") consists of multiple wearable displays in the form of electronically augmented basketball jerseys, which are worn by athletes during game-play. While athletes are the primary users and 'wearers' of this system, the intended TeamAwear application takes into consideration *all* team sports stakeholders, including coaches, referees and spectators. These additional user-types are equally crucial to the outcomes and successes of a basketball game (Deltow et al., 1984).

In practice, each athlete wears a unique TeamAwear jersey during game-play. Each jersey is linked wirelessly to a game official's computer terminal (see Figure 1). Throughout game-play, each athlete's wearable display is immediately updated based on specific information that is dynamically generated during a basketball game.

By perceiving the displays, it is expected that the athletes become more consciously 'aware' of crucial game-play related information in the periphery of their attention. Therefore, this approach is similar to that of ambient display, which supports the non-distracting monitoring of information in an aesthetical way (Mankoff et al., 2003). Using the information shown on these jersey-based displays, all team sports stakeholders become more conscious of game events, which can potentially lead to: improved performance, more accurate decision making, and increased understanding of series of events, and ultimately a more enjoyable game experience.

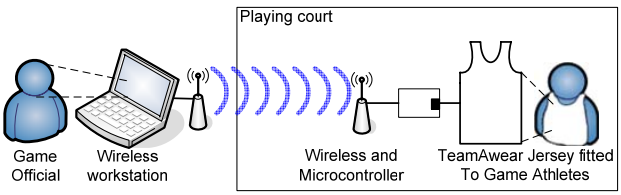

Figure 1: Diagram showing TeamAwear during use

3 Designing For Users, With Users

HCI research generally focuses on the evaluation and finetuning of existing systems, or on the design of novel systems. In both cases, user feedback is a major means of obtaining context-specific design criteria, which is used to increase its usability and usefulness. For a novel wearable display system, one thus needs to acquire essential usage knowledge, such as on what information to display, how to show it, and who to show it to. The user-based process contains three consecutive stages that gradually become more focused on the final end-product: Evaluative Ethnography, User-centred Discussion, and User-centred Participative Design (see Figure 2).

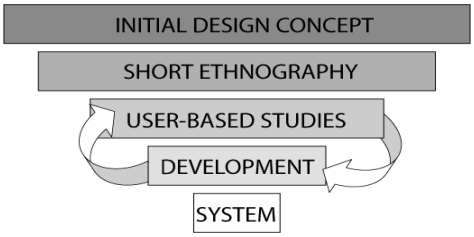

Figure 2: User-centred design process

One of the issues inherent with user-based design is ethical approval, which is especially true for wearable computing devices. One should note that in the case of this particular research, important ethical concerns were raised due to the inherent electrical properties of the device, which is positioned in close contact to the human body (e.g. heavy perspiration), and the unpredictable and active usage context (e.g. potential physical contact and falling, damaging the device and/or injuring body).

3.1 Evaluative Ethnography

Ethnography is a research approach which provides valuable means of analyzing the contextual circumstances of a systems usage (Crabtree, 2003). However, this is typically an extensive process which can often take many months or even years to perform (Ball and Ormerod, 2000). Evaluative ethnography, however, does not require a long-term period of fieldwork, but rather seeks relevant information quickly in order to establish the 'work-ability' of a proposed design system (Hughes et al., 1995).

Here, an evaluative ethnography study was carried out over a period of approximately eight weeks to examine the intended users during their normal 'work state'. This occurred both at scheduled training sessions and during competitive basketball games. Observation can be facilitated with the aid of specific observational tools, such as written field notes and proxemic diagrams (see Figure 3). These tools allowed primary system design tasks to be discerned, which in this case included: understanding each stakeholder's role during game-play, recognizing their major actions, and determining any useful relationships between them.

An extensive amount of data was collected during this stage which allowed recognition of the typical and reoccurring patterns in user behaviour during game-play. This study also facilitated a number of early design decisions, including: the identification of appropriate display media technologies, potential display media surfaces and display materials, and the uncovering of valuable game-play related data types that could be visually represented. Table 1 summarizes these discoveries.

Issue	Observation/Results
Game-play	- Auditory and kinesthetic channels - Fast-paced decision making - Regular physical contact - Unsafe items against rules - Playing environment brightly lit
User Roles	- Athlete: centre of game-play - Referee: maintain rules and fairness - Coach: instruct and guide athletes - Spectator: observes, learns, enjoys
Observable data types	- Publicly accessible and relevant to all stakeholders - Include: Time, foul, score, rebound, assist, steal, block, turnover, point
TeamAwear Design	- Visual medium - Flexible materials to avoid breakage - Flat, non-protruding - High visibility/brightness - Limit data types to avoid cognitive load

Table 1: A brief look at results of ethnography

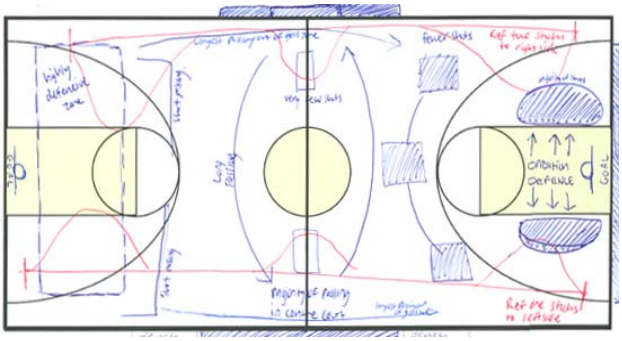

Figure 3: A proxemic study during ethnography

3.2 User-Centred Discussion Sessions

Based on results derived during the evaluative ethnographical study, the next stage in system design concerns the organisation of user discussion sessions involving the users themselves. Recruitment of specific volunteers for user research generally occurs via flyers or handouts within the intended users' normal environments. In this case, local sports centres were targeted to recruit basketball stakeholders. Unfortunately, the response from this method was minimal as users seem to be unaware, and probably afraid, of the technologies involved. This issue was overcome by attending games 'in person' and inviting potential users to participate in the research, briefly informing them of the concepts surrounding the proposed TeamAwear system.

In this research, the specific numbers of volunteer users that were invited to the sessions was based on the relative importance of their roles to the intended application during game-play. Therefore, the discussions involved about six semi-professional athletes, one coach and referee, and three spectators. The discussions were deliberately left open-ended, allowing unexpected possibilities for the proposed design system to be explored. However, discussion topics were related to conceptual outcomes that needed to be achieved in order to progress system development. In this case, the

outcomes primarily focused on underpinning the *conceptual design* of the TeamAwear system. This involved obtaining the users feedback regarding the proof of concept, potential usages, requirements, needs, and important data types to be visually represented. With the majority of users unfamiliar with ubiquitous display technology, this feedback allowed them to arrive at important design decisions independently, and convince them of the needs of a TeamAwear system.

Once sufficient 'open-ended' feedback had been obtained, users were given in-depth explanations and shown various examples of similar systems. This introduced familiar concepts to users who might not have a design background. A number of existing wearable display systems were revealed to the users, as well as results from the evaluative ethnography study. Based on this new knowledge, the users were able to refine these results to their own needs.

3.3 User-Centred Participative Design Studies

While the role of the previous discussions was to consider conceptual issues for a design system, these participative design studies are largely concerned with *physical design*. During this stage, attention was focused on more progressive and guided design tasks towards the end product. Using the same volunteers for these studies maintained design fidelity and consistency. Introducing extra volunteers within the existing user group provided fresh, additional perspectives on the design.

Similarly to prior user-centred discussions, participative design studies are based on outcomes that are tied down to system development. For the TeamAwear system, these outcomes focused on finalizing the conceptual design decisions made by users during the previous discussion sessions. The identified data types were narrowed down and selected, and specific visual representations were mapped onto them. Construction-related issues were solved, including: the positioning and constellations of materials, and the layout, shape and size of the individual displays. Any technical details which would limit their design considerations were withheld.

It is crucial that each stakeholder's opinion be actively voiced, which unfortunately is not always achievable in larger group discussions. Therefore, users were separated into smaller groups, in which they participated in creativity sessions alongside the researcher. Here, the aim was to discuss layout ideas and generate design sketches. The groups consisted of a variety of each user-type to obtain a diverse range of design conclusions. This small group setting gave each user an opportunity to voice any opinions openly, allowing individuality to become more apparent than in the previous discussions. Ultimately, each group was able to reveal unique design sketches for the system, which was then presented, critiqued and refined by the larger group, following a common studio-based design teaching methodology (Reimer and Douglas, 2003). This process resulted in the completion of a tangible TeamAwear prototype (see Figure 4). A common similarity among the sketches was the positioning of displays for maximum visibility and movement, while the size and shape was variable.

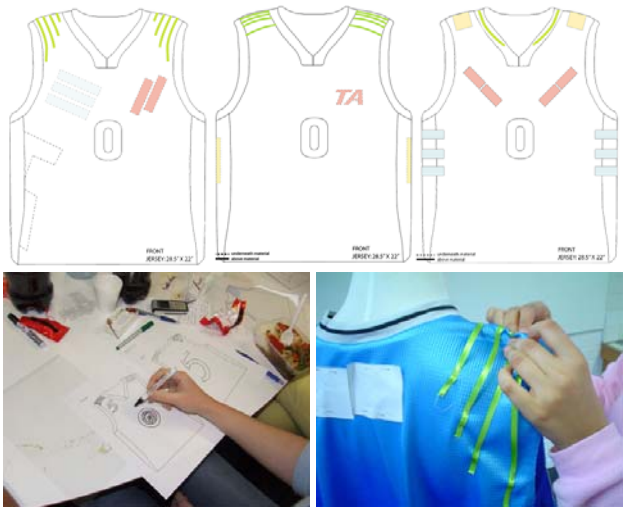

Figure 4: Early jersey sketches and group design tasks during user studies

4 Development of Wearable Display

A general principle for user-centred design is to involve users as much as possible so they can influence the design at all stages (Preece et al., 1994). In support of this, the participation of users did not stop at this point. Some of the more specific and technical development issues, such as the display attachment (Figure 5), washability issues, and weight, which lay outside the scope of the previous user-centred discussions and studies, now required more consideration. User feedback was required to critically evaluate the system prototype during the midst of its development. This allowed any unforeseen undesirables to be amended before completion. Table 2 shows some of the comments used to further refine the system prototype.

Issue	Question	Comments
Weight	*"How does the weight of the device feel on your body?"*	Lightweight, should not be any heavier
Attachment	*"How do you think the device should be attached to the body?"*	Harness, elastic and Velcro
Comfort	*"Describe how comfortable it felt while on your body?"*	Normal, unnoticeable
Size	*"Comment on the size of the device?"*	Too thick, longer and thin

Table 2: User feedback during development

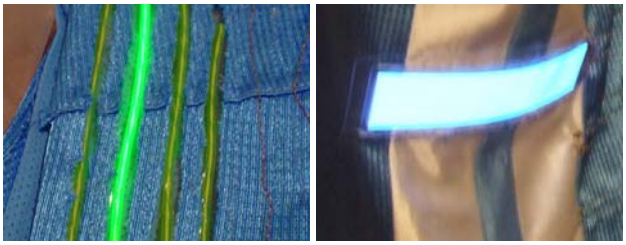

Figure 5: Development of the TeamAwear system

4.1 System Prototype

During the prototype development process, technical aspects of the system are integrated with the design requirements and user needs. The TeamAwear system was finalized this way by combining predetermined wearable computing components with the design criteria

identified during the design sessions and studies. The final tangible result from this research is the development of a functional prototype wearable display system for team sports (see Figure 6). However, the most significant results have been insights acquired by the user-centred design process itself. Exposure to each user's vast experience 'in the field' provided knowledge of how the system *could* and *should* be used. Some design decisions would otherwise have been overlooked, such as the aesthetic appearance of the system (e.g. powerful, cool-looking), the usability and arrangement of components (e.g. unobtrusive to movements, placement of batteries on body), and the placement and amount of information content (e.g. relatively to the position of team members versus opponents).

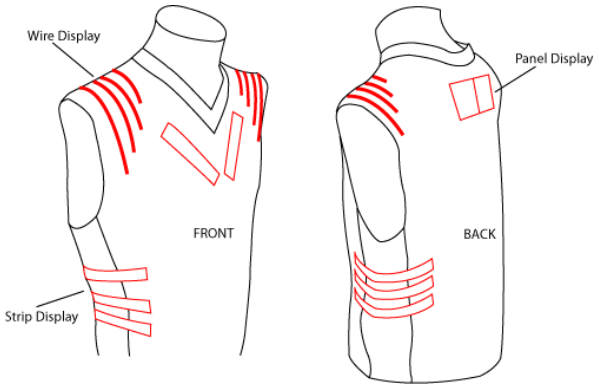

Figure 6: The final TeamAwear system

5 Discussion and Conclusion

The introduction of new sports technology can be difficult, especially when users are not aware of its purpose or when it is uncertain whether there is even a need for it. In such cases, a user-based design approach provides several benefits. Engaging in ethnographical studies prior to user-studies equips researchers with specialized knowledge, specific language and context-based experience that enable them to more actively participate with users. The user-based studies then become a democratic design process, in which each user's ideas and opinions can be considered equally.

This research introduced a user-centred process for the development of a team sports wearable display. This approach allowed users to work alongside researchers in order to identify and acknowledge typical design factors facing the implementation of such a system. Especially in a sports context, in which both the user and the technology are exposed to strenuous conditions, it is critical that the design takes into consideration the user needs, and not just technical requirements. Currently many team sports forbid the use of such technologies based on tradition. However, the participation and acceptance of the users is a major step towards the application of similar systems in the near future. Notwithstanding that the outcomes of each user-centred stage here were tailored specifically for basketball, it is expected that a similar approach could be utilised for the development of future ubiquitous team sports technologies. It has already been documented that information provided in an appropriate manner is a major factor in the improvement of sport performance (Liebermann et al., 2002). Therefore, a detailed evaluation study will take place that will ascertain the value and usability of the system, in the form of multiple jerseys worn simultaneously, in the context of competitive game-play.

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