DIGITAL FASHION: WEARING YOUR HEART ON YOUR SLEEVE

by

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Abstract

Clothes and fashion open a secondary i.e. non-verbal communication channel that allows individuals to make connections with each other. Our work proposes the concept of Digital Fashion, which uses technology to connect people in close proximity by enhancing a visual secondary communication channel. Non-private profile information known as shared knowledge is communicated via an online poll system that activates poll questions periodically. Our Digital Fashion implementation utilizes a handheld computer connected to a wireless radio network to drive a public wearable display worn on the user's body. The wearable display system consists of flexible electroluminescent wire and a light controller responsive to wireless communications. Shared knowledge is stored as answers to poll questions. As poll questions become active, the wearable display changes colours to reflect the wearers' answer to the active poll question.

Several user studies were conducted to evaluate this technology with data from field observations, questionnaires and interviews. The results from our user studies revealed that technology could play a useful role within social settings if designed appropriately. We found the choice of fashion as a secondary communication channel very appropriate because of its unobtrusiveness. Our system did not appear to hinder interactions but rather helped to create richer social interactions.

Dedication

To Papa.

Acknowledgements

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I owe my thanks to many other people and for more specific things, but nobody wants to read about that.

May God bless all those who love me and all those whom I love.

Table of Contents

List of Tables

List of Figures

People who ***wear their heart on their sleeve*** express their emotions freely and openly, for all to see. Example: "She is kind of player who never hides how she's feeling. One look at her and you know if she's winning or losing." Reply: "She **wears her heart on her sleeve.**"

You can see how these people feel as easily as if they were "**wearing**" their "**heart**" on the "**sleeve**" of their shirt. Example: "Some people love him and some people hate him, but my brother always lets you know how he feels. He **wears his heart on his sleeve.**"

People who ***wear their heart on their sleeve*** do not hold back their emotions, for good or for bad. It is clear how they feel in each moment. Example: "She's a shy person. She's never been one to **wear her heart on her sleeve.**"

Source: Go English.com
http://www.goenglish.com/2209.asp

1. Wearing your heart on your sleeve

For better or for worse, visual characteristics are an important part of a person's perception. People's dress and demeanour influences how other people react towards them. These signals can be very effective or can be misinterpreted and lead others to make incorrect judgments. The English idiom "to wear your heart on your sleeve" is an appropriate way to describe the purpose of the Digital Fashion project. With their heart on their sleeves, people become more approachable and open to interactions. Digital fashion allows people to put their heart on their sleeves while using technology appropriate for social settings.

Observations of people in public places suggest that people tend to choose clothing that reflects their personality and interests. For example, keen basketball fans are often seen with basketball shoes and a jersey when they are at the mall; an avid skier might wear a jacket from his/her favourite ski resort. This non-verbal communication channel is useful when people do not already know each other or if they are separated by short distances. People are able to interpret body language and alter their interactions based on their observations. Noisy environments can make it impossible to communicate verbally, for example in a crowded, noisy party. People are also reluctant to share some information verbally that they would otherwise be comfortable sharing in a non-verbal way. It would be awkward to reveal personal details to someone without having a context for revealing it. Non-verbal communication channels allow this to occur in a less awkward way.

This thesis proposes a way to provide a secondary non-verbal communication channel of in the form of digital fashion by using a public wearable display. Public wearable displays represent a class of displays that are worn on the body and are viewed by people around the wearer. The wearable display communicates information about the wearer to other people. The wearer controls what information he or she wants to share by choosing to participate in a series of online polls. We call this information '*shared knowledge*'. The results of these polls are displayed on the wearable displays and represent the secondary communication channel.

The goal of our system is to facilitate informal interactions between both acquainted and unacquainted individuals in a social setting. There are many reasons why this would be useful. The system could be used for initiating conversations with people we have not met by providing a simple fact about that person. In common etiquette it is proper to introduce people and say something about that person. For example, "Jenna meet Jim. Jim this is Jenna. Jim likes ice hockey and inline skates. Jenna is a dancer and likes Italian food." Digital fashion could provide a similar sort of interaction without requiring a mutual friend.

Another way our system could be useful is during conversations where the topic has lost its momentum. The system could provide new topics that engage individuals when they have nothing left to say to each other. Rather than being involved in awkward moments of silence or simply excusing themselves and walking away, people can continue conversing about other topics suggested by the changing poll questions.

This introduction lays out the motivation behind digital fashion by presenting the idea of fashion as a communication channel, our concept of shared knowledge and the role of technology in social situations. We explain the relationships between our system and other domains of inquiry such as small group research and face-to-face interactions as well as discuss the goals of our work.

1.1. Fashion as a communication channel

Fashion is an often-used non-verbal communication channel. People dress to reflect individual preferences. For example, people easily identify bikers by their dark leather jackets. Similarly skateboarders have their own clothing style and choose their clothes carefully to reflect this. People use these identifying styles to connect with people of similar interests or to avoid people with certain interests.

We know that people are expressive and like to customize their belongings to reflect their own individual preferences. For example, cellular phones have interchangeable faceplates that can be customized to a specific colour, or pattern. These customizations are used for personal satisfaction or as an expressive tool to set the wearer apart from other people or conversely to connect with other people.

Another popular form of expression is to wear sport teams jerseys to sporting events and sports bars. Showing support through clothes was very apparent during the 2002 Salt Lake City Winter Olympics. Clothing styles worn by Canadian athletes at the games were popular items all around Canada during the games. One can imagine the many informal interactions that occurred as a result of Canadian fans with Canadian colours meeting at the Salt Lake City Games.

Many people identify with the wearing of ribbons or other pins and flowers in remembrance or as a show of support for various causes. The list of ribbons and other items that are used by different charitable organizations include pink ribbons for promoting awareness of Breast Cancer, red, white and blue ribbons for the remembrance of the September 11th tragedy, and red poppies for Remembrance Day here in Canada. People who regularly attend conferences may also be familiar with ribbons attached to nametags that show affiliations with different groups or to identify keynote speakers, presenters, conference chairs, session chairs, and so forth.

These examples demonstrate the important role fashion plays in our lives. However the problem with clothing and fashion as a secondary communication channel is that fashion can only communicate a limited amount of information. Our clothes cannot communicate information dynamically. The information is sometimes misrepresented, misunderstood, or ambiguous. We believe we can augment the concept of fashion using technology and overcome fashion's limitations as a secondary communication channel. In this sense we are exploring fashion as a communicative medium for concrete ideas rather than as an aesthetic expression of an abstract sense of style. We see fashion as an appropriate platform for using technology to support social interactions.

1.2. Shared knowledge

Shared knowledge refers to information about a person that is shared with others in the same environment. It is knowledge specifically about that individual. This is sometimes referred to as profile information. It is shared through the communication of beliefs, ideas, opinions, and facts with other parties. Borovoy uses the term common ground to describe profile information that is used for facilitating informal interactions [6]. We do not to use this definition as it implies the narrower domain of interaction between like-minded individuals. Shared knowledge does not require a similarity of ideas and opinions for facilitating interactions. Our definition of shared knowledge allows us a broader range of techniques to examine informal interactions.

1.3. The Role of Technology

Technology has often acted as a barrier to face-to-face interactions. People can be intimidated by users of technology and place these people in a position of power [11]. The field of wearable computing faces the challenge of creating wearable computers that do not intimidate non-users and allow normal social interactions to occur.

Our desire to use technology for facilitating social interactions goes against the common perception of technology as a deterrent to social interactions. We start by reviewing technology in social settings and trying to discover their shortcomings. We use this knowledge to build and evaluate our own design and advance our understanding of technology in a social context. We use existing guidelines from the work of Weiser [36], and Erickson and Kellogg [13] to continue to learn and adopt new guidelines. We evaluate our system in different settings and discover more about the ways in which technology affects our interactions.

1.4. Understanding the domain

We consider this work to be interdisciplinary. We are focussed on the technical, sociological, and psychological aspects of using technology in social settings. As part of our design methodology we concern ourselves with gaining an understanding of the research domain. Research on face-to-face interactions from the field of sociology helps us to understand the types of interactions that occur within these settings and in these environments.

In the social situations we are interested in, interactions occur within small groups. An understanding of previous work in small group research serves as an important guide to our investigation. In particularly we consider the treatment of small group interaction as a complex dynamic system and modify our evaluation methodology to reflect this.

1.5. Goal of the work

Computers are becoming more pervasive in people's lives as a result of smaller footprints and the availability of wireless networks. The concept of an *always-on* or *instant-on* device that is carried in our pockets is gaining momentum. Research into the use of these technologies in social settings will become more important as these devices gain popularity and appear more frequently in our everyday lives. However the amount of research in this field is currently lacking. Any exploration and discovery in this field is welcomed and promises interesting results. As the area is fairly new, broad initial explorations will yield specific areas where further research must be directed.

The goal of our work is to use explore how technology can be used as a tool for facilitating and enhancing informal interactions. Public wearable displays act as a secondary communication channel to provide a shared context and allow informal interaction to occur. Shared knowledge can be used to help initiate interactions, or enhance existing interactions. We examine the effect of this technology on actual social interactions and observe how public wearable displays interfere with or facilitate interactions. In this way we demonstrate how technology can be used successfully within social situations. This also allows us to identify problems that might exist for similar technologies before they are deployed into the real world.

Our work supports the following hypotheses; that technology as fashion can work in the periphery to facilitate interactions in social settings without disrupting these interactions because it is designed to take into account the needs and privacy of the users of the technology, and that providing added context to a social situation does create richer types of interactions.

We want our work to be a case study for designing socially adept technologies. We do this by identifying both our successes and our failures in the hope that future projects will repeat the successes and avoid the failures. Building more socially adept technologies is not simple, nor is it practiced as much as it could be. We hope that our work encourages more socially aware design practices.

In the rest of this thesis, we explore the areas of research that have contributed to this work including the fields of social computing, pervasive computing, face-to-face interactions, public wearable displays, and small group research. We present our work in detail, including the idea of digital fashion along with the design and implementation of both hardware and software components. We explain our iterative user study designs and discuss the results of our work.

2. Background

In this section we structure and organize the body of existing research we have collected into appropriate categories. Grouping existing work together allows us to better understand how the work influences our own research. The grouping shows how our work fits within the structure of existing research. We distinguish our work from previous research by advancing the efforts of other researchers and by learning from their endeavours.

We group the previous research into the following categories: Social Computing, Face-to-face Interactions, Pervasive and Ubiquitous Computing, Public Wearable Displays, and Small Group Research. Social computing looks at the impact of technology on our social lives.

Pervasive computing examines systems that impact users lives outside their usual workplace environment. These systems support the user in mobile environments, across boundaries, and utilize the changing environment to provide context sensitive and timely information. Public wearable display technology is a major component of our research. We collected examples of systems employing similar approaches for a variety of purposes. Although our training and experience is primarily on human factors in computing and systems design, we present a section on face-to-face interactions from a sociological perspective. We also discuss the influence of small group research in the design of our user study and evaluations.

2.1. Social Computing

Social computing systems participate in everyday social interactions. The design of these systems must take into account the person operating the system. System designers often treat the operator of their systems as a part of the system itself, ignoring their analytical, social, and perceptive abilities. The operators are treated like automata, and expected to produce reasonable output at every cycle while responding to errors in a logical way.

We examined systems that attempt to treat their users as social beings. We looked at a class of systems that serve as mediators in human-to-human communication using the concept of social translucence. We examined research that points out the mobile nature of work and how technology can support informal interactions that occur away from the desktop. This research points out the benefits of this type of interaction. Finally we look at a design rationale that advocates support for activities in an unobtrusive and calm manner. This is important if technology is to be successful in social settings.

2.1.1. SOCIAL TRANSLUCENCE

In the digital world, our sense of privacy is being compromised. Websites are tracking our web browsing habits for the sake of providing us better service. They promise personalized advertising, targeted specifically for us based on our online behaviour. We are encouraged to sign up for various web-based services such as free email, greeting cards, matchmaking sites, and online forums. In return, we provide information such as our date of birth, home address, email address, or our mothers' maiden name. Although this compromises our sense of privacy, some of this information can be useful in providing context-based information to enhance our information systems.

Socially translucent systems are systems that make use of personalized contextual information without infringing on the privacy that is a part of our physical world. Erickson and Kellogg [13] describe translucent systems as being the grey area between transparent systems, where all information is public and opaque systems where all information is private. These systems follow three simple principles: visibility, awareness, and accountability to support the creation of socially aware systems. A good analogy that explains socially translucent systems is a windowed door that opens on both sides. A windowless door will hit someone on the other side as it is opened. The addition of a window provides the three principles of visibility, awareness, and accountability. The window allows users of the door to see if there is someone on the other side. Awareness of that person prompts them to open the door slowly to avoid injury to that person. Having the accountability by being visible to the person on the other side, dissuades users from purposely opening the door into the other person. The window solves problems in an elegant way without creating more problems.

Erickson and Kellogg [13] point out that in the digital world, users are socially blind. They often have no awareness of the person they are communicating with. It is by no accident that the most common introduction in online chats is "a/s/l", meaning, "What's your age? What's your sex? What's your location?" This is a means of obtaining contextual information we would normally have obtained through observation in a face-to-face situation.

Information that is presented through someone's dress and demeanour shapes the way we react to them. We have become so well adapted to conducting ourselves in this way that it has become an automatic process. Socially blind systems do not have access to this type of information. While computing devices begin to assist us in our social interactions, system designers should be more sensitive to the problem of socially blind systems. They should be aware of how distributed communication differs from face-to-face communication and how by augmenting the interaction with social contextual information, they can minimize this disparity.

Another way technology can help is by enhancing the effects of contextual information in existing face-to-face interactions. Erickson and Kellogg point out that socially translucent systems can be used to facilitate social interactions (by connecting like-minded individuals), visualize and restructure the interaction (through the use of an awareness tool such as the Babble system), as well as for organizing the interaction.

2.1.2. INFORMAL COMMUNICATIONS

Opportunistic encounters are a welcome part of life. There are undoubtedly many romantic stories regarding relationships that grew out of chance encounters. People are often excited about a chance encounter with someone they had not met before, or someone they have not seen in a long time. Sometimes an unplanned encounter with a colleague may provide an unexpected benefit through the sharing of ideas and experiences. These serendipitous exchanges belong to a class of encounters called informal communications. The defining feature, as pointed out by Bergqvist et. al. [5] that differentiates informal communications from planned meetings and mobile meetings is that informal communications have no agenda.

An example of informal communication in the workplace is the water cooler chat. When two or more employees enter a communal area such as the water cooler or kitchen, they may begin to converse informally about the weather, a popular television program or other employees. These exchanges sometimes evolve into serendipitous interactions as the topic of conversation moves away from simple small talk.

The notion of informal communication was the focus of a paper by Whittaker et. al. [37]. They classified informal communications as being brief, unplanned, and frequent. They also stressed the importance of physical proximity to informal interactions as well as the effect of social and cultural knowledge on informal interactions. Previous systems that were designed to encourage informal communications between distributed workgroups failed because they arbitrarily connected two users through a two-way video feed. The failure was attributed to a fundamental issue in human interaction, which is the need for some common ground or agenda to fuel the interaction. They raised the question of how shared knowledge affects the initiation and management of conversational context.

A theme throughout their observations was the importance of contextual information. This information is derived from the behaviour of the participants and their awareness of other participants including subjective interpretations of body movements, body language as well as being able to eavesdrop on other conversations. We may not be aware that we are using these subtle hints to guide our behaviour during face-to-face interaction. These hints are absent from distributed interactions. Whittaker et. al. supports the assumption that face-to-face interactions are much richer in informational content than computer-mediated communications and that contextual information, or shared knowledge could be used as a catalyst for establishing a dialogue between individuals.

2.1.3. CALM COMPUTING

Calm computing [36] began as an important design rationale in the era of ubiquitous computing [35]. It is the idea that as computers become more pervasive, they must also be less intrusive. We are seeing more computers in the world today. The growth and pervasiveness of computers is shocking. In 1943, IBM's Thomas J. Watson said, "there is a world market for perhaps five computers." Today the average modern home contains dozens of microprocessors embedded into appliances, telecommunication devices and personal computing devices. A typical North American living room reveals microprocessors in remote controls, in the video cassette player, the compact disc player, and the burglar alarm system. There has been a gradual transition from the early days of computing where multiple users shared a single mainframe computer, into a period where each person has a single personal computing device and now to the era of ubiquitous computing where each of us share many computing devices. While the microprocessors in the average living room clearly outnumber its occupants, the lack of collaboration and communication between the microprocessors prevents them from achieving the true promise of ubiquitous computing.

We are working towards the goal of ubiquitous computing by exploring new applications that take advantage of pervasive computers. These applications will be involved in our social interactions, work-related interactions, and leisure-time activities. Ubiquitous computing will change our relationship with computers. It may not even be possible to turn them off or to force them out of our everyday lives. Our generation and others before it can still remember living without computers but future generations cannot escape the dependency to the ubiquitous computer. In the past, similar technologies have affected people in this way. Mark Weiser, the father of ubiquitous computing [35], cites electricity and writing as two similar examples.

While ubiquitous computing can improve our lives immensely, there are warnings that people must be aware of. Weiser recognized the possibility for harm and has proposed calm computing as a method for designing technologies that can be more easily adapted into our lives [36]. Weiser identified the technologies that are "enemies" of calmness, including pagers, cellular phones, the World Wide Web, television, email, and radio.

Calm computing advocates designs that are functional in a subtle and less intrusive way. Calm computing is based on people's awareness of their periphery. While our consciousness can focus on only a handful of things at one time, our peripheral awareness can monitor more things, albeit at a lower granularity. What we notice in our periphery is the unusual. Once discovered, it can be brought out of the periphery to the centre and dealt with. Calm computing advocates the design of technologies that sit quietly in the background until attention is required. Calm computing then motivates the user to act, without impacting other users who are not interested in it.

We support the notion of Calm systems and we have designed our system along the same principles. Our system functions in the periphery and allows the user to decide when to bring the system into focus.

2.2. Face-to-face interactions

In this section we look at research outside the area of computer science to answer some of the questions about the dynamics of face-to-face interactions and the role of fashion. This is not a comprehensive examination but rather an interpretation of some of the literature in this area.

Outside the field of Computer Science, there has been a significant amount of work related to the study and observation of human behaviour during face-to-face encounters. Most of this literature can be found in the field of Sociology. The most recognized figure in the Sociology of face-to-face interactions is Erving Goffman. Goffman spent a lot of time observing people's behaviour in face-to-face social situations and wrote several books based on this. Some of his most noted works include '*The Presentation of Self in Everyday Life*' (1956), '*Behaviour in Public Places*' (1963), and '*Frame Analysis*' (1974). In '*Behaviour in Public Places*' [16], Goffman examined face-to-face interactions among *the unacquainted.* His writings provide a basic insight into the sociology of face-to-face interactions. This section presents face-to-face interactions from the sociological perspective by viewing Goffman's work as fundamental to the study of face-to-face interactions.

Goffman examines and identifies the basic components of a face-to-face interaction. He picks out certain ideas and concepts that are central to its study and uses this to create a language that allows him to explain human behaviour in these environments. He looks at how people interact with strangers and poses the question:

> *When does the individual have the right to initiate overtures to those with whom he is unacquainted?*

Goffman identified the following situations in which it may be appropriate to initiate an interaction:

Open persons. It is acceptable for people to *accost* others if the initiating party is deemed to have a *built-in licence* to do so. This applies to people who are always social, perhaps with an extroverted personality, for example a class joker or a social butterfly.

Intention to accost others. People who are known to *accost* others, as seen through past experiences can do so without causing *undue* surprise. For example, the police or nuns may start conversations with unacquainted individuals while conforming to social norms.

Responsibility. Certain jobs require interaction with unacquainted individuals. For example, store clerks, shopkeepers, and security guards have a responsibility to either serve their customers, or warn against illegal or undesirable activity.

The Alien self. Goffman recognized situations where the *inner self* is distinguished from the *presented self*. These situations include being drunk or wearing some sort of costume. An avatar[1] on the Internet could also be conceived as a presentation of the alien self.

Free needs. Certain services are provided to other people without much thought. For example, it is common for people, to ask a stranger for directions, the time or a light (for a cigarette).

Defence of honour. When involved in a situation where one's honour is at stake in front of strangers, an individual can address the strangers in order to defend his or her honour. Following a heated argument in a restaurant for example, a person may sometimes turn to their neighbour to utter something in defence of any attacks to his or her character. People also defend their honour by reassuring others of their own well being after a nasty fall.

Goffman recognised that in face-to-face interactions, verbal exchanges, represent only a portion of the bandwidth of communication. In these settings, people often notice and make assumptions based on a person's bodily appearance, personal acts, dress, bearing (position in life), movement, location, sound level, physical gestures, facial and bodily decorations, and an overall broad emotional expression (explained by facial expression and body language). While people are not always

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[1] An avatar is a virtual identity in a virtual space such as a chat room.

conscious of all these information channels, they will often notice anomalies in any of these aspects. This helps to explain why people adopt certain stereotypes and discriminate against them. It should be noted that while the information communicated in this way may be purposeful, the observer's interpretations are subjective and may not always offer the intended impression.

Goffman's work supports the idea that secondary communication channels are used when interacting with strangers. A lot of information can be interpreted from the context of the interaction, particularly from a person's clothes.

2.3. Pervasive and ubiquitous computing

As the market for personal mobile computing devices continues to grow, more research has been aimed at leveraging the mobility of these devices to add value to existing services as well as to create services and applications that make use of the pervasiveness and context sensitivity of these devices. Location and proximity awareness is one of the key features of the ubiquitous computing era that we are steadily approaching. This section discusses some of the past and ongoing research in the area of context sensitive and ubiquitous computing.

2.3.1. ACTIVE BADGES

One of the earliest and most well known work in ubiquitous computing is the work by Roy Want et. al. on Active Badges at the Olivetti research lab [32]. Active Badges are devices that contain hardware that act as a beacon, broadcasting a unique identifier at periodic intervals. Sensors placed strategically around a building pick up these transmissions and are able to determine the location of the sensors and map them to locations within a building. This data is fed to the receptionist or PBX phone system, which routes calls to a particular individual based on his or her location.

With only the user's identity as context information, Want el. al. created an interesting application. More advanced context sensitive applications could include more user-specific information. This creates a problem because systems want to use profile information while, users want to safeguard their personal information. Active badges opened the way for more systems to leverage context and mobility. It is considered a precursor to other systems discussed in this paper and represents an important first step.

2.3.2. INTER-PERSONAL AWARENESS DEVICES

Inter-Personal Awareness Devices (IPADs) are handheld or wearable devices that are designed to support awareness and collaboration between people in the physical vicinity of one another. There has been a lot of work promoting the use of technology for collaboration in distributed environments but it is also important to explore the use of technology in supporting co-located collaboration. Now that computers have become more mobile, they are able to assist us in domains from which they have been excluded from in the past. The goal of IPAD systems is to leverage the added contextual information gained from their mobility to provide usable services that promote collaboration. This section examines three IPAD systems. The Hummingbird system and the ProxyLady are both projects from the PLAY research group from the Viktoria Institute in Sweden while the Proem system is a project from the University of Oregon.

- HUMMINGBIRD

The Hummingbird system [29] takes the role of a contact facilitator, rather than a contact mediator as most technological devices such as cellular phones do. The Hummingbird relies on short-range radio frequency communications to communicate with other Hummingbirds. The Hummingbirds emit a hum when they detect another Hummingbird in their vicinity. Research into the use of Hummingbirds in different settings reveals the social nature of these devices. For example when Hummingbirds were given to ski instructors, they were used to find people to have lunch with [34]. Although some instructors used it for work related purposes such as organizing students for a bus trip, the bias was towards more social uses for example as a location awareness tool in the discotheque. Users of the Hummingbird commented on the calm nature of this device. They note that it "does not demand anything from you". The designers wanted to make the Hummingbirds as unobtrusive as possible and remove the perception of the Hummingbird as a surveillance device. Observations from the Hummingbird system show how computers can be used to support social activities, regardless of the initial intended purpose. The users of the Hummingbird system used their location-based devices for work to coordinate activities, but the system works equally well for coordinating social activities.

- PROXYLADY

A more work-related use of IPADs can be seen in the ProxyLady system. Here the goal is to support mobile meetings among coworkers. The ProxyLady system assists in mobile meetings by using information items such as emails and tasks (which are digital in nature) to establish face-to-face encounters. These information items identify meeting candidates. When a meeting candidate appears in the proximity of the Proxy Lady IPAD device, the Proxy Lady client software notifies the user. He or she can then decide to initiate a mobile meeting with the meeting candidate and can easily bring the information item to support the meeting. In a paper on mobile meetings, Bergvist et. al. noted that the use of technology in mobile meetings was minimal [5]. This was attributed to the characteristics of the tools associated with the technology or the design of the technology and not the aversion of users to technology. Bergqvist et. al. advocated a more group-oriented approach to groupware applications and cited the mobile nature of workplace interaction as a motivating factor. Since each worker has his own office, at least one worker has to leave his or her desk, in order to meet another co-worker. This means that except when workers share desk space, every meeting is a mobile meeting for at least one worker. This highlights the importance of supporting mobility in the workplace. However not all workplace encounters are entirely work related. As social beings, we tend to interject some social communication into even the most serious situations. Disregarding this aspect of face-to-face encounters may lead to a degeneration of social etiquette and practices.

- PROEM

According to Kortuem et. al. the term 'Proem' refers to a brief introduction. The goal of the first Proem system was to support awareness and informal communications between mobile users in a face-to-face environment through the exchange of profile information [20]. This system uses the concept of profile-based cooperation by facilitating the exchange of profile information between users in an ad hoc environment. Profile exchanges occur within an encounter and are governed by the following principles:

Owner control – The owner of the information controls what profile information to share and who to share it with.

Reader selection – The reader controls the dissemination the information. That is, they control when information is transferred. This helps to alleviate information overload by placing the control of incoming data to the reader.

Reciprocity – Owners should be able to restrict access to exclude those who are unwilling to share information about themselves.

The designers of Proem see profile-based cooperation assisting the functions of awareness tools, reminder systems, diary systems and matchmaking systems. All these functions rely on the use of profile information as context while providing context-based services. Kortuem et. al. also touched on the use of degrees of separation as a way of grouping users and enabling collaboration between users separated by one or more degrees. The Proem system is an important initial step in using technology to assist in allowing informal interactions to occur. However, limited availability to the system and the small user population hampered the evaluation of the system. It is important for such systems to be deployed on a larger scale or at least in a more controlled population to fully examine its effect.

2.3.3. NTN

The NTN system [24] is present in many bars and restaurants around North America. The NTN system allows people to compete with one another in a trivia game. Players earn points based on how quickly they answer a trivia question. Television screens around the establishment display questions and possible answers for people to select. Players input their answers using a wireless terminal.

The NTN system uses technology in a social setting. The format of the game encourages interaction between friends as well as between other people who use the context of the questions to create opportunities for interactions. For example, having the wireless terminal on one's table, advertises participation in the game. While the players' names on the scoreboard might not clearly identify them directly, this information can often be deduced indirectly through certain gestures such as changing one's answer several times as clues are given, or the opposite action of not changing the answer, resulting in a perfect score[2]. Cheering and expressions of disappointment also help to map patrons to the names on the public display.

By observing a player's score during the course of the game, one can build an impression of that person. For example, if a player answers perfectly on many philosophically related questions, one can assume that the player is knowledgeable in this area and would be interested in discussing other philosophical topics.

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[2] The earlier an answer is provided, the more points are awarded. Players who change their answers close to the end will have lower scores while players who picked the correct answer from the beginning will have a higher and often perfect score.

The context achieved through answering trivia questions provides a means for creating new interactions however, we believe that this can be improved with a more intimate set of questions without sacrificing the user's comfort and privacy. NTN encouraged the use of large public displays and the successful use of wireless terminals for their system also prompted us to adopt the same technologies. However the addition of a wearable display unit to enhance the secondary communication channel differentiates our system from NTN.

2.4. Public Wearable Displays

This section surveys a class of applications that employ a display carried or worn by the user. This display is designed to be viewed by other people. We call this class of display public wearable displays. Systems using public wearable displays are only successful in environments where there are people to view the displays. Public wearable displays are not effective in a personal or private space. As such, these systems are typically social in nature and influence human-to-human interaction. In this section we discuss three such applications of public wearable displays, namely Meme Tags, Wear Boys and Hot Badges.

2.4.1. MEME TAGS

An important piece of research that contributed to our use of digital fashion is the work of Rick Borovoy at the MIT Media Lab. His work on Meme Tags [6] motivated our interest in the use of technology to initiate informal social interactions. Meme Tags are small computers that are able to communicate with other tags by exchanging pieces of data called memes. Memes are succinct ideas or opinions that are created and subscribed to by the Meme Tag wearers. Users can create memes and share them with other users. Each tag stores only seven memes. This forces the user to select their memes very carefully. During an exchange between two tags, each Meme tag displays the meme to exchange with the other user. The recipient views this meme on the senders tag. If the recipient chooses to accept the meme, he or she clicks a button and meme is transferred. Users could control which meme to send. Kiosks download meme interaction data and allow users to create their own memes. Large public displays called community mirrors are used to visualize the dynamics of the meme interaction. The purpose of the mirrors is to create an understanding of the local community.

Meme Tags targeted a conference setting where interactions were work related. The memes themselves were also community specific (targeted at a computing science community). While the meme can represent user's opinions and ideas, the meme does so at a lower granularity and does not make an accurate representation of the user, as much as it does, the community. The meme tags only work in a point-to-point fashion, where one individual engages another through meme exchanges. This is not quite the same as fashion where the clothes we wear are visible to everyone in the vicinity, at the same time. The meme tag study was originally concerned with the propagation of ideas through the community. However the technology also assisted in supporting human-to-human interactions, which was a welcomed side effect. Our work extends the idea of technology as fashion proposed by Borovoy by explicitly supporting human-to-human interactions. Digital fashion increases the bandwidth of shared knowledge information communicated by public wearable displays by making the information more concrete and representative, more dynamic and more available.

2.4.2. WEARBOY

The Play research group from the Viktoria Institute in Sweden has experimented with wearable computers that employ a public display rather than a private display. They modified a popular handheld video game device (Nintendo Gameboy) and made it wearable in the form of a badge [15][21]. They choose this form factor after exploring conventional public wearable displays such as jewellery and clothing. Their choice of a brooch/badge was made to draw attention to the wearer's face so as to promote a face-to-face interaction by encouraging eye contact. They explored three different applications for the public display:

- The wearer as the information provider
- The viewer as the information provider
- The environment as the information provider

The Wearboy system was used for two different projects, namely the ActiveJewel and the BubbleBadge. The ActiveJewel displayed abstract computer generated patterns that changed over time, while the BubbleBadge displayed news of local events or Star Trek quotations. Observations from these projects showed that under certain conditions, users could see themselves wanting to wear these devices. Users preferred to look at shorter messages on the displays, as they were less distracting. While these displays were helpful in the formative stages of the interaction, they continued to provide information as people interacted. This can be a way of reviving diminishing conversations. The Wearboy system supports the use of public wearable displays for augmenting face-to-face interactions by providing supplementary information without being intrusive. However Wearboy systems were not used to display shared knowledge information and were not deployed in any formal user study.

2.4.3. HOT BADGES

In 1996 the Phillips design group published eight issues of a web magazine entitled Vision of the Future. Each issue focussed on the design of new technologies for specific domains including technology for children, the home and for personal use. The designs represented a futurist's vision of how technology can change people's lives. One of the designs, called Hot Badges, was for simple short-range communicators that helped to facilitate initial contact between people with similar interests [27]. The badges store and transmit information about the wearer's interest and receive similar information from badges worn by other people. When two people wearing hot badges with overlapping interests meet, their badges signal each other by blinking. The designers felt this would make it easier to "break the ice" and start conversations.

This type of interaction was copied by the Lovegety in 1998 [18]. The Lovegety is a Japanese toy aimed at matching singles. Lovegetys operate by communicating with other Lovegetys in the surrounding area. There are male (blue) and female (pink) Lovegettys. Users select one of three modes based on the activity they have in mind (talk, karaoke, get2[3]). If users with the same mode and opposite sex are in the same area, the "Get" light flashes and the device beeps. If there are users with different modes, the "Find" light flashes and a different sound is played. The flashing lights enable Lovegety users to find each other. Interactions are enabled on the basis of common ground. Lovegety users can be brought together by their interest in Karaoke (one of the modes) or simply by the possession of the Lovegety device.

Hot badges were never brought into production, although similar match making devices have been marketed. Our intention is not to create a

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[3] The terms Karaoke, Talk and Get2 are taken verbatim from the descriptions of the system [18]. Get2 refers to a mode for finding love interests.

matchmaking device that decides whether two people are compatible. Instead digital fashion hopes to bring people together regardless of their interests and allow individuals to decide which interactions are meaningful. We are interested in facilitating all types of interactions, not just romantic ones.

2.4.4. BIOMETRIC WEARABLE DISPLAYS

There are several wearable displays systems which display one's emotions through the measurement of biometric information similar to the concept of a mood ring. These systems include the Galvactivator [26], a glove where the galvanic skin response controls the intensity of an LED embedded into the glove. A project shown at the ISWC 2002 Gadget Show called Heart of My Sleeve, [28] displayed an animation of a beating heart on the screen or a handheld computer strapped to the arm of the wearer. The animation was controlled by a pulse sensor on the person's body. A similar system called the 2Hearts system [23] maps heart rate to musical parameters in order to allow two users to control music via social interaction. Here the display is auditory and ambient to the environment.

Biometric wearable displays allow people to express their emotions more easily and openly using a secondary communication channel. Picard and Scheirer [26] describe how a Galvactivator user had an argument with her mother which raised the intensity of the LED on the Galactivator.

The indicator caused both parties to sit down and talk about what caused the LED to intensify and led them to resolve their argument.

These projects reflect the importance of secondary communication channels in communicating information that is not easily shared verbally. However the limited range of the information conveyed as well as the arbitrary mapping of the biometric data limit their use in social situations.

2.5. Methodology Issues For Small Group Research

The study of technology in social settings requires participants to be observed in social situations with other participants. These situations range from unplanned, ad hoc exchanges to planned parties and social events. These social situations always involve at least two participants but there is no upper limit on the number of participants involved. The study of technology in social settings presents a number of challenges for researchers and has been mostly neglected for a variety of reasons.

One of the challenges for conducting research in social situations is that new systems need time to become established and be prevalent in everyday use. This is important because these systems need to be studied in the environment for which they will be used. Testing these systems in an artificial setting can yield incomplete or incorrect results. However running studies within their appropriate context requires that the systems be deployed and used. This yields the chicken and egg problem and raises the question of whether systems should be deployed before they have been evaluated. We are exploring our technology in a laboratory setting while trying to familiarize our participants to the technology as much as possible.

Another challenge is the difficulty of studying interactions within small groups. To guide us in our examination of interactions using technology within small groups we employ the research from the field of psychology and small group research. We focus on the work of psychologists Arrow, McGrath, and Berdahl in their book titled *Small Groups as Complex Systems* [3]. Their work makes the case for the treatment of small groups as open, complex, adaptive, and dynamical systems. Small groups create an interesting but complex dynamic system that is difficult to evaluate using traditional methods used to study single user or simple collaborative systems. In small group research the focus is not only on the interaction between the user and the system, but also on the interaction between users.

Small groups are open systems that are dependent on external factors such as context and history. These factors significantly affect the group and cannot be ignored. Groups adapt to changing context. This context represents an important part of the group relation with its environment. Traditional research practices try to strip away the context to produce results that can be generalized across different groups. Groups also evolve and change over time to such an extent that the same group at different points in time must be treated as an entirely different group. This dynamic quality makes context an important factor in the study of small groups and complicates efforts to study small group interaction using quantitative methods.

Small group studies also suffer from problems in longitudinal studies due to the temporary absence of members and member loss due to external factors. This can impact the study substantially. In small group research, the group is studied as a whole and the results hinge on the success of the group. Small group research is more prone to problems that may affect the collection of quantitative data. In user studies involving single users, tainted results can be discarded and the study repeated with a new participant. However repeating studies involving small groups is much more difficult.

Another issue raised by the Arrow et. al. is that quantitative methods work by taking a snapshot of the group at a particular point. This is not a good measure of the group's behaviour over time. A better measure is the group's trajectory over time. Qualitative measures can be used infer the patterns for the rules of interaction for the group.

From the description of small groups and the complexity inherent within these groups, we realize the problem of conducting research using traditional quantitative methods. Arrow et. al. proposes using a combination of quantitative and qualitative methodologies in the search for patterns of group behaviour. This type of evaluation provides meaningful results that are more easily reproduced with different groups along different contexts.

3. Designing components for Digital Fashion

Designing technology where no similar device existed before is difficult and challenging. Before this work, the concept of digital fashion existed as a collection of promising ideas. While the Digital Fashion project extends ideas from other projects including Meme Tags, Bubble Badges, and Hot Badges, it does not and cannot rely on the existing platforms that these projects were developed on. Both Bubble Badges and Meme Tags served their own purposes and raised interesting questions about the use of technology, particularly public wearable displays in social situations but these questions remained unanswered.

To address these questions the Digital Fashion project needed new hardware and software systems to be built in order to study the use of public wearable displays in social settings effectively. This involved a large body of work in designing and implementing both hardware and software components for the specific needs of the project. In order to appreciate the component systems that make up the overall system, they are described in the following sections, starting with the overall design requirements. This is followed by a discussion of the system setup, design methodology, hardware and software components, the testing and evaluation phase as well as problems and issues discovered.

3.1. Design requirements

The purpose of the Digital Fashion project was to build a public wearable display that makes use of a secondary communication channel for sharing information with others and facilitating the initiation and interactions among people who do not know each other. The wearable display communicates non-sensitive profile information (shared knowledge) visually with other people. This visual channel allows communication to occur in a non-obtrusive and specialized way that does not require introductions or proximity.

The wearer decides what information he or she wishes to share by participating in a series of polls. The wearer participates in the poll by selecting an answer from a list of possible answers. Answers to poll questions are mapped to unique representations on the wearable display. The number of available answers corresponds to the number of distinguishable representations made by the wearable display. The poll answers will typically be collected off-line through a web-based polling system prior to social events. The choice of poll questions is managed by a centralized system that maintains a poll question queue. The question at the front of the queue becomes the active question for a period of time, after which it is removed. Users who have previously input their answer to the active question using the web-based polling system have their wearable display change representations to reflect the chosen answer. This is an important aspect of the system because it reduces the amount of interaction required from the user at the social event.

Only one question is active at one time. If a user did not participate in the poll (meaning no answer was submitted), their wearable display will not display anything. The user can add questions to the back of the poll question queue. When the queue is almost empty, new questions are added randomly by the centralized system.

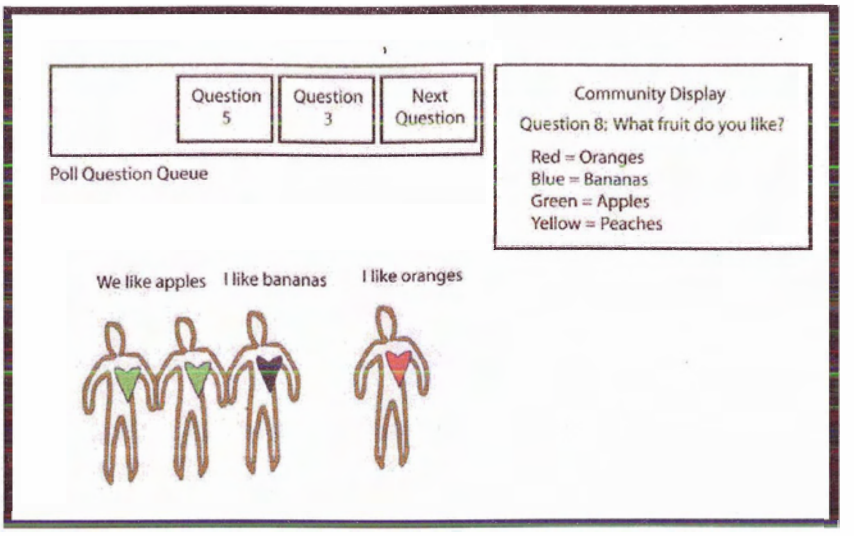

Figure 3-1 Digital Fashion Abstract Representation.
Questions are added to the back of the Poll Question Queue. Questions are removed from the queue and displayed on the Community Display. A device on worn by the user (the heart in the figure) provides a mapping to the wearer's answer.

Figure 3-1 illustrates the concept of how the system works. This abstract representation will become clearer as more concrete details are revealed. The number of components that comprise the entire system make describing the system as a whole problematic.

The system is supported by a variety of components including a website for pre-event preparation, handheld devices for mobile operation, computer kiosks for accessing the website during the event, and a centralized server to manage the question queue. These components work together while employing different technologies to perform their specific tasks.

Since the technology for this system is new and constantly improving, the design was made very modular to accommodate changes when it was beneficial to do so. Modules encapsulate technology within abstract interfaces so that new technologies can be swapped in with minimal changes to the rest of the system.

3.2. System setup

Figure 3-2 shows all the components of the systems. Users have a handheld computer (Cybiko Client) and a wearable display powered by the light controller. The handheld computer communicates with the wearable display as well as with the central server using the Cybiko Server as a gateway. The handheld computer functions as a thin client and retrieves data about the user from the central server. The central server stores user data as well as the poll question queue in the database. This means that a user can pick up any device and log into the system. This is an important factor if the system is used in bars and clubs because users do not need to bring their own device to the environment. They are able to pick any device and make it theirs. However storing the data in a central server creates problems in terms of security and privacy. Users may also be reluctant to use wearable devices that have been previously worn by other people.

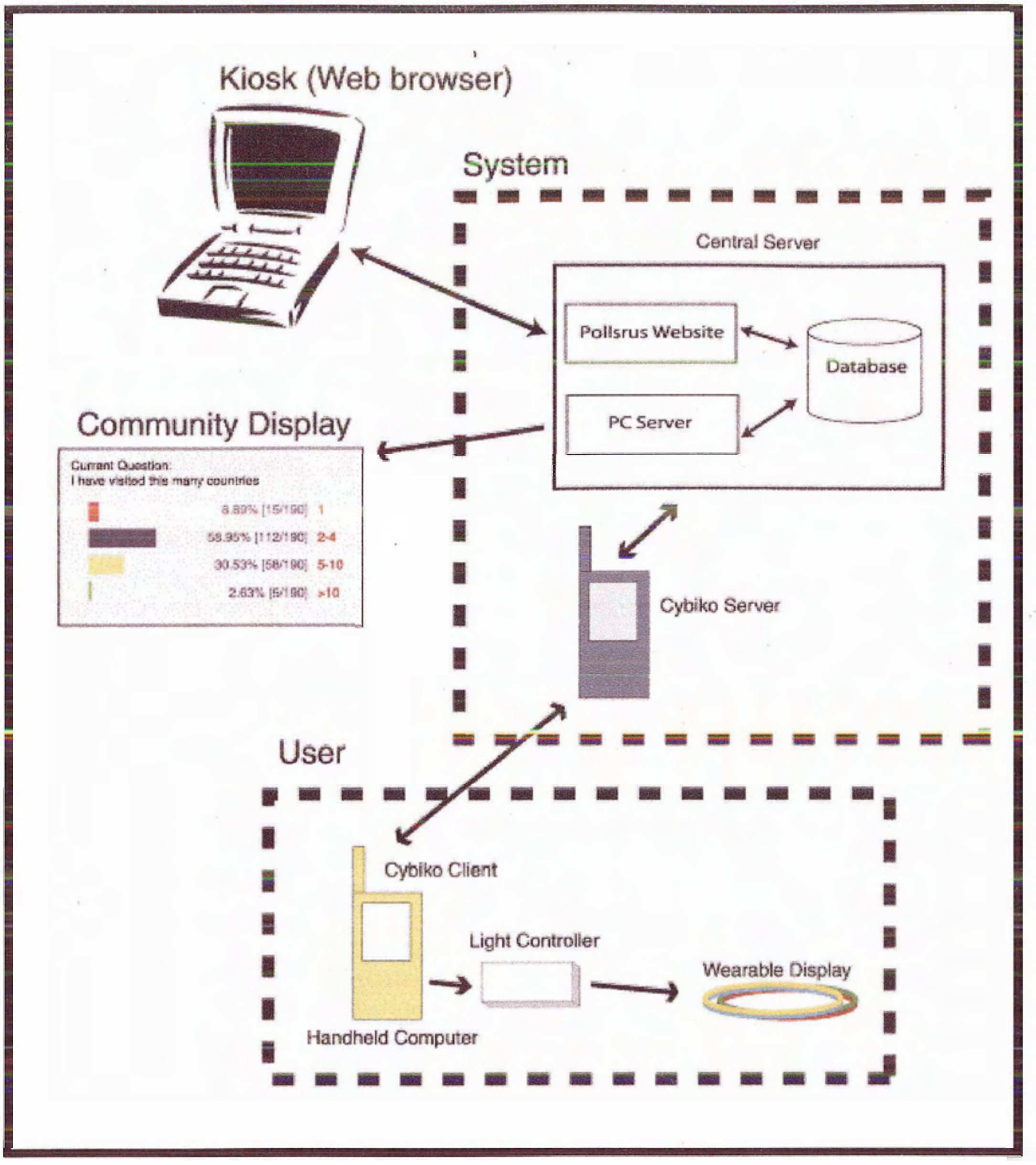

Figure 3-2 Components of the system.
Arrows denote data communications.

A web system supports the handheld computers by offloading more input intensive operations to the kiosk system. This setup was preferred because of the limited functionality, small footprint and cumbersome input methods for handheld devices. Certain operations such as question creation are much easier on kiosks. However as mobile technologies advance, more of this functionality could be provided effectively on the handheld system.

At an event where the system is used, the poll question queue is populated with an initial set of questions. The minimum number of questions in the queue is two. A question cannot appear in the queue more than once. This avoids situations where a question is added multiple times so as to monopolize the queue. A more forgiving technique allowing multiple instances of the same question if separated by an appropriate number of questions may be more desirable.

As users login to the system using their handheld computers, the active poll question is downloaded from the server to their handheld, along with the users' current answer. If users have not answered the question or wish to change their answer, they may select a new answer using the handheld. The current answer for each user is displayed on their wearable display.

Each answer to the question is mapped to a unique representation. We chose four unique colours (red, blue, yellow, and green). These colours were chosen because they were the most distinguishable colours that could be represented by our display system. The colours are mapped in the following way:

Answer 1	Red
Answer 2	Blue
Answer 3	Yellow
Answer 4	Green

Table 3-1 Answer mapping

For example, if a user chooses Answer 1, their wearable display presents a red colour until a new poll question becomes active. This process repeats for each new poll question that becomes active.

The system maintains a list of users who have logged in as well as a list of questions in the question queue. New poll questions can be added to the question queue using the kiosks or the handheld computers. The system also drives a Community Display, which displays statistics about how users who have logged in to the system answered the current active poll questions.

3.2.1. COMMUNICATION/COMPUTING PLATFORM

The underlying system was built to allow modularity of both communication protocol and computing platform. This allows different devices and communication protocols to be used interchangeably. The computing platform should be accessible to a large number of people. While there are many people who own Palm devices and Pocket PCs, the most ubiquitous device that fits this requirement is the Wireless Access Protocol (WAP) enabled cellular phone [33]. WAP allows cellular phones to access web services using a lightweight protocol similar to the Hypertext Transfer Protocol (HTTP). However cellular phones are expensive and do not have a way to communicate with the wearable display. This may change as more Bluetooth[4] enabled phones emerge on the market.

Palm and Pocket PC based devices have adapters for both Bluetooth and IEEE 802.11 (Wireless Ethernet Protocol). They also have connectors for either serial port or Universal Serial Bus (USB) ports that allows them to connect to a computer. This makes them ideal candidates. Unfortunately they were not a cost effective solution for this research project.

The chosen platform was a handheld device called the Cybiko. This device is marketed as a wireless entertainment unit for teenagers. This device is discussed in detail in section 3.5.3. We were able to obtain a generous equipment loan from Cybiko Inc. of 50 Cybiko Classic handheld computers for the purpose of our research.

3.2.2. DISPLAY TECHNOLOGY CHOICES

Although a display is assumed to be visual this is not necessarily the case. Non-visual communication channels were considered including using audio, tactile, and scent. However the visual channel affords

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[4] Bluetooth is a wire replacement technology using short-range radio waves.

certain advantages over the other channels. The visual channel is directional so the source of the communication can be determined easily. It is also less obtrusive and can be more easily filtered and ignored. Visual displays can be recognized at short and even medium distances except when occluded. For these reasons, we chose a visual display.

A survey of display technologies was conducted and yielded several choices. Passive displays such as E-Ink electronic paper displays require no power to maintain the display and only a minimal amount of power to change the display. They provide very high contrast and are flexible so that they can be easily fashioned into clothing accessories. However at this time, the technology is still in developmental phases and is not ready for use off-the-shelf.

Light emitting diodes (LEDs) are available in many colours. ColorKinetics [8] have been able to combine these colours to produce an even wider array of colours in their CK Sauce products. One of these products is a wand that is worn around the neck and can be programmed to change to different colours. LEDs do not consume a lot of power and last for a long time. However they are only available as bulbs and are less flexible as a wearable component compared to other alternatives. They are also not very attractive as a wearable light source because they are often used with most electronic products. We wanted a light source that did not immediately convey a sense of using technology because of its association with existing electronics.

Electroluminescent wire (EL-Wire) consists of a phosphor-coated wire surrounded by a thin strand of wire wrapped around the phosphor. When an alternating current (AC) is applied between the two wires, the phosphor coating glows in a bluish white colour. A coloured sheath alters the basic bluish white colour of the wire to almost any desired colour. The colour is uniform and does not dissipate heat. This technology is commonly found in LCD backlights, and flat nightlights. They consume very little power and last for long periods of time. The wire can be cut to any desired length and can extend for many feet. The wire is flexible and can be easily fashioned into bracelets, necklaces, and armbands. EL-wire was selected as the display technology for the Digital Fashion project because it provided a form factor that could most easily be integrated into peoples' clothing.

3.3. Design methodology

To guide our design we relied on social computing concepts such as Calm Computing and Social Translucence discussed in the previous chapter. We based our design on these principles in an attempt to create a system that would not interfere with existing social norms. We wanted a system that would not hinder existing interactions but instead add to the interaction to make it more meaningful. Based on Calm computing concepts, we allowed the system to reside in the periphery but let it be easily brought into focus when required. We tried to ensure that users remained in control of their information and were empowered with choices throughout the use of the system.

Our design methodology followed an iterative process involving three main steps that were repeated several times. Our three-step process involved:

Design and implementation – Requirements were defined and then implemented. We followed software engineering and interface design techniques throughout the process.

Evaluation and testing – We tested and evaluated our system in order to discover flaws in either the design or implementation. Modularizing components simplified the design process and resulted in more robust components but also increased the number of tests that were required to ensure that these components would work together in the finished system.

Research and problem solving – When flaws were discovered, they needed to be addressed. If the problem was non-trivial, further research or creative problem solving techniques were used to resolve the problem. This occurred throughout the development of this system. We refined our design several times after problems were detected in our system.

3.4. Hardware Components

This section discusses the hardware components driving the wearable display, which we call the Lifeware system. It is composed of the EL-wires and the light controller.

3.4.1. EL-WIRE LIGHTS

The EL-wires are driven by a low alternating current at moderately high voltages (90 – 300 Volts). An inverter is required to create these voltages from a battery. The inverter converts direct current (DC) from a battery to alternating current (AC), similar to the electricity one expects to find from a household power point.

Hooking up the EL-wire to conventional wire was difficult because of the fragile outer wire. This thin wire was prone to breakage, which caused the wire to become disconnected and remain unlit. In addition, EL-wires that have been twisted and mishandled tend to lose their luminescence in certain areas of the wire. While the characteristics of the EL-wires were appropriate for our prototype system, issues of robustness for larger scale systems are still an issue.

3.4.2. LIGHT CONTROLLER

We used an existing circuit [19] for handling serial port data using the PIC Microcontroller along with the program code to drive the circuit. Circuit designs from other applications [30][31] were also adapted to construct our light controller. Figure 3-3 (a) shows the circuit diagram.

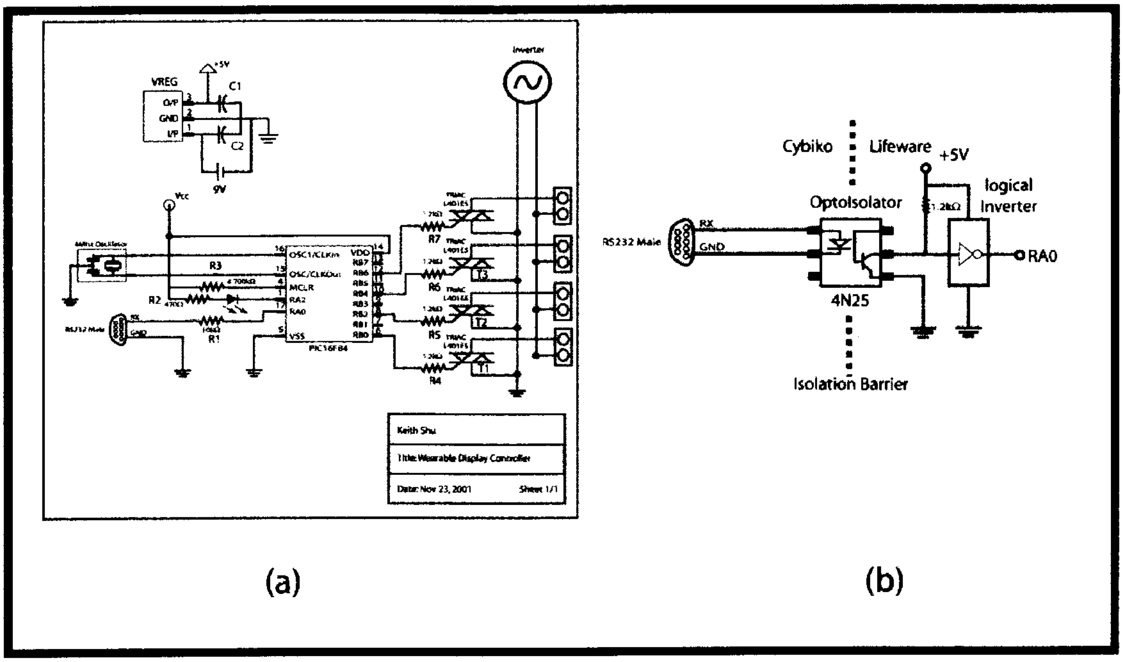

Figure 3-3 Circuit Diagram
The optoisolator circuit (b) replaces the 10kΩ resistor connected to the serial port in (a).

The circuit consists of a microprocessor, an oscillator, voltage regulator, a bank of triacs, and an inverter. An optoisolator circuit was added after complications were discovered in the original circuit. This is shown in Figure 3-3 (b). The oscillator and voltage regulator are common standard circuits and do not differ from other similar circuit designs. A byte sent via an RS232 connection determines which combination of lights to illuminate. Details of this circuit are presented in Appendix F.

Once a working prototype was made, the circuit was sent for printed circuit board (PCB) fabrication. PCB production was outsourced to a local PCB fabrication facility [25]. Automated PCB fabrication requires Gerber files that tell the machinery how to fabricate the boards and machine them to specification. These Gerber files were created using a freeware program called Eagle Layout Editor [7].

The light controller and the lights were integrated to enable us to control the EL-wire using the serial port of the Cybiko device. The controller was fitted into a plastic enclosure with holes drilled for wires, cables and power switches (Figure 3-4).

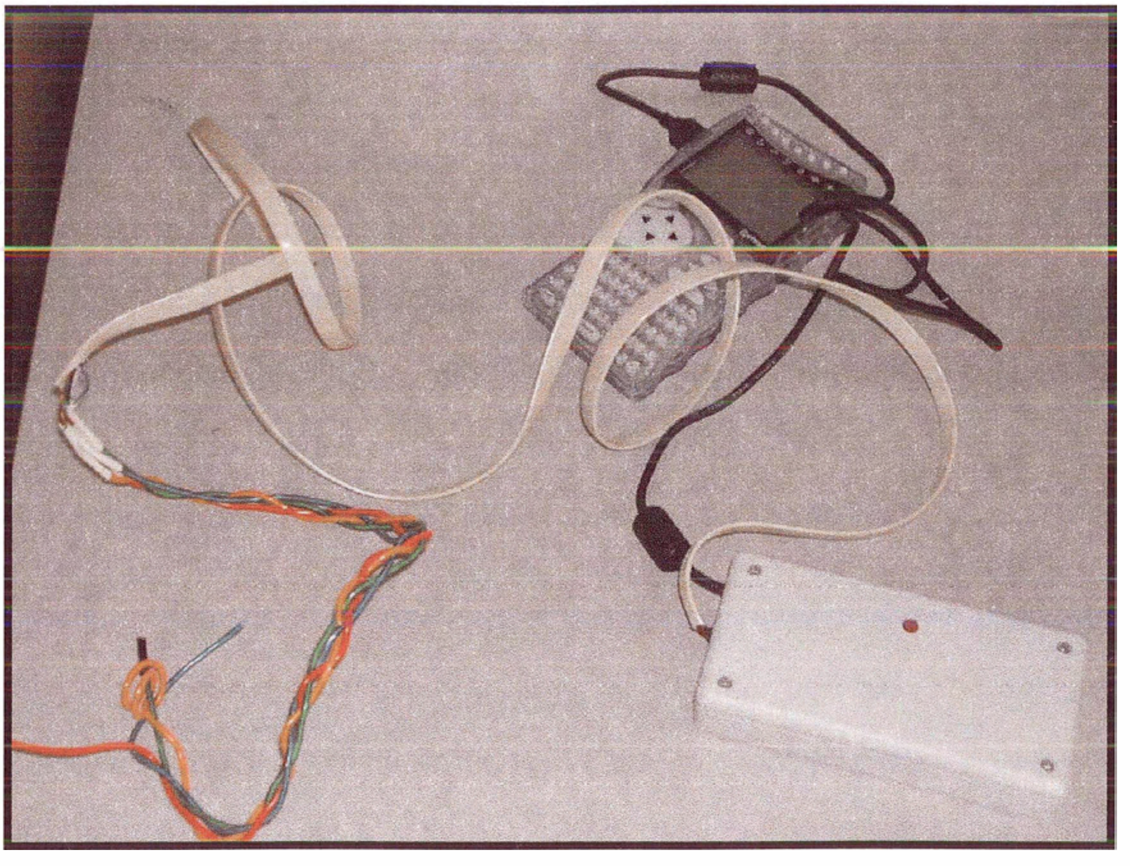

Figure 3-4 Hardware system
The Cybiko connects to the light controller (white box). The light controller is connected to the EL wire via the white cable. The EL wire is braided and is approximately 1 foot in length.

To communicate between the EL light and the wearable display we connected the light controller to the display using eight-conductor telephone wire. These wires could handle the low currents of the AC lines and had enough conductors to connect each of the four lights to their own two lines.

The Lifeware system had to be electrically isolated from the Cybiko in order to avoid electrical interference. Since the Cybiko is connected to the Lifeware system through a single serial port line, we decided to isolate this line using an optoisolator. An ordinary bicycle pack[5] was used to allow users to carry the Lifeware system.

3.5. Software Components

The software components consisted of an extensive collection of code running on different platforms all working together to create a singular system, which we call the Pollsrus system. The name Pollsrus originated from a website created for the online poll system. The name was derived from the abbreviation of the phrase “Polls are us”.

There are four main components of the Pollsrus system shown in Figure 3-5. The *Pollsrus database* is utilized by all other systems. The *Pollsrus website* provides a remote interface to the database and allows users to input their data from a remote location using a conventional computer system. The *handheld component* includes the client and server software

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[5] Pack worn around the waist, also referred to as a fanny pack.

written for the Cybiko platform. The Cybiko client serves as the primary interface between the polling system and the wearable devices while the Cybiko server acts as the gateway for all clients to the system. The *PC Server* component is at the heart of the operation. It provides some logic to the database data and interfaces to the handheld component. Each component can be separated and served by an independent computer. This improves the scalability of the system. The following sections discuss each of the components in detail.

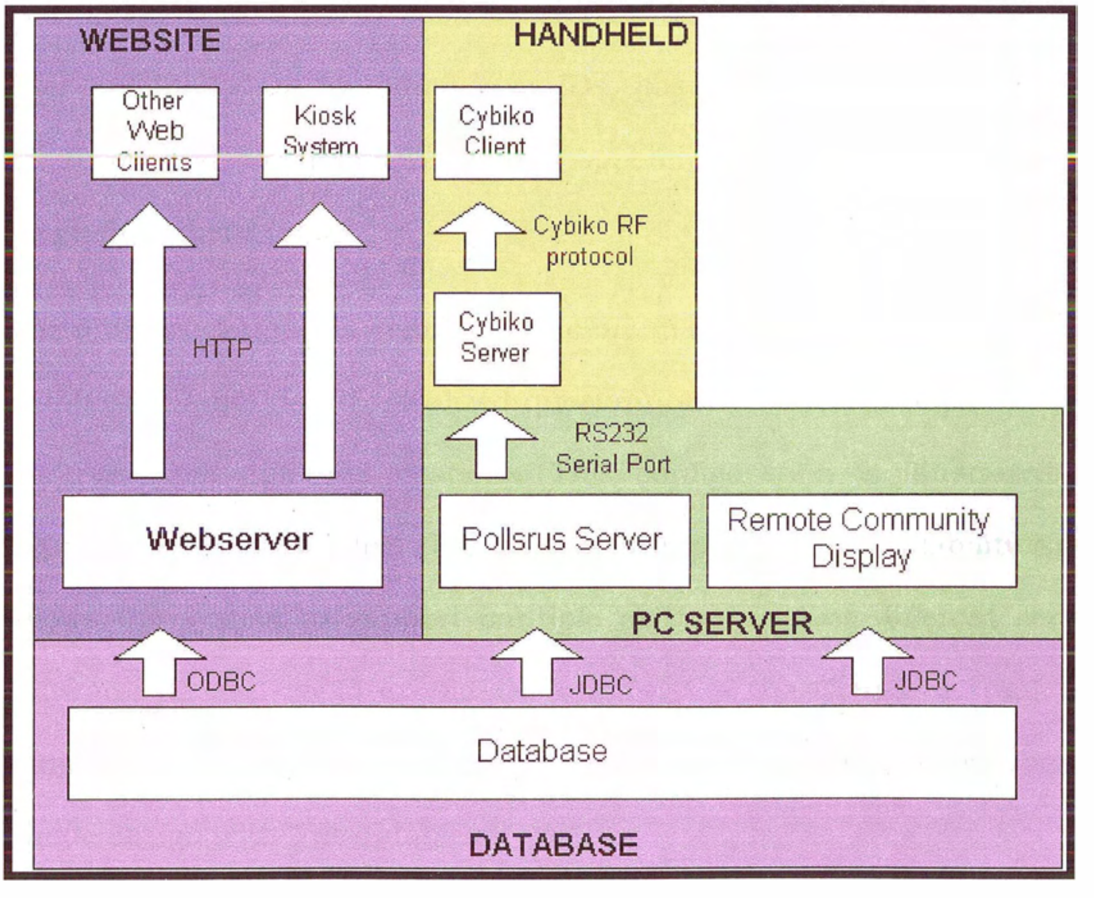


Figure 3-5 Block Diagram of System Components
The components of the system are grouped into the Database, Website, Handheld, and PC Server subsystems.

3.5.1. THE POLLSRUS DATABASE

We used a common database format that could be easily ported to more enterprise database systems. The database was configured as an ODBC (Open Database Connectivity) data source and integrated with our web application server.

The Pollsrus database consists of six simple tables. Of these six tables, two tables contain dynamic data including user activity and the current poll question queue. The user activity table stores the timestamp of the last action performed by each user. The remaining four tables contain user and poll data including user IDs, passwords, user answers, poll questions and poll question choices. Appendix A contains a relationship diagram of these tables.

The database supports centralized queue management. This means the database maintains a centralized question queue when multiple servers are run from different locations. This configuration is illustrated in Figure 3-6 below. We feel this feature is important for scalability as it allows the system to support multiple platforms using different server software, as well as to extend the coverage of the Cybiko beyond the range of a single Cybiko server. It is also possible to use a distributed queue design with this database.

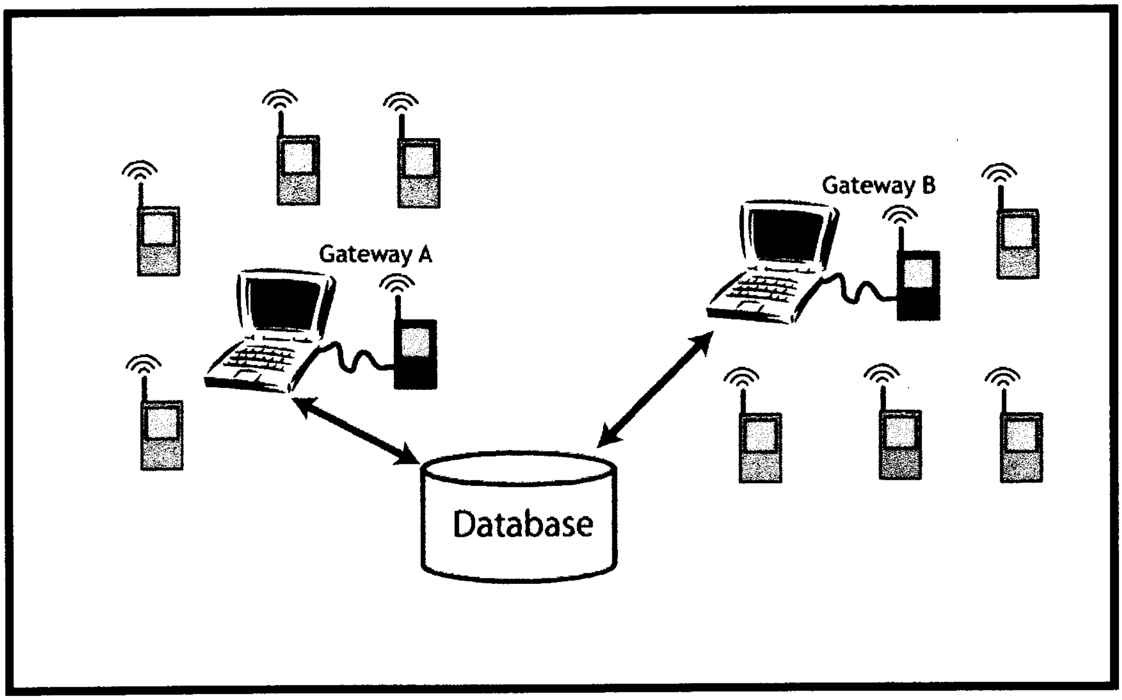


Figure 3-6 Multi-server configuration
Gateway A and B can be used to service separate locations using the same database. Using multiple gateways also increases the number of devices supported.

One drawback of the database system is that passwords are stored as plain text. This allows anyone with access to the database to easily read the user's password. The database does not provide transactions management. Although this was not an issue for the current project, larger scale projects should rely on a more powerful database.

3.5.2. THE POLLSRUS WEBSITE

Along with the Pollsrus database, the Pollsrus website was the one of the first two components designed and implemented for this project. Building the website and database concurrently helped validate the requirements for both systems. It also defined the set of features that could be included in the Pollsrus Cybiko program. The role of the website was to provide access to the poll database prior to the social events where the system would be deployed. This allows users to input their answers to poll questions prior to the event so that they are not distracted from their conversations during the event.

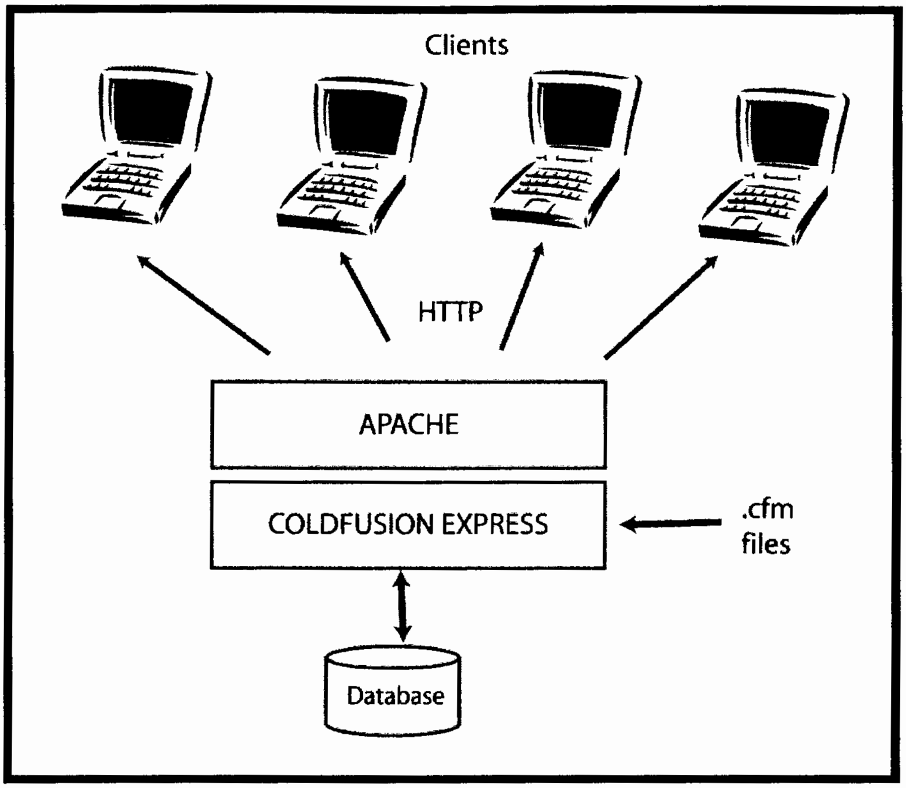


Figure 3-7 Website architecture
The ColdFusion module combines the data from the database with the ColdFusion files and sends the result to clients via the Hypertext Transfer Protocol (HTTP).

The Pollsrus website uses a web-server scripting framework that allows web services to be deployed quickly and easily. The architecture consists of an Apache web server [2] with a Cold Fusion Express plug-in module [22] that performs server-side scripting of Cold Fusion files (with a `.cfm` extension) before delivering the final html file to the web browser (Figure 3-7).

The Pollsrus site tracks user sessions by sending a cookie to the web browser. This means that only web browsers that are configured to accept cookies can be used to login to the system. Cookies are small files written to the client computer that contain small bits of information.

The Pollsrus website uses style sheets and templates to maintain a consistent look and feel that can be easily changed. These changes were necessary to customize the website for use by different groups. The website also has a context sensitive help system. The help system is a set of easy to follow guides on how to use the website. The help system shows helpful information for the current page with links to other topics as well.

The Pollsrus website underwent continuous testing using a variety of web browser software including Konqueror, Opera, Internet Explorer, Netscape and Mozilla web browsers. Each web browser provided adequate support.

The website requires users to create an account. User IDs are assigned on a first-come-first-served basis. This ensures added privacy for the user as descriptive user names may expose identification information. The registration process consists of picking a password, entering it twice, and filling in an optional email address field for password retrieval.

Information about privacy and the registration process is provided on the registration page.

After registration, the user is redirected to the login page with the user ID field filled. They must enter their password to login. Once logged in, users are shown the introduction page, which describes the website. Users can create, answer and browse poll questions, search for poll question containing a specified keyword, analyze poll results, and queue a question into the *poll question queue.*

3.5.3. THE CYBIKO HANDHELD COMPUTER

Although we utilized a single homogeneous handheld device, our system is able to support other handheld and palmtop devices such as the Palm and Pocket PC with minimal modifications to the other components. Our choice of the Cybiko was motivated by the availability and cost effectiveness of using a less expensive device.

The Cybiko is a wireless handheld computer with a 32-bit 11Mhz Hitachi microprocessor and 512kb of flash memory. It runs a proprietary operating system called CYOS. It has a radio frequency transceiver that allows it to communicate with other Cybikos within a 150 feet radius indoors and 300 feet radius outdoors at 19200 bits per second. The screen is capable of 4 levels of greyscale at 160x100 pixel resolution. The Cybiko is equipped with a single audio speaker and a mechanical actuator that causes the device to vibrate. There is a custom 4-pin serial port connector on the Cybiko that allows the Cybiko to communicate with a personal computer via a 9-pin (DB9) serial port. Games and applications can be downloaded from the Cybiko website and uploaded to the Cybiko. The Cybiko also has an expansion port, which is used to interface with add-on devices. The only currently available add-on device is an MP3 player. The batteries on the Cybiko last roughly two hours. The Cybiko has a power save mode which blanks the screen after a few minutes without activity.

The most important feature of the Cybiko is its radio transceiver, which allows users to chat with each other using the built in keyboard. Interest in the device grew when Cybiko released a powerful Software Development Kit (SDK) that allowed programmers to develop their own applications for the platform. The Cybiko SDK provides a comprehensive toolkit for developing on the platform. A compiler and several example programs are provided to guide new developers. The language used is a C variant. The compiler produces bytecodes which can be uploaded to the Cybiko and run. A professional SDK was later released and included a native compiler that could compile a program into the native assembly language of the Hitachi microprocessor.

- CYBIKO CLIENT

The client program was written using the Cybiko SDK and employed virtually all the API libraries including communication, message queues, sound and serial port access. The Cybiko Client has a range of features that interact with the Pollsrus system. It implements a subset of the functions available on the Pollsrus website. Using the client, users can login to the Pollsrus system, retrieve the current active question, browse available questions, answer questions, and add questions to the poll question queue. At periodic intervals, the server tells the client to retrieve the active question along with the user's answer. When this question is retrieved, the Cybiko will vibrate to indicate that a new active question has arrived. The Cybiko then communicates with the wearable display and changes the colour of the display to match the user's answer.

The client discovers the server using a hidden API call. It calls a method that returns the CYID of a server Cybiko. A CYID is a 7 character alphanumeric string that uniquely identifies each Cybiko that Cybiko Inc. makes. A Cybiko can be made into a server Cybiko using another hidden API call.

Several other methods of server discovery were investigated. One method was to hard code the CYID of the server into the client. This was not acceptable because if the server failed, a new client program needed to be recompiled and distributed to all the other Cybikos. We attempted using a unique Cybiko name to indicate the server. Each Cybiko can be named (usually with the name of the owner). This was also not acceptable because these names could be discovered and users could easily change their Cybikos to the server name and disrupt the system. A third option was to utilize hidden fields on the Cybiko user profile. Each user can enter some profile information on the Cybiko such as their age, gender, height, weight, and hobbies. There are three hidden fields, which could be used to store a key that identified a Cybiko as a server Cybiko. All three alternative methods were discarded in favour of the more secure hidden API call.

The interface to the wearable display is fairly simple. A byte of data must be send to the Light Controller. The port must be configured at 9600 baud 8 data bits, 1 stop bit, and no parity. The byte to send for the various colours are listed in the table below:

Colour	Byte Value
Red	0xFE
Blue	0xFB
Yellow	0xEF
Green	0xBF

Table 3-2 Byte to colour mappings

All Cybikos can send messages to other Cybikos by addressing these messages to the CYID and the application name. These messages will be received by the Cybiko and added to the application's message queue. If the Cybiko with the CYID is not available or if the application is not running, the message delivery fails.

The sender can check if messages are successfully delivered or if the message delivery failed. It can then try to resend the message or perform some error handling measures if the message was undelivered. Problems with the Cybiko communication were discovered during the testing phases. Communication failed to work reliably at high volumes. Several techniques were used to resolve this issue. The system was modified to resend lost messages. A *maximum retry value* was used to limit the number of times a message could be resent. An appropriate *maximum retry value* was chosen to avoid overloading the server with multiple retry attempts for clients that have been switched off without logging out of the server.

The reliability of the Cybiko radio transmissions depends on the size of the room and the amount of electronic devices in the room. Even with the added measures used to ensure bandwidth for the required operations, messages are sometimes left undelivered. When the client fails to deliver a message it notifies the user with a double beep.

- CYBIKO SERVER

The server works as a simple relay between the system server software and each of the clients. We implemented a simple messaging protocol that is understood by both systems. The address of the message is included in the message. The server parses the first few lines of the message to obtain the address of recipient and then delivers the rest of the message to the recipient.

The server needs to monitor both its message queue and the serial port. Messages from other Cybikos appear in the message queue while messages from the Pollsrus system appear on the serial port. Both the message queue and the serial port must be polled periodically to check for new messages. We attempted to use a multithreaded approach to handle both operations however this approach met with poor results because the threading API functionality was not well documented. An alternative technique discovered through the Cybiko newsgroups suggested using a timeout value from polling the message queue to check the serial port for new messages. This technique was used in our implementation.

The server appears to be the bottleneck of the system. While we had hoped to support up to 25 devices using a single server, our tests yielded excellent performance when supporting two devices, adequate performance supporting between three and eight devices, and poor performance with nine or more devices. Above certain limits the server is overloaded and is unable to send or receive any messages.

3.5.4. SERVER SYSTEM SOFTWARE

- PC SERVER

The PC Server software was written in Java using the Java Development Kit (JDK) version 1.4. Database access was provided with Java Database Connectivity (JDBC) while Serial Communication functionality was provided through the JavaComm package for the Windows x86 platform.

As with the other components of the Pollsrus system the PC Server component was modularized into the *database layer, communication layer,* and the *user interface layer* (UI). Each layer separates the underlying technology and is designed so that the modules can be interchanged to support other technologies. For example the communication layer could be replaced with one that supports Transmission Control Protocol (TCP) sockets instead of serial port or both. These layers are shown in Figure 3-8.

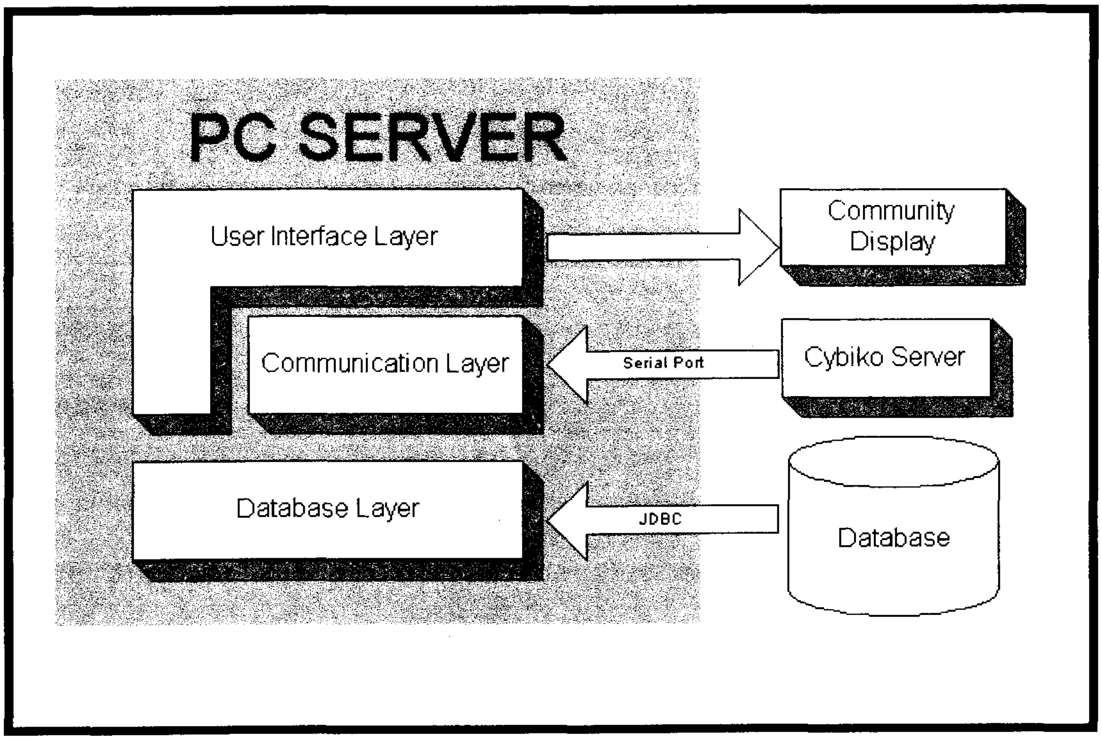


Figure 3-8 PC Server layers
The PC Server is composed of several layers. The communication layer which supports the Cybiko platform using a serial port connection can be replaced with one that supports other device platforms such as Pocket PC, Palm OS and cellular phones.

The *communication layer* is important because it allows the server software to be used on other systems with other handheld platforms such as Pocket PC or Palm with less modification to the other components. The communication layer separates the rest of the system from the specific technology used to communicate with handheld devices. The interface between the server software and the Cybiko server occurs through a serial port. This port is configured at 57,600 baud, 8 data bits, 1 stop bit, and no parity. A simple protocol was implemented for communicating messages between the server software and the Cybiko server. We felt that a simple protocol would be sufficient for our purposes.

The *database layer* contains the interface to the Pollsrus database. This module provides functions to perform certain operations on the data. The database layer provides a high level interface for data stored in the database.

The *User Interface layer* consists of a Graphical User Interface (GUI) and some program logic to act as the glue between the database and communication layer. Figure 3-9 shows the UI layer diagnostic interface and each of the controls. There are controls to connect and disconnect from the Cybiko Server, to select which serial port to use for the connection, to select the delay interval between successive active poll questions, to pop new questions from the poll question queue and to resend the active question to all the Cybikos that are currently logged into the system.

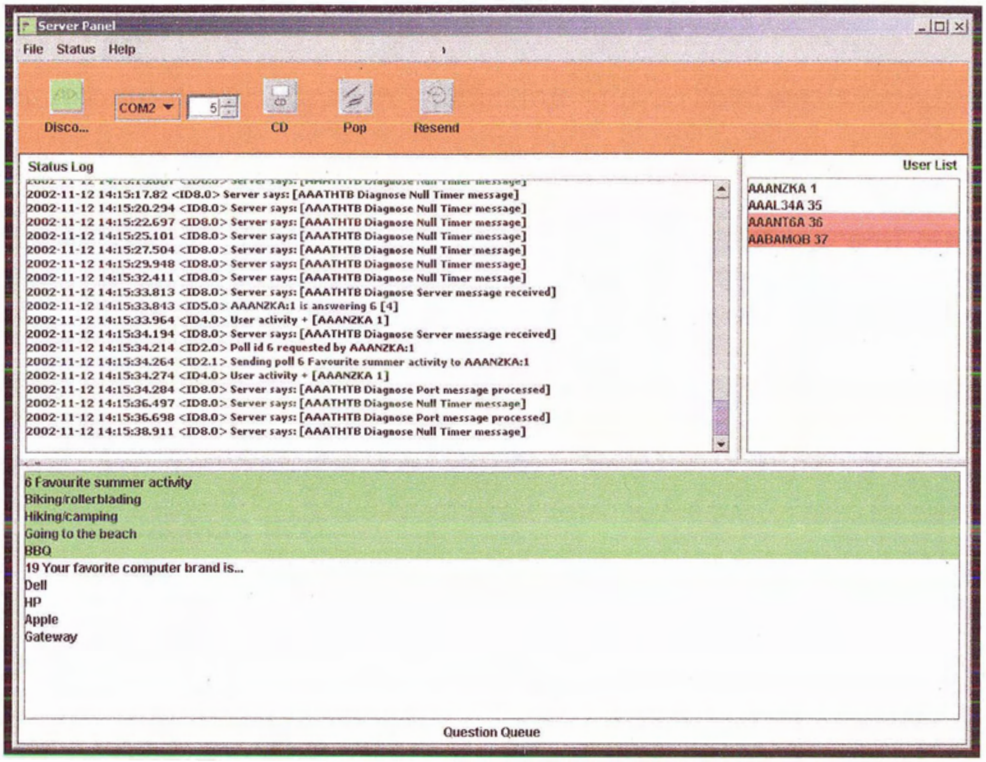


Figure 3-9 Server Diagnostics Screen Capture
The level of red in the user list denotes user activity. The Status Log records all operations on the system. The set of buttons on the top controls the system. The question queue is shown at the bottom of the window.

The UI layer manages a list of users currently connected to the system in the *user list*. It also tracks the user activity over time. Each user is represented as an entry in a list. When the user is active (for example by answering poll questions or communicating with the server using the Cybiko), the level of red in the background is set to the highest value. The value decays over time. This provides a visual cue when looking at the user list. The most active users appear in a bright red background, the less active users in a pink background and the inactive users in a white background.

The UI layer offers a view of the poll question queue. Our first generation server managed the question queue internally. This was changed to a centralized queue management system supported by the Pollsrus database. The UI layer still manages some aspects of the poll question queue such as seeding the queue with random questions when the queue had fewer than two questions. The diagnostic system also displayed the contents of the queue so that the experimenter could see what questions were next.

As a diagnostic and evaluation tool, we logged all important events from the PC Server software on the status panel of the Server Diagnostic GUI. This data is also saved into a text file for later analysis. Events were coded and time-stamped to allow easy filtering. This data can be used to replay the events that occurred in the system including:

- What poll questions became active
- What questions were added to the poll question queue
- Which users logged in and from which devices
- How did each user answer the poll questions
- Did users change their answers
- Did users receive the server messages sent to them

We also stored all serial port traffic between the PC server system and the Cybiko server. The amount of the serial port data for a one-hour event with eight users was less than 1 MB of text. This data allowed us to check that the server system was functioning properly and to diagnose any problems that occurred. We were also able to see active questions as they appeared and reconstruct the operation of the system. Our data logs allowed us to observe user-to-user interactions during the event rather than focus on the user-to-device interactions.

The UI layer also controls the Community Display, which is discussed the next section.

- COMMUNITY DISPLAY

The term Community Display came from a similar use of a large display to show information to a wider community of users in the Meme Tag project called the Community Mirror [6]. As with the Meme Tag project, a community of users with personal devices interact with each other in a single location. The Community Display relays information that all members of the community may consider interesting. The Pollsrus system uses the Community Display to show the current poll question along with statistics of how all the users who have logged in answered the poll questions and indicate the mapping between the colours and the poll question answers. Figure 3-10 shows the Community Display.

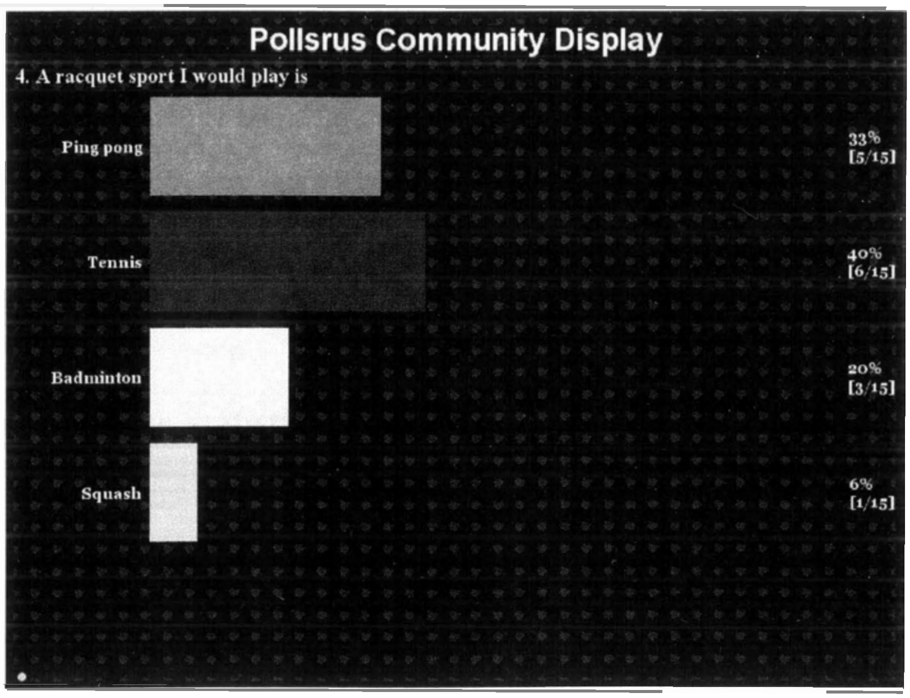


Figure 3-10 Community Display Screen Capture
The current question along with results from all logged in users are presented. We see that 33% (5 people) of logged in users (15 people) would play ping-pong. The pulse monitor is visible in the lower left of the screen.

The colour of the bar corresponds to the colour of the light on the wearable display. For example, if Jane answered *tennis* for this question, her wearable display would display a blue colour (the second choice). Anyone who saw Jane's display while this question was active would see her blue light and be able to tell that she plays tennis.

When the Community Display is active, the server diagnostic window is hidden. We added an indicator component that pulses when there is server activity. The indicator is a circular spot of colour with a decay effect. The Cybiko server sends a ping message to notify the PC server system that it is still alive. When the ping is received, the circular spot is changed to red. The load on the Cybiko server can get to such levels that cause the Cybiko server to stop functioning. This can be detected using the server pulse monitor. The broken Cybiko server can then be replaced quickly with a new Cybiko with minimal disruptions.

The Community Display shows statistics on users who are currently logged into the system. This is called the local statistics view. Another variation of these statistics include statistics from all recorded answers in the system, regardless of whether or not users are logged in. We found that both views are useful but we used local statistics instead of global statistics for the purpose of our user study.

➢ REMOTE COMMUNITY DISPLAY

We designed a Remote Community Display (RCD) that serves as a portable Community Display server without a lot of the underlying PC Server logic. The purpose of this component is to independently drive a Community Display from a remote location without needing the Cybiko server components. The RCD attached to the appropriate ODBC data source could show a live version of the centralized Pollsrus question queue. It could be made to run in standalone mode which means it would add random poll questions to the poll question queue when the queue reached its minimum length and pop questions from off the queue when required. In remote mode it would simply read the poll question queue at regular intervals and update the Community Display. To control the RCD we used a simple text console for text-based commands.

3.6. Testing and Evaluation

We designed and built a lot of components for this project. To keep things manageable, major components were divided into smaller components that could be built and tested individually. Each component had to be tested on its own and then combined with other components and tested again. While this technique simplified the design and implementation of the system, the testing component was very time consuming. However it is preferred to a combined test where errors have to be thoroughly investigated before a diagnosis can be found.

Since this is a multi-user system, we conducted both single and multi-user testing. While the system worked well in a single user scenario, this result did not translate to the multi-user scenario. Testing the system with multiple users required a major investment of time and effort. Multi-user testing sessions are more difficult to organize and the errors are sometimes hard to diagnose because they cannot be reproduced in the lab by a single developer.

Both the Cybiko client and server had to be tested together because each provided functionality to the other. They were developed concurrently although the server did not change significantly over the course of the development because its functionality was fairly simple. The client was tested with the server incrementally. Each new function was tested quickly using a single client. The testing process involved compiling the

Cybiko program into bytecodes and transferring the bytecodes from the PC to the Cybiko via a serial port. A Cybiko emulator was under development but was not in a usable state at the time of the development.

Most of the testing occurred using a single client. Testing with multiple clients was difficult and time consuming because of the following reasons:

Each Cybiko had to be loaded with the new program bytecodes. This process required each Cybiko to be plugged into the computer, while the bytecodes were uploaded into the Cybiko memory. Seeding multiple Cybikos with the new program bytecodes was time consuming and was typically only done after major code revisions.

Multiple clients had to be tested concurrently. To simulate an operating environment of multiple users, many Cybikos had to be used at the same time. Since the program consists of functions requiring a lot of user interactivity, these functions had to be initiated by different test users. For small incremental changes, it was difficult to obtain test users. We relied on running demonstrations of the software during lab visits and pilot studies as our multi-user testing ground.

With all these issues, the testing of the system in actual use conditions was not to our satisfaction. We relied on our pilot studies, which were difficult and expensive to organize and we had to be very careful about the adjustments that we made from one study to the other because major changes could affect the running of the study. Testing the system with actual usage conditions exposed problems with the amount of bandwidth the system was capable of handling. We claim that this is a result of the choice of hardware we were using and the way we were using it. The Cybiko is better at peer-to-peer communications rather than as a communication hub. A different wireless protocol might yield better results.

3.7. Problems and Issues

The system tests always yielded new problems. All major problems were addressed and sometimes required further research and some creative problem solving. Our system was constantly being improved upon through our iterative design, implementation, and evaluation production cycle. Several of the major problems and issues encountered are explained in Appendix H including the floating ground problem and server discovery problem.

The choice of technologies employed for our system yielded many complications that we had difficulty overcoming. We chose to use a device that was affordable and that could perform the tasks required because our initial goal was to perform a large scale exploration of the system with many users. However the device we chose, the Cybikos, had other limitations that eventually forced us to scale back the number of users that we could support. The EL wire technology was chosen for its flexibility and ease of integration. However, actual use of the EL wire required a large number of supporting components which made the eventual device quite large and cumbersome. Although these limitations did not appear to adversely disrupt the goals of our research, a second iteration of the system deployed with the lessons learned from this experience would contribute to a more satisfactory user experience.

4. Early Explorations

Before implementing the Pollsrus system, an informal paper-based exploration was designed and conducted to evaluate our conceptual ideas of digital fashion. This early exploration helped to validate our belief that public wearable displays could be beneficial to encourage social interactions. During the implementation stage of our Pollsrus system, several workshops were also conducted to evaluate the system and explore our hypotheses. Results from these early workshops were used to iterate the design of the system. The following sections describe our early experiences including using a paper-based version of the system called PollTags and the informal findings obtained from our exploratory workshops.

4.1. Paper-Based PollTags

The goal of this study was to explore our theory of how a non-verbal secondary communication channel might influence social interactions among individuals. This study simulated our proposed environment using paper displays that were manually manipulated to show poll question answers. Although we were aware of many drawbacks inherent from using a paper-based version, we wanted to validate the idea that the added context provided by the secondary communication channel could create richer interactions and promote serendipitous exchanges.

4.1.1. SETUP

Paper-based wearable displays were created using coloured strips of construction paper. Five coloured strips of paper in red, blue, green, yellow, and black were cut and folded in half. Once folded in half, the visible area measured 2.75"x4.25" (7.0 x 10.8 centimetres).

The coloured strips were folded together and fastened using a paperclip so that only the top-most strip would be visible. A beige ribbon was strung through the coloured strips and tied to form a loop. This loop could then be worn around the neck. The entire assembly called a PollTag is shown in Figure 4-1.

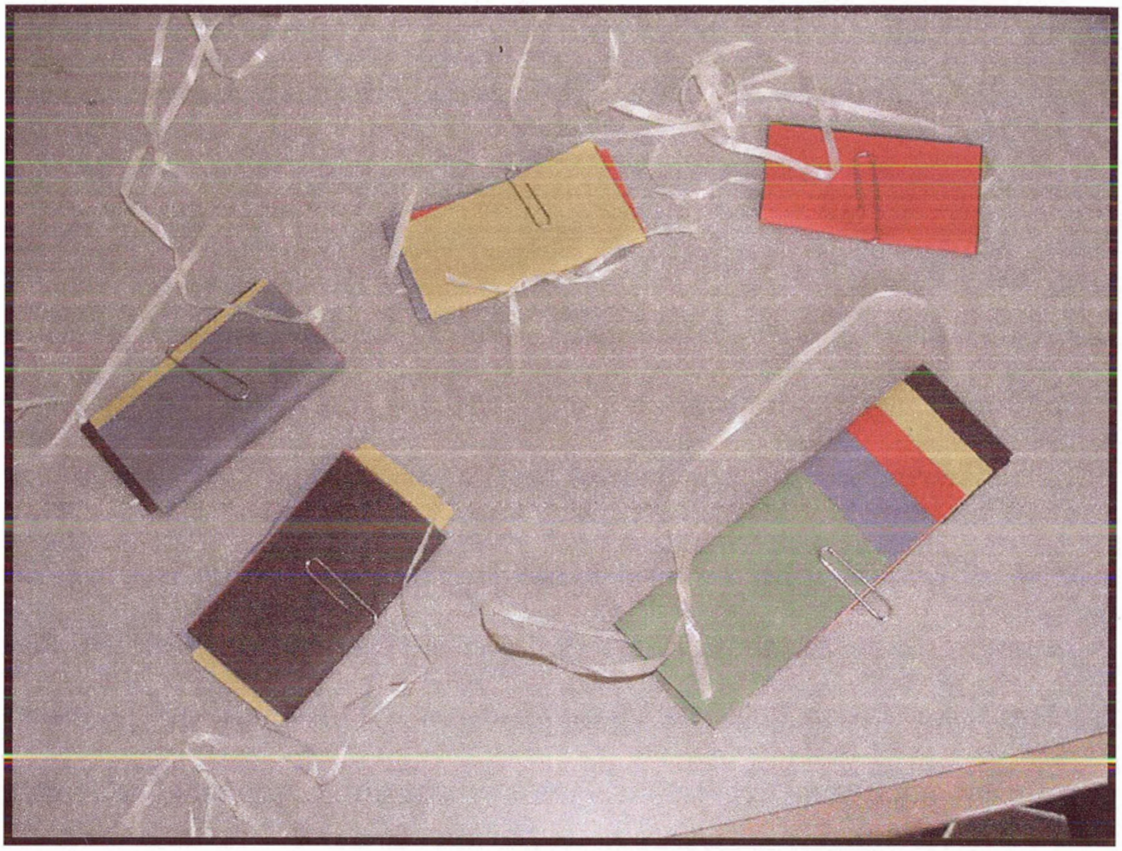


Figure 4-1 PollTags
Coloured strips of construction paper are held together by paperclip. A beige ribbon tied in a loop is used to hang the tag around the neck. All five tag colours are shown here.

Users of the PollTags system were periodically asked to change the top-most strip to correspond to answers for the active poll question. Each question had four possible answers. Each answer corresponded to a colour with black representing a refusal to answer to the question. For example a question, “Where do you call home” would have “Vancouver”, “Canada”, “North America”, and “Other” in red, blue, green, and yellow respectively as the choices. If the user selected Vancouver, he would place the red coloured strip on top and fold the pile down over the ribbon. The coloured strips would be held together using the paperclip.

Similarly users could choose any of the other colours to represent their answer or black if they did not wish to answer this question.

The PollTags study was run during the SFU Computing Science Christmas party. During this two-hour event, food and refreshments were served. A Master of Ceremony conducted various events such as talent performances and a baby photo identification contest. The paper-based wearable displays were offered to partygoers as they arrived.

An overhead projector and transparencies were used to display the active poll question throughout the evening. This functioned as a Community Display. Questions and colour mappings for each of the four choices were handwritten on the transparencies. The poll questions were kept active for five to ten minutes. At the beginning of the event, the Master of Ceremony described how the displays worked and what they were for. He also announced when new questions became active and reminded people to change their paper displays.

4.1.2. RESULTS

A large majority of the attendees participated in the activity by wearing the display. The party atmosphere and the novelty of the PollTags helped increase participation. We think many people participated because they did not want to be left out of the game. Some attendees accepted the PollTag without asking about the purpose of the tag. A total of 12 poll questions were displayed during the course of the event. Attendees were also asked to contribute questions. Prizes were offered for the best question, however no questions were contributed.

The first question, "Where do you call home", was slightly too obvious. This information could be gathered through other cues such as ethnicity and language accents. We saw in this case that people did not rely on the tags to discover anything new about other people. While an easy and benign question is preferred while people get accustomed to the system, it must reveal something about the wearer, not already communicated by physical attributes.

The simple construction of the PollTag made it unobtrusive during the course of the event. People had no difficulty with the tag impeding motion. In fact some participants could be seen walking home while still wearing their PollTag. We liked the fact that the PollTag could be worn and forgotten. It did not constantly demand focus.

As was expected, people often forgot to change their PollTag colour to correspond to the question. Even though the Master of Ceremony made announcements about new questions, people involved in conversations or other activities did not change their PollTag colours. This became more evident as the night went on. Participants who did not change their PollTag colours, had colours that did not correspond to what their actual answers would be. This caused some confusion and embarrassment, particularly when a more sensitive question followed.

Some participants decided to "turn off" their PollTag by using the black colour strip for the rest of the evening. It is interesting that some people chose to do this rather than take the tag off. This could mean that they were not interested in the current question, or that they still wanted to wear the PollTag, even if it said nothing about them. We also suspect that social pressure might have influenced people to wear the PollTag even though they did not want to participate in the event.

Many of the participants commented positively about the activity. For some, it allowed them to express things about themselves that they would not otherwise do without a context. For example, it is awkward to tell someone that you are single without some context for that exchange. Others could live as avatars by answering questions that were not representative of themselves if they so desired.

The PollTags themselves became objects of conversation. This was unexpected. We wanted the PollTags to create conversation, but did not expect conversations *about* the PollTags. These conversations need to be distinguished from conversations created by the colours displayed on the PollTags as responses to the poll questions.

We found that PollTags was also a safe method of breaking awkward silences during a conversation. We felt that this would be a useful effect that may be repeated in future studies.

PollTag wearers made modifications to how they answered some poll questions. For example in the "All I want for X'mas" question, some tag wearers displayed all the colours to show that they wanted many things for Christmas. The design of our database did not support multiple answers, however our light display system could be made to show multiple colours at the same time. This is an interesting feature that had not been considered previously.

Participants also modified how the PollTags were worn. Since the PollTags were lightweight and came on a paperclip, some participants simply clipped the PollTags to their shirt, rather than wear it around their neck. Others were able to shorten the length of the ribbon depending on their height. The ability to reconfigure the PollTags seemed to create a sense of ownership with the PollTags. It also mimics the personalization that occurs with regular fashion expressions.

Overall, managing 60 low-tech PollTags during this study was not a major problem, but it became apparent that managing a similar number of handheld computers tied to the same number of wearable accessories would represent a huge system with multiple points of failure. As a result we decided to design and conduct smaller more manageable user studies to evaluate the prototype system.

A number of valuable insights regarding the communication of shared knowledge were gathered from observations of the paper-based version of the system. However, the static nature of this prototype was very limiting in terms of the overall goals of this research. For example, the need to continuously interrupt users in order to notify them about changing questions interfered with our desire to build a system that could be present in the background and brought to the foreground only when required. Also, given the fact that the paper-based version had no memory, there was a need for the wearer to be constantly aware of the changing context and this was an added burden that should be avoided in the midst of social interactions. In addition, occasions where users forgot to change their answers after a new question was posed, resulted in an embarrassing situation for the users. A technology-based system can offload all of these duties (except for providing the answer) and allow the user to be more involved in conversations.

4.2. SCWIST Workshop

A 45-minute workshop on the Digital Fashion project was conducted for High School girls from around British Columbia. This workshop was organized by the Society of Canadian Women in Science and Technology (SCWIST) to encourage women to take a more active role in Science and Technology. Participants attend a one-day series of workshops at Simon Fraser University run by several departments from the Faculty of Science.

4.2.1. SETUP

In following the spirit of the event, we began with a ten-minute discussion on interesting aspects of Computing Science and talked specifically about the area of Human-Computer interaction. The participants were led in a ten-minute brainstorming session about the concept of digital fashion and the use of clothing as a communication medium. A short demonstration of the system was given after which the participants were allowed to play with the system and explore its use. We set aside 20 minutes for a free-play session. A question and answer session followed before the participants moved on to the next workshop.

4.2.2. RESULTS

One group of 5 girls participated in the workshop along with a chaperone and several parents. Including the girls, the adults, and ourselves, a total of ten Cybikos were used to access the Pollsrus system. We discovered a technical problem (the floating ground problem) prior to the workshop but had not solved it at this point. A prototype Lifeware light system was demonstrated but the participants were only given a Cybiko to play with.

We found that a long lead-time for orienting the users to the system was required. We were still explaining how to use the system, far into the free-play time. The participants enjoyed using the Cybiko because of its novelty. They explored various external features of the Cybiko besides the Pollsrus program such as the Chat program and several games.

The Cybiko server stopped functioning several times. We also experienced corrupted packets that affected the displays on the clients. This was one of the first main multi-user trials and many software issues were discovered.

We managed to get over 50% responses for two of the poll questions that became active during the free play session. This was an encouraging result. Participants also enjoyed the EL light display. No new questions were generated as the participants were overwhelmed by the novelty of the Cybiko computer.

We could not evaluate any interactions that occurred as a result of the light display. However this was a realistic test of the software system in action and helped us to identify issues with both the system as well as the effect of introducing a new technology to the participants. The most important discovery from this workshop was that the Cybiko must be introduced gradually. Otherwise participants will be overwhelmed with trying to understand the polling system and the Cybiko device at the same time.

4.3. Shad Valley Workshop

Shad Valley is a summer camp program for outstanding senior high school students who are in the process of selecting universities. The students attend a six-week summer camp at one of the participating Canadian Universities. Students attend workshops and participate in entrepreneurship projects as well as recreational activities. The University of British Columbia hosted over 50 students (Shads) this year. We used this opportunity to introduce the Pollsrus system to these students and to evaluate the system. The Shads came from various provinces around Canada as well as from overseas. They would not have known each other and the Pollsrus system would be an excellent tool for them to get to know each other during the course of the Shad program.

4.3.1. SETUP

We negotiated with the organizers of the Shad valley program at UBC and arranged to interact with the Shads on two separate occasions. We intended to use our first meeting with the Shads to introduce the project and the system. This would give the participants an opportunity to get acquainted with the Pollsrus system, Pollsrus website, and the Cybiko. We would use the second meeting to run a user study and collect data on how the Shads interacted with each other using the Pollsrus system.

The first meeting was scheduled during a visit to the SFU campus to attend several 50-minute workshops given by different departments around SFU. With over 50 students, the Shads had to be divided into four groups. We ran a 50 minute workshop with each of the four groups to explain the Pollsrus system and allowed them to play with the various components of the system including the Pollsrus website, Cybikos, and the Pollsrus client.

We designed the first meeting to follow the same format we had done for the SCWIST workshop except we extended the amount of time allocated to free-play. We wanted the Shads to become familiar with the system during this meeting rather than waste valuable time at the second meeting.

The second meeting was held five days later at the UBC campus. We ran a three-hour workshop with a small subset of Shad students. We designed several activities for them to do while using the Pollsrus system. This was intended to simulate a party or social atmosphere instead of the usual educational/learning environments that the Shads had been used to in other workshops. The activities included a voting game to test how well the Shads got to know other Shads during the event, a video game event, where the Shads competed against each other and a clay Sculpting event.

In the voting event, the Shads were given a sheet of paper with a set of award categories. The Shads were asked to vote for each other to receive one of the awards on the list. They voted for each person by writing the person's name next to the award with the restriction that they could only vote for each person once. They also had to vote for themselves to receive an award. At the end of the event, the votes were counted and awards were handed to people who received the most votes. Shads received points for voting for the winner as well as for votes they received for the award that they eventually won. The purpose of the voting event was to encourage the Shads to use the system to discover clues about the other Shads that would help them distribute the awards to the right people. For example, to discover who was the best athlete, the Shads would have to pay attention to poll questions about sports, or create a new question that would distinguish people who liked sports from people who didn't like sports. Further interactions would reveal the extent of each individual's athletic ability and allow the Shads to vote for the right candidate.

In the video game event, half the Shads played a video game against each other while the other half were free to use the kiosks or do their own activities. The game allowed four Shads to play at the same time. We used a game called Fusion Frenzy on the X-Box platform. At the end of the game, the players were ranked from first to last. The Shads were divided into two groups of four students. The groups played one round each. The bottom two players from each group then played against each other, followed by the top two players from each group. The players were then ranked and awarded points.

In the sculpting event, Shads were asked to sculpt an object that represented another Shad in the group. The Shads were asked not to disclose whom they were sculpting. The Shads were given ten minutes to sculpt the objects. Once the sculpting was completed, the other Shads voted on whom the sculpture represented. Correct guesses were awarded points. The sculptor also received points for correct guesses. Once the votes were collected, the sculptor was asked to reveal whom they sculpted and why they chose to sculpt the objects used to represent their subject. At the end of the three events, total points were calculated for the three events. The winner and runner-up received prizes.

At this point the system was complete. During testing prior to the event, we experienced occasional bandwidth problems but we did not feel that it was a major issue. We had major difficulties obtaining consent for our user study as the Shads were just below the age of majority and were away from home at the time they were contacted to participate. We accepted faxed consent forms signed by parent or legal guardian of the Shads. However we did not receive enough responses to proceed with a formal study. We abandoned our plans for a formal study and did not collect user data for these events.

The Shads were already familiar with the devices from the previous workshop. They were given the devices and asked to wear the device throughout the entire event while participating in the other party events. Poll questions were changed every five minutes. The Shads used the system in the background while participating in the other events.

4.3.2. ISSUES UNCOVERED

The first meeting was a partial success. The Shads enjoyed using the Pollsrus website to create poll questions and answer poll questions that were submitted by other Shads. The website had been seeded with a set of generic poll questions. Over 50 new poll questions were added over the course of the four workshops.

The type of poll questions created reflected common experiences that the Shads had shared over the course of their summer program. For example: "Which event did you like best at Shad?" and "Who is your favourite Shad staff?" Other questions were communicative or disparaging in nature. For example: "Who has the biggest forehead at Shad?" where the 4 choices were descriptions of the same person.

The second meeting was not considered a success for a number of reasons:

Consent Forms - We did not receive enough consent forms to continue with a formal study. We had to call off the formal study a day prior to the second meeting. However since we were already committed to running the workshop it was run for the benefit of the Shad program but no data was collected.

Change in participant numbers – A last minute change left us with two more participants than we had expected. The Shad Valley program organizers handled the selection of workshop participants. A miscommunication caused them to send ten Shads, which was two more than we were expecting. This affected the rest of the workshop. We tried to accommodate the new Shads by adding new Award categories and pairing up four of the students to create two pairs and six individual students.

Level of acquaintanceship – By the time we were allowed to interact with the Shads, they had been together for around four weeks. We did not know what type of effect this would have on the workshop. We discovered that since the Shads knew each other well, they would ask the person how they answered rather than view their wearable display when an interesting question came up on the Community Display or on their handheld device. They could ask and receive an answer without turning to look at their counterpart. This allowed them continue with their activity of using the Cybiko or using the Pollsrus website.

System Failure - The system did not function perfectly and some of the Shads did not like using it. The bandwidth problem became more evident at this event. Shads who were frustrated at receiving slow responses kept sending more messages to the server. This caused the server to slow down even more.

Focussed Activity - The video game event dominated the attention of the Shads and was too distracting for other activities. This was true even for the observers of the game. We had suspected that this would be the case for the players of the game but we did not anticipate that the spectators of the video game would be engrossed in the on-going game as well. We found that during the first round all ten participants were focused on the computer game rather than trying to interact with each other. After switching groups, the Shads who had just played the video game was less interested in being a spectator to the video game. However the video game players ignored the wearable displays and the handheld devices.

The sculpting event was very positive. We believe that it was a good way to evaluate as well as motivate the use of the Pollsrus system. Users would want to get to know each other in order to sculpt an object representing someone they had just met. Doing the sculpting also forced the sculptor to think about the person they were sculpting seriously and recall facts about them they might have easily forgotten. However our Shads used existing knowledge about the other participants to produce their sculptures.

5. User study

5.1. Introduction

The results gathered from our earlier work contributed to the design of our user study. We incorporated our discoveries from these experiences and modified our user study design to avoid the problems previously encountered. This chapter discusses our user study in detail and our results.

5.2. User Study Goals

The goal of this user study was to assess the effectiveness of our system in facilitating informal interactions between participants in a social setting. Viewing our system in action would allow us to better understand how it can influence the dynamics of social interaction. The study was an opportunity to validate the effectiveness of our design in an actual social environment. We wanted to observe whether or not shared knowledge communicated through the use of digital fashion could be helpful and contribute to richer interactions.

The complexity of small-group interactions, meant that any controlled or contrived situation would seriously interfere with the naturalness of the participants' interactions. Informal interactions, by their nature, cannot be studied in a controlled environment. These problems compromise the overall goals of the research. As such we chose to conduct an experiential user study and introduce our system in a very natural social setting and observe its impact on the interactions between the participants. In addition, given the fact that most people engage in social interactions on a regular basis, we felt that participants would also be able to comment on how their interactions in our setting, facilitated by our system, differed from their normal experiences in social situations.

5.3. Experimental Design

To explore the use of our system, we chose to deploy it at a social environment such as a party. In a party environment a user's attention is primarily focused on other participants. We wanted a group of people who did not already know each other very well so that we could explore the effect of the technology on unacquainted individuals. We chose to observe new graduate students entering the Computing Science program at Simon Fraser University because they were a group of people we had access to and who did not already know each other very well. We were also fortunate that the School of Computing Science already organizes a social event to welcome the new students to the school. In addition, these participants would already be comfortable around technology, especially new technology.

Although we felt that our participants would be able to understand the system easily and would require less training to become familiar with the system, experience from past studies indicated that users of our system require a lot of time to become comfortable. As such, we divided our study into two separate phases. The goal of the first phase was to expose parts of the system and familiarize our participants with the Pollsrus website and Community Display. The goal of the second phase was to fully deploy the system, observe the interactions that occurred, and collect data from our participants.

5.3.1. PARTICIPANTS

Eight graduate students were recruited to participate in our study (six in phase one and eight in phase two). The participants were recruited using handouts included in new graduate student packages. The handouts advertised the user study, the Pollsrus website, and remuneration of $20 for participation in the study. In addition, a random set of students received a personal email asking for their participation in the study. The email explained the requirements of the study (attending two social events and two 30-minute interviews) including the information in the handout.

5.3.2. EXPERIMENTAL SETUP: POLLSRUS WEBSITE

A website was set up to allow the new computing science students to browse poll questions and answer them. We seeded the database with 15 poll questions based on the target population. Poll questions were oriented to a computing science community and referred to experiences of being a new graduate student at SFU.

The website was operational before the handouts and other methods of obtaining participants were carried out. We also included a web counter to track the use of the website and located it on the first page that is visited by visitors to the website. This was the only login page available for the system. We used the web counter to track the number of page views per day. We also examined the number of user IDs created by the system. This information helped us track the success of our participant recruitment methods.

Students were encouraged to visit the website and answer poll questions. They were told that the results of these poll questions would be displayed at the first social event.

5.3.3. PHASE ONE: WINE AND CHEESE GATHERING

The first event was a Wine and Cheese party organized by the School of Computing Science. This three-hour event was an opportunity for new graduate students to meet the faculty and other graduate students in the department. We asked our participants to attend the event. We did not provide any further instructions to them except to visit the Pollsrus website before the event and answer some poll questions. A data projector and a laptop computer were set up to drive a remote Community Display to present randomly selected poll questions every five minutes. Approximately 60 people attended the event however the actual number at any given time varied as people arrived and left throughout the event.

5.3.4. PHASE TWO: PIZZA PARTY

The second phase was a pizza party for our participants. It was held in a room (ASB9896) in the Applied Science Building at SFU. A data projector and a computer were set up as both the Pollsrus server and the Community Display. We recruited two more participants from our lab to increase the number of participants to eight. The participants were introduced to the system and guided through the login process. We also demonstrated how the Lifeware light system could be worn and recommended wearing it around their neck as a necklace. With those instructions, the participants were free to enjoy the pizza and interact amongst themselves. We monitored the system, the user interactions, and their devices but otherwise attempted not to interfere with the party. The event lasted one hour.

5.3.5. DATA COLLECTION

Following the Wine and Cheese gathering, 30-minute interviews were conducted with each of our participants. Participants were required to fill in a questionnaire at the beginning of the interview (See Appendix B). The questionnaire investigated our participants' habits in social settings including discussion topics and levels of introversion or extroversion. We queried their familiarity with mobile computing devices as well as their experience with similar use of fashion as a communicative tool. The interview process followed a preset list of questions but changes in the process were encouraged especially when interesting topics were uncovered during the interview. See Appendix C for the preset list of questions.

During the pizza party, field notes were gathered to record our observations. Data logging methods were also used to record data traffic between the Cybikos and the Pollsrus system. Another set of 30-minute interviews was conducted with each participant following the pizza party. Participants were required to fill in another questionnaire at the beginning of the interview (See Appendix D). This questionnaire contained a new set of questions including a list of statements that participants could agree or disagree with by choosing answers in the form of a seven point Likert scale with "1" labelled "strongly disagree" and "7" labelled "strongly agree." The set of interview questions are available in Appendix E.

5.4. The Event

In this section we report on our observations of people using the Lifeware system at the pizza party event.

At the pizza party, participants were gathered and briefed on the purpose of the study. This was the participants' first contact with the wearable system and handheld computers. They were shown how to turn the devices on, and how to locate and run the Cybiko Pollsrus client program. It was recommended to the participants that they wear the wearable display as a necklace. Several of the participants had difficulty typing user IDs and passwords as they were not familiar with the smaller keyboards on the Cybikos. Also some users forgot their passwords. Several new participants who had not used the website previously had to be issued new user IDs and passwords. Initially, there was some discussion about the system while the participants familiarized themselves with the functionality of the wearable system. This was expected as the Cybiko and wearable lights were novel devices. Other discussions about the system occurred when parts of the system did not work as expected and had to be fixed (e.g EL wires that would not light up, and multiple wires that lit up simultaneously).

Participants who had previously entered answers using the website had their wearable displays light up with their answers as they logged into the system. Some participants were surprised by comments made by others because they could not see their own light as it was wrapped around their neck. This concern was echoed by another participant who decided to wear the display in a different way in order to view his light.

While it was recommended that the Cybiko devices be placed in the fanny pack, most of the participants continued to hold on to the handhelds. This made it difficult to eat pizza. After the first two questions, participants did not appear to have trouble understanding how the system worked. Once issues related to the devices were resolved the participants proceeded to get pizza and talk amongst themselves.

We did not introduce the participants to each other. Most of the participants already knew one or more of the other participants in the group because they had met at an earlier event or because they were not new to the department (three of the participants). Within this casual setting, our participants managed to introduce themselves to one another. As the setting was small and intimate, the devices did not seem to be used to facilitate introductions between individuals. The interactions were done primarily within a large group. During the conversations, several extroverted individuals took turns guiding the conversation. However the introverted participants were brought into the conversation by the virtue of their lights. They could 'say' something using their wearable displays that they would not normally be able to do because of their quiet nature.

The poll questions introduced many topics of discussion that extended beyond the initial topic of the question. Questions also brought people with matching interests together. For example several participants found other participants who liked to play Cribbage, or go hiking. Disparate answers also created interesting exchanges where participants were asked why they answered a question a certain way. Interviews from the earlier Wine and Cheese gathering indicated that people primarily discussed school related topics. However having the poll system and the wearable display at this party seemed to help guide conversations in new directions.

As expected there were still moments of silence when a topic of conversation ended. While the questions were set to change every five minutes, a new question can be made active by the experimenter. This was done from time to time when conversations seemed to die out, or when a question was repeated as the active question. We observed that some participants, particularly those that had not used the website to answer poll questions before hand were very interested in interacting with the device, often waiting for the next question to become active. For these participants, the system was their primary focus which is contrary to our intended use. The degree of focus on the system was reduced over time as the users of the system answered more and more questions and did not need to input answers to questions that have previously been active. To avoid the problem of the system requiring too much focus, participants in future studies should be encouraged to spend more time using the website and answer a larger majority of the available poll questions. Passwords and user IDs should also be retrieved easily if participants have forgotten them. Although we observed over 20 user IDs created by the CS grads, the level of participation could be higher (we expected 30-40 website users out of over 100 CS graduate students). Observations from the Shad Valley workshops have shown that the website was very popular among established groups (the Shad students).

Overall a wide variety of topics were discussed including, choice of alcoholic beverages, experiences watching high stakes blackjack games, preference for pictures with no people in them, sharing similar experiences with the graduate school buddy system, and the improper preparation of a variety of asparagus.

We were pleased with the outcome of the event as we now had examples of how the system could be used in a social setting to facilitate interactions, and how it offered a wider variety of contexts for continuing conversations. Our ability to break moments of silences by surreptitiously changing the new active question was welcomed by the participants of the event. The decision to use five minutes intervals between questions as well as the random poll queue population proved inappropriate for this study. A shorter interval and a pseudo random queue population algorithm that avoids adding questions that have been recently added would have improved the experience. Through our observations, we were satisfied that the system helped create a fun environment for the participants to interact. We now present the interview data which was used to further explore our initial goals by having the participant discuss the system in relation to their experience at the pizza party and other social events they have attended.

5.5. Results

The goal of our evaluation was to examine how our devices could enhance and enrich interactions between individuals in social environments compared to situations without the technology. Given the open-ended and variable nature of social environments, it was not reasonable to introduce artificial controls and use strong quantitative methods. As such, we believed a quantitative evaluation would not produce a reproducible result and would only represent a snapshot of a particular group at a particular point in time. Instead we chose to look at the system from a rich qualitative perspective while still gathering some quantitative data to support our observations.

Our findings represent data from the two separate social events: the Wine and Cheese gathering and the pizza party. We have organized our results by concepts, which are important for small group interactions. These concepts include group formation and dispersion, topics of conversation, user comfort, overall usability, system effects on social settings, and system usefulness.

5.5.1. GROUP FORMATION AND GROUP DISSOLUTION

Drawing from Goffman's observations of the behaviour of people in public places [16], we noted that certain situations place people in open positions where they are easily approached by other people. Goffman's work shows the importance of context on social interactions, particularly during group formation.

We investigated methods used to initiate conversations during the Wine and Cheese gathering, particularly introductions. Participants were either introduced to new people by mutual friends or tried to meet new people on their own. Meetings facilitated by introductions were more common and preferred. The most introverted participants found it difficult to meet new people on their own and relied on the assistance of other people introducing them to strangers.

> *There wasn't really any activity where you were forced to go and talk to them. Its basically up to you, I find it really hard to strike a conversation that way.*

We also looked at how conversations ended and how groups dissolved. We believed that moments involving awkward silences occurred during group interaction and often led to group dissolution. These situations typically occur when people have exhausted a particular topic and have no agreement on a new topic to talk about. We asked participants about these situations related to their experience from the first party. Our participants explained that during awkward silences, they would quietly leave the conversation or try to continue the conversation if the topic was interesting. They also noted how other people would take advantage of the situation by joining the group and introduce a new topic. These results suggest that context is an important aspect for both initiating and continuing conversations. Therefore the problems of group formation and dissolution can possibly be improved with the use of context information such as shared knowledge.

5.5.2. TOPICS OF CONVERSATION

Our observation and interview data showed that conversations from the Wine and Cheese gathering began with school related topics and seldom progressed further than that. In contrast, the pizza party event allowed participants to engage in conversations about topics being offered as shared knowledge by the polling system, as well as topics extending beyond these initial poll question topics.

> *Yeah because sometimes they would talk about some story, that is related to the answers that are interesting.*

This change is partly attributed to the different social dynamics of the events. The pizza party involved fewer participants with interactions lasting for a longer period of time, while the Wine and Cheese gathering involved a larger set of people with many smaller interactions occurring within.

Some of the topics that were discussed at the pizza party were directly related to the poll questions. One person mentioned that he liked to ice skate and actually coaches a women's ice-hockey team. Participants who enjoyed hiking used the poll question on summer activities to connect with other hikers and discuss trails that they have been to and could recommend to others. These two examples show that the poll question initiated exchanges that extended beyond the topic of the poll question and created richer interactions.

Our interview data showed that several participants expressed concern over the possibility of viewing questions that they are not comfortable answering.

> *As long as it doesn't reveal any private information like, private information such as you know where is my family, how many family members, that's private information, aside from that its fine.*

We were also very concerned about users' privacy and their comfort with the sensitive nature of our system. As a result, we selected topics that we thought would not be considered too private or personal (although users could opt not to answer any question).

We found that we were successful in avoiding a lot of sensitive questions when we seeded the question database. Users of the system could add sensitive personal questions to the system but we did not observe these types of questions in our database. Our participants responded well to the combined set of questions (seeded and submitted questions). They did not feel that any of these questions were too personal and felt comfortable answering them. Our participants agreed strongly to the statement "I felt comfortable answering the questions", with a mean value of 6.3 on our 7-point Likert scale.

5.5.3. USER COMFORT

User comfort is an important factor to consider in any system where devices are worn on the body and used in social situations. Both psychological and physiological user comfort were evaluated in our user study.

From the psychological perspective we were interested in how participants responded to sharing personal information using the abstract visual representation and having this representation worn on the body. We were surprised to note that some participants did not immediately realize that they were sharing their information in this way. After they realized that the display revealed their answer to others, they became comfortable with the situation.

> *It feels like you have no secrets to hide. It first surprised me. I'm not very clear about the lights...*

> *I was kinda surprised. I didn't know what those lights were for before. Jack told me "Hey you play music" and I didn't realize where he got that answer and then I looked down oh it was my necklace, I gave it away, I'm fine with it, I would have shared it anyways.*

Some participants were concerned about where on the body the light was worn. They mentioned that they would like to be able to see their lights to make sure that it was correctly displaying their answer. This is because the system had some latency and lacked synchronization when changing active poll questions. The lights did not all change at the same time. This meant that some participants still maintained representations from their answer to the previous question for a short period of time.

Users of the system should be aware that they are sharing information, including knowing exactly what information they are sharing. They should also be able to see others doing the same. This observation agrees with Erickson & Kellogg's concepts of awareness, visibility, and accountability for socially translucent systems. Users were aware that they were exposing personal information because their display could be worn in a way that was visible to them. They could also view the display worn by others. Each user of the device was accountable for the information that they provided by virtue of possessing the wearable display. Although our system was designed to provide all three properties of translucent systems, our results reveal that there is still room for improvement. Users were in control of their data at all times because they had the option of not answering any poll questions. However some of our participants perceived having no answer as being a type of answer in itself.

Several participants did not like wearing necklaces or any other type of jewellery or body adornment. They suggested alternatives that were not close to the face.

> *I don't wear necklaces. I don't like wearing anything on my neck.*
>
> *I never wear stuff. I don't like wearing something on the neck, fingers ... I don't wear even a watch.*
>
> *If it's an armband I'd probably be more comfortable wearing it ... or something around your head ... I wear hats so... it'd be natural for me to wear something on my head as well.*

We suggested the wearable display be worn as a necklace because we found that this is the most visible location especially for face-to-face interactions. Ljungstrand research related to the Wearboy system also supported this observation [21]. This raises the question of whether or not allowing users to customize the system by picking the form factor of the device will affect the usefulness of the device.

In terms of the physiological comfort of the system, participants commented on how bulky the device was to wear. They were unhappy with the amount of wires and the weight of the prototype device. Some participants suggested integrating the device tightly to existing pieces clothes.

The only thing that wasn't very effective is the fact that there is a lot of cables running around... if it were wireless and you wear the necklace like a regular necklace it would probably be more effective.

The device should (be) more integrated into the clothes, maybe you should integrate it into your jacket or something... maybe the handheld could be integrated into the jacket as well.

(It) was a little chubby. The size was ok; the weight was a little heavy.

I felt they were a little bulky and wired so with the system as it is; I wouldn't really want to wear it. ... (If) its not wired to other things on my body, then I'd be more comfortable wearing it.

Some of our participants said that they felt comfortable wearing the lights and hardly noticed it after wearing it for short period of time.

You barely notice there is a wire around your neck, but you feel weird, why is a wire there?

While there were a few problems with user comfort, particularly concerning the size and form factor of the device, these issues can be resolved with better engineering. As a prototype, the system served its purpose.

5.5.4. USABILITY

We evaluated the three system components used by our participants: the Pollsrus website, the Cybiko handheld computer, and the Cybiko Pollsrus program. We asked our participants to rate how easy each component was to use, how well they understood how to use each component and how fun it was to use each component. Figure 5-1 shows the results.

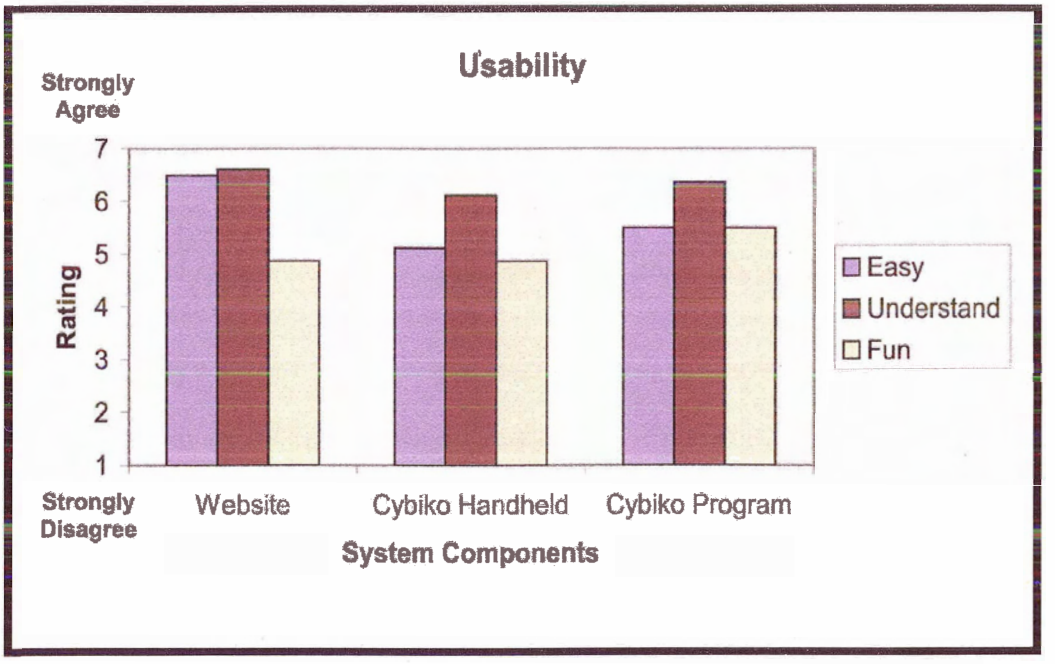


Figure 5-1 Usability Evaluation Graph
Blue, red, and beige bars represents ease, understanding, and the fun level of each system respectively. The Cybiko Handheld was examined separately from the Pollsrus Cybiko Program, which is denoted in the far right.

Overall, people were very comfortable using these systems. There were positive ratings for all measures across the board for each component system. While the participants' level of understanding for each component was high, ease of use levels were lower than for the website. We attribute this to the problems with the system (discussed in chapter 3) and the fact that people are very familiar with interacting with websites. Overall our system was well received by our participants.

5.5.5. SYSTEM EFFECT ON SOCIAL SETTINGS

We investigated user distraction at the Wine and Cheese gathering. At this gathering, participants were only exposed to the Community Display. They reported that the Community Display at the Wine and

Cheese gathering was not particularly distracting to general interactions at the event. One participant compared the Community Display to an advertisement that was easily ignored.

> *I think of it as an advertisement and you don't notice it, if you don't want to.*

Our participants said that they could ignore the screen when they were far away from it. When asked about the distractions that did occur, participants reported that the Community Display distracted people between conversations.

> *How were they distracted?*
>
> > *I've noticed that some people were looking at the screen so I guess they had some interchange or they are busy with the screen?*
>
> *During or between conversations?*
>
> > *Between conversation*
>
> *Not during?*
>
> > *No I don't think during, between.*

We also investigated the impact of having the complete wearable system on the social setting at the pizza party. We found that acceptance of the device depended on how the users were perceived by others. Some participants would only use the device if other people were using it as well or if they know other people knew the purpose of the device.

> *I can't see people wanting to wear that kind of thing. I certainly don't want to wear that kind of thing in a social setting unless everyone was wearing it, then it's probably good.*

I was curious about the light system and it was ok for me. Yeah (It was comfortable) because everybody (was) wearing it.

I'll be more comfortable ... if most of the people know what kind of thing that (the wearable display) is.

Some participants commented about power relations between the users and non-users. We observed a reverse power relation as our participants mentioned possible feelings of vulnerability if they would be the only ones using the system.

I wouldn't want to wear it that much because it takes a lot of privacy but at a party like that (pizza party) I would do it, ... depends how many people have it. If I was the only one... it feels like I am being watched

Participants expressed that they were more comfortable when there were more people wearing the devices. This finding agreed with our observations from the PollTags study, that a large user base is important for this type of system to be successful.

5.5.6. SYSTEM USEFULNESS

We asked participants if our system helped them interact at the pizza party and whether the system made the event more enjoyable. The results are shown in Figure 5-2.

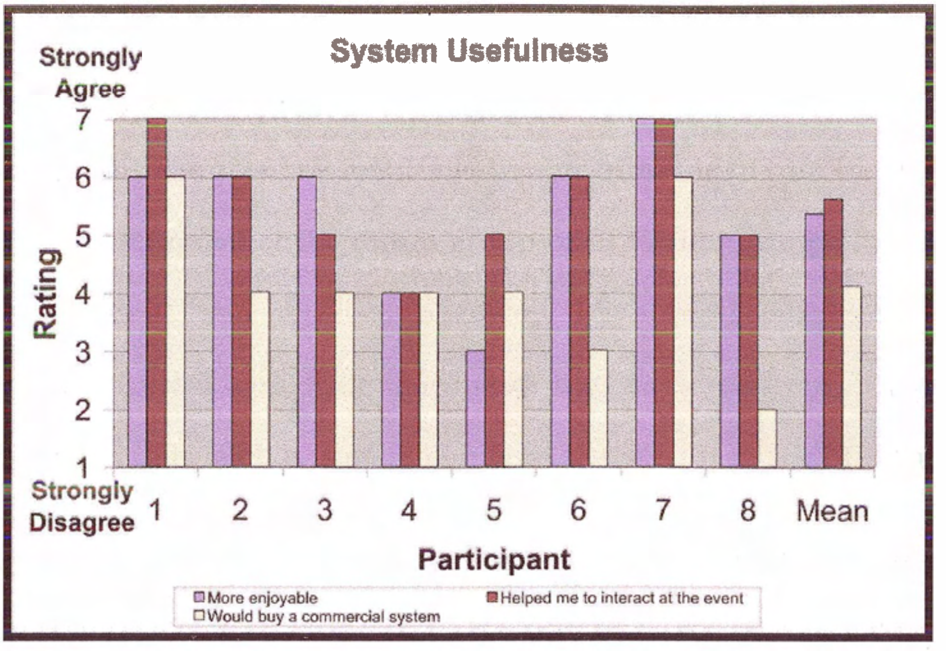


Figure 5-2 System Usefulness
Individual results from each participant show that participants felt the system made the event more enjoyable and helped participants to interact during the event. Reactions to a commercial system were mixed.

Interviews after phase one and phase two allowed us to observe an attitude change in some of our participants. They appeared to be more enthusiastic about the system after actually using it.

> *It's suited very well in initiating conversations, because it tells you something about that person through the choice that he or she made to the polling question.*
>
> *I would consider buying one – seriously*
>
> *This is a stereotype but, computer people tend to be shy and withdrawn and not as talkative and it worked well for them so I going to assume that for people who are naturally outgoing and talk a lot it would work especially well for them.*

Although all the participants thought the device was useful, one participant questioned the need for such a device.

I don't really see it being used in the future... it doesn't need to be used, I don't think.

5.6. Summary of results

We realize that some of the results gathered from individual participants are not representative of the entire group or of similar groups. We do feel that the system was received positively by several participants. We believe the system could be improved but as a concept, this work demonstrates that such a system could be successful in social settings.

The results from this user study allowed us to see the system in action and evaluate its strengths and weaknesses. We gained important insights into the dynamics of social interactions and how shared knowledge can be useful in facilitating interactions. We designed a calm system that exhibited properties of social translucence and investigated its effect in social situations.

6. Discussion

We used Dryers social computing factors to evaluate the effect of our system in social settings. Dryer's 16 social computing factors [11] are grouped into four larger categories as presented in the table below.

System Design	Human Behaviour	Social Attribution	Interaction Outcome
Accessibility Familiarity Input sharing Output sharing Relevance	Appeal Disruption Perceiver distraction Power User distraction	Agreeableness Extroversion Identification	Device satisfaction Productivity Social attraction

Table 6-1 Social Computing Factors (from Dryer et.al.)

6.1. System Design.

System design examines how the design of the system affects people in the social context. Characteristics of the system can influence how both users and non-users perceive the system.

Accessibility - Accessibility measures how well non-users believe they could use the device and how well they understand how it works. We believe aspects of the system such as the visibility of the wearable display along with the Community Display would help non-users understand the system. Non-users in the Wine and Cheese party easily understood what was shown on the Community Display.

Familiarity - Familiarity refers to the form factor of the device as being appropriate for the context of the use. We think that by choosing form factors such as necklaces and bracelets, we are already tapping into a common understanding of jewellery as a form of self-expression. These form factors are also comfortable and make it easier to hide the technology by behaving as typical wearable accessories.

Input Sharing - Input sharing considers whether or not non-users are allowed to input information easily. Our web kiosks support non-users by allowing them to create questions and queue poll questions into the poll question queue.

Output Sharing - Output sharing considers whether non-users can easily perceive and understand output. The design of the public wearable display and Community Display, allows anyone within the social setting to discover how a user answered poll questions. Output sharing in the form of shared knowledge, is in fact one of the main goals of the system.

Relevance - Relevance measures how useful the system could be for non-users. The Digital Fashion system allows both users and non-users to approach others in order to start conversations based on their exposed context information. However this effect may be less in the case of the non-users because their interaction has no inherent reciprocity.

6.2. Human Behaviour

Human Behaviour looks at the people's actions within the social context, while the device is in use. In this section we look at how people react to the system within their environment.

Appeal - Appeal represents whether or not the user is comfortable being seen using the device and whether non-users find the device attractive. Our work found several ways to make the device more comfortable and more appealing to users and non-users. Opinions varied on the appropriate form factor of the device. The device should be less visible either using wireless technology or hiding the wires under one's clothes. The device appealed to non-users because it allowed them to gather information about the wearer.

Disruption - Disruption refers to whether or not the device disrupts an individual's natural social behaviour and makes the interaction less natural. Digital fashion emphasizes natural interactions by supplying the context prior to the interaction and lingering in the background throughout the interaction. Indeed the goal of the system is to facilitate people's natural interactions.

Perceiver Distraction - Our evaluation of the levels of distraction for the Community Display and wearable displays showed that overall, people were not significantly bothered by either system and that it did not appear to disrupt their interactions except to create new interactions, prolong existing interactions, or switch topics within an interaction.

Power - Power examines whether the device puts one person more "in charge" than another person and the difference in status. Interestingly, we found that people wearing the device felt more vulnerable than those not wearing the device because they felt that they were being watched. Since the wearable display is meant for people around the wearer, the definition of user is less distinct. Is the user the wearer of the device, i.e. the person who controls what information is displayed to others, or is the user of the system the viewer of the display? There is still a difference in status between those wearing the displays versus those without the display. However digital fashion creates an interesting dynamic between people in control of the information and people using the information.

User Distraction - User distraction questions how much cognitive load is placed on the user of the system. We consider the use of the device in terms of the wearer who must input answers to new poll questions. The cognitive load of picking one of four possible answers is quite low. Ideally the users would have input their answers ahead of time using the website or at a previous social event. We do not consider the use of the system to be very demanding for the wearer. Users were distracted when their lights did not display the appropriate answer to the active question due to system lag. Some cognitive load was obviously required because viewers of the system had to perceive the display and map colours to answers. However, we found that users were able to do this very easily.

6.3. Social Attribution

Social attribution refers to judgements a person makes about others. In this case we need to consider how viewers of the system perceive wearers of our system.

Agreeableness - This is a measure of whether the user is perceived to be agreeable or disagreeable. We believe the ability of the device to share knowledge, allows the viewer to choose who they would like to interact with and make the interaction more positive. We expect the system to result in more interactions where the wearer is perceived to be agreeable. However we leave the actual exploration of this hypothesis for future work.

Extroversion - As Goffman suggests, extroverts seem approachable and have a built-in license to approach others. We believe the Digital Fashion systems can help encourage extroversion for both introverts and extroverts. By virtue of wearing the device, the wearer is considered to be interested in meeting others. We think viewers will perceive these people to be more extroverted and open to interactions.

Identification - Identification refers to whether the device excludes or includes users in certain communities. We designed the wearable display to use existing forms in fashion such as necklaces that are inconspicuous to others when turned off. However with the presence of the Community Display, the displays do create two classes of users. We believe that both parties benefit from the system, although there remains a perception of power when viewers do not reciprocate the sharing of information.

6.4. Interaction Outcome

This section looks at the result of the interaction given the participation of the system. Benefits of the system are discussed in terms of the outcome of the interaction.

Device satisfaction - Overall our users were satisfied with the device. They enjoyed using it and felt comfortable doing so. Suggestions for improving the device provided by our user study participants, such as making the device smaller, reducing the number of wires, and integrating the device into clothing or existing devices, had been anticipated prior to the study.

Productivity - Productivity refers to how well the user was able to accomplish their task. Our user study participants agreed that the system helped facilitate interactions.

Social attraction - This factor refers to whether or not the interaction with other people was positive. Our analysis did not focus on how well people interacted with each other or how the device influenced the interaction that occurred. We were more focussed on the initiation of interactions rather than the content of the exchanges. We did however measure whether or not users would use the devices again. Three responded that they would (6), one responded that they wouldn't (3) while four were neutral (4). See Appendix G for questionnaire data.

6.5. Discussion Summary

The Digital Fashion system performed well on almost all these factors. This represents a successful implementation of a socially adept system. Our research has also raised several interesting issues that are summarized in the next chapter.

7. Conclusion

7.1. Summary of Methodology

The Digital Fashion system utilized a secondary communication channel to exchange shared knowledge information in order to facilitate informal interactions. We collected research on public wearable displays in the field of computer science as well as examples of the use of secondary communication channels for supporting and facilitating interactions. We designed and implemented a public wearable display system specifically for this project with the help from experience gained from studying previous work in the area. Our new system utilized both custom software and hardware components. We evaluated our system in a variety of social settings. Several pilot studies were conducted using our system prior to a more formal user study. Our user study involved a two-phase process with up to eight participants using our system.

7.2. Summary of Results

We successfully evaluated our system and found that users of our system had a positive experience using the technology in social settings. We discovered interesting issues concerning our technology.

Device form factor: The device must be pleasing to the user for device to be successful. Users have different preferences for the type of wearable accessory to be used. More choices for the wearable accessories would help user's perception of the device. Users wanted smaller devices with fewer wires. Bulky systems with many wires were not acceptable.

Critical mass: A large user population is important for the system to be adopted. Users preferred when they were not the only ones using the technology. Users wanted others to know how their devices worked and did not want to have to explain their wearable accessory to others.

Secondary channel is not distracting: Our results indicate that the visual channel can be easily ignored or filtered by our users. We found that the system did not distract our users from their normal interactions.

Benefits to both wearer and viewer: Both parties benefited from the system as the wearer appeared more approachable to others while the viewer is able to establish a context to approach the wearer.

7.3. Summary of Contribution

The Digital Fashion project brought together an extensive amount of work in several major areas. First this work involved development at the software level on several different platforms, to integrate components into a ubiquitous, wearable computing device. In particular, this involved website design, database design, application and middle layer implementations, handheld device programming, and microcontroller programming. Second, low level hardware and electronics work was needed to wire electronic components together and build the logic system to provide power to our lighting system. Third, several initial explorations were conducted to gather preliminary data on the various system components, followed by a full experience session where the complete prototype was utilized and evaluated with multiple participants interacting as a small group.

The results from our research indicate that our system helps create an open environment suitable for supporting informal interactions between both acquainted and unacquainted individuals in social settings. We designed technology to support interactions in a social setting and found that it worked well in these situations. In particular, we found that our system did not hinder interactions but rather helped to create richer interactions. We found that the system was able to have a positive impact on conversations by initiating topics that would not normally occur. The system allowed users to probe people's interest in an indirect way.

Our system is an example of a social computing system that was designed with guidelines from past social computing literature and whose use was explored during several discrete events. These experiences utilizing new technology in social settings have provided a great deal of insight into the design of these types of systems such as the need for critical mass and a stylish design to promote device adoption as well as considering people in the vicinity of technology users in social settings as partial users.

7.4. Future Work

7.4.1. SYSTEMS

We have identified several areas in which the Digital Fashion system could be improved. In terms of the system itself, we can modify the software to take advantage of different hardware platforms as they appear. This allows us to use existing technologies that have a wider user base. Since a large user base is important for the success of the system, adapting to more popular hardware platforms will improve the adoption of the system by new users and make the system more attractive. Some platforms that we have identified include IEEE 802.11 wireless Ethernet for communication, WAP access for better cellular phone integration, Bluetooth radio for communicating wirelessly with the lighting system and LEDs for low power, miniature lighting systems. We want to integrate the public wearable display technology into more comfortable forms of fashion accessories. An example of a good integration is the "Smart" jacket by Dunne [12]. We believe a better hardware system will allow us to make the system more attractive to users. This will make it easier to run more extensive studies to study the effect of shared knowledge in various situations.

7.4.2. USER STUDIES

New studies we would like to run will look at the long-term effects of wearing a public display on social interactions as well as the effect on the user's personality. We would also like to run more focussed studies exploring specific issues uncovered during our user study including:

The reverse power relation: Some users experienced a feeling of vulnerability when using the system to communicate information about themselves. We would like to investigate this interesting effect by varying the user population, length of time using the system and using different social settings.

Viewers as users of a system: We have noticed an interesting social dynamic when we consider the user of our system as the viewer of the wearable display. A deeper examination of this intriguing situation where those around us are thrust into using a system with little or no previous experience can affect and help guide the design of future social computing applications.

References

[1] Alcor Group, The. A*Chat The First Wireless Internet Chat Application for the Cybiko Handheld Computer. Available at: http://devcybiko.com/achat.html

[2] Apache Software Foundation, The. *The Apache Software Foundation.* Available at: http://www.apache.org/ (8 Dec 2001).

[3] Arrow, H., McGrath, J. E., & Berdahl, J. L. (2000). Small groups as complex systems: Formation, coordination, development, and adaptation. Thousand Oaks, CA: Sage Publications, Inc.

[4] Bergqvist, J., Dahlberg, P., Fagrell, H., and Redström, J. (1999) Location Awareness and Local Mobility;- Exploring Proximity Awareness. *Proceedings of The Twenty Second IRIS Conference (Information Systems Research Seminar In Scandinavia)*, University of Jyväskylä Press. 1999.

[5] Bergqvist, J., Dahlberg, P., Kristoffersen, S., and Ljungberg, F (1999) Moving Out of the Meeting Room: Exploring support for mobile meetings. *Proceeding of the Sixth European Conference on Computer Supported Cooperative Work ECSCW'99*, Copenhagen 12-16, September 1999, Pp. 81-98.

[6] Borovoy, R., Martin, F., Vemuri, S., Resnick, M., Silverman, B., and Hancock, C. (1998) Meme Tags and Community Mirrors: Moving from Conferences to Collaboration. *Proceedings of the 1998 ACM Conference on Computer Supported Cooperative Work (CSCW-98)*, Seattle, November 1998.

[7] CadSoft Inc. *CadSoft Online: Home of the EAGLE Layout Editor.* Available at: http://www.cadsoft.de/ (11 Dec 2001).

[8] Color Kinetics Inc. *Sauce: The Coolest Color Changing Lights.* Available at: http://www.cksauce.com/ (

[9] Coolneon. *Coolneon.* Available at: http://www.coolneon.com/ (10 May 2002).

[10] Cybiko Inc. *Cybiko, Inc. - Main Page.* Available at http://www.cybiko.com/ (10 July 2001).

[11] Dryer, D.C., Eisbach, C., and Ark, W.S. (1999) At what cost pervasive? A social computing view of mobile computing systems. IBM Systems Journal, vol. 38(4): 652-677.

[12] Dunne, L., Ashdown, S., McDonald, E. "Smart Systems": Wearable Integration of Intelligent Technology. To appear in *International Centre of Excellence for Wearable Electronics and Smart Fashion Products (ICEWES) Conference 2002*, Cottbus, Germany, December 2002.

[13] Erickson, T. and Kellogg, W.A. (2000) Social Translucence: An Approach to Designing Systems that Support Social Processes. Trans. on HCI, 7, 1, 2000, 59-83.

[14] Erickson, T., D. N. Smith, W. A. Kellogg, M. R. Laff, J. T. Richards, and Bradner E. (1999) Socially Translucent Systems: Social Proxies, Persistant Conversations and the Design of Babble. *CHI 99 Conference Proceedings: Human Factors in Computing Systems*, ACM Press. 1999. 72-79.

[15] Falk, J. and Bjork, S. (1999) The BubbleBadge: A Wearable Public Display. *Extended Abstracts of CHI'99*, pp. 318-319, 1999.

[16] Goffman, E. Behavior in Public Places Notes on the Social Organization of Gatherings. NY: Free Press of Glencoe, 1963.

[17] Holmquist, L.E., Falk J., and J. Wigström. (1999) Supporting Group Collaboration with Inter-Personal Awareness Devices. *Journal of Personal Technologies* 3, 1-2.

[18] Iwatani, Y. (1998) Love: Japanese Style. *Love: Japanese Style.* Available at: http://www.wired.com/news/print/0,1294,12899,00.html (23 Sept 2001)

[19] Klingaman, A. *Luminus.cx 8 Channel Light Controller.* Available at: http://www.luminus.cx/projects/chaser/ (5 Sept 2001)

[20] Kortuem, G., Segall, Z., Cowan G.T. (1999) Close Encounters: Supporting Mobile Collaboration through Interchange of User Profiles. *Proceedings of HUC 1999.* Karlsruhe, Germany, 27-29 September 1999.

[21] Ljungstrand, P., Bjork S. and Falk, J. (1999) The WearBoy: A Platform for Low-cost Public Wearable Devices. *Proc. IEEE ISWC `99*, IEEE Press, 1999.

[22] Macromedia Inc. *Macromedia - ColdFusion Express : Trial Download.* Available at: http://www.macromedia.com/software/coldfusion/trial/cf_server_express.html (12 Dec 2001)

[23] McCaig, G., Fels, S. Playing on Heart-Strings: (2002) Experiences with the 2Hearts System. *Proceedings of the 2002 Conference on New Instruments for Musical Expression (NIME-02), Dublin, Ireland, May 24-26, 2002*

[24] NTN Communications, Inc. *NTN Network Available at:* http://www.ntnnetwork.com/index.html (21 Nov 2001)

[25] Omni Graphics Ltd. PCB's - *Quick turn printed circuit board prototype - Multilayer circuit boards.* Available at: http://www.omnigraph.com/ (14 Mar 2002)

[26] Picard,R.W., Scheirer,J. (2001) The Galvactivator: A Glove that Senses and Communicates Skin Conductivity. *Proceedings 9th Int. Conf. on H.C.I., 2001.*

[27] Phillips. *Vision of the Future: Hot Badges.* Available at http://www.design.philips.com/vof/vofsite3/vof3lev1/badg1/badg1.htm (23 Oct 2001).

[28] Randell, C. Heart On My Sleeve. Available at http://wearables.cs.bris.ac.uk/public/homs.htm (26 Nov 2002)

[29] Redström, J., Dahlberg, P., Ljungstrand, P., and Holmquist, L.E. (1999), *Designing for Local Interaction*, In Proceedings of MANSE '99, Springer Verlag.

[30] Sirichote, W. *Isolated RS232C for PIC18F84.* Available at: http://chaokhun.kmitl.ac.th/~kswichit/isolated/isolated.htm (18 June 2002).

[31] Solberg, G. *RHINO8 EL Sequencer.* Available at: http://www.acmeart.com/greg/rhino/rhino8.pdf (5 Sept 2001).

[32] Want, R., Hopper, A., Falcco, V., and Gibbons, J. (1992) The Active Badge Location System. *ACM Transactions on Office Information Systems*, January, 1992, 10(1), pp. 91-102.

[33] Wireless Application Protocol Forum Ltd. *WAP Forum.* Available at: http://www.wapforum.com/ (6 Sept 2001).

[34] Weilenmann, A., and L.E. Holmquist. (1999) Hummingbirds Go Skiing: Using Wearable Computers to Support Social Interaction. *Proceedings IEEE International Symposium on Wearable Computing (ISWC) 1999*, IEEE Press. 1999.

[35] Weiser, M. The Computer for the 21st Century.(1991) *Scientific American* 256, 3 (September 1991): 66-75.

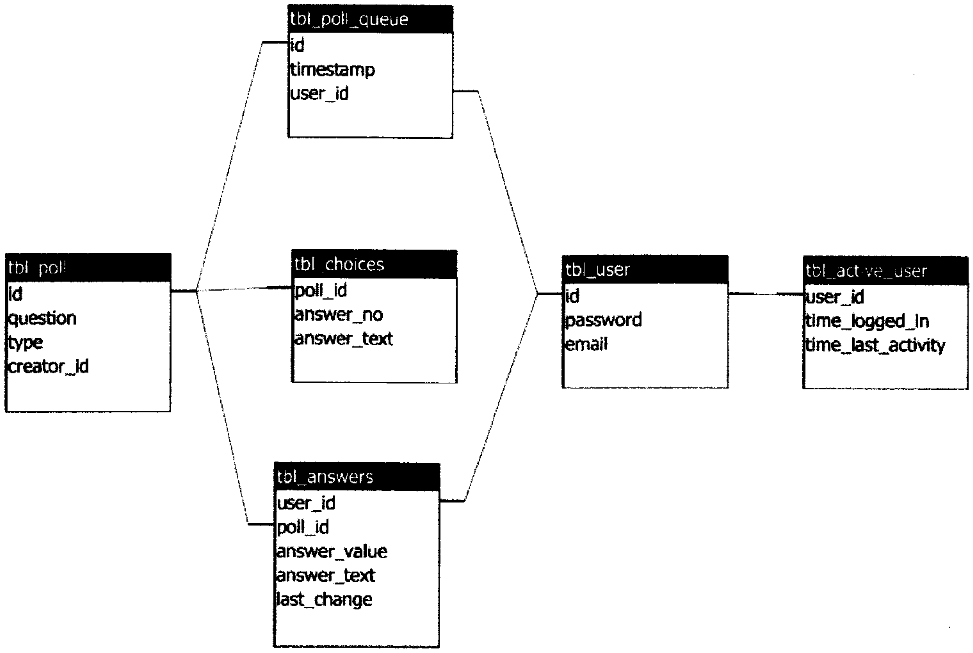
[36] Weiser, M., and Brown J. (1996) *Designing Calm Technology.* Available at: http://www.powergrid.com/1.01/calmtech.html (6 Sept 2001).

[37] Whittaker, S., Fohlich D. and Daly-Jones, O. (1994) Informal workplace communication: What is it like and how might we support it? *Proceedings of CHI 1994 Conference* Boston USA. ACM Press. 1994. Pp. 131-137.

Appendix A

Database ER Diagram

Entity Relationship Diagram for the Pollsrus Database



Appendix B
Wine and Cheese Questionnaire

This pre trial questionnaire is used to the get a view of the composition of the group. We look at the level of introvert / extrovertness, within the group, familiarity with technology and fashion and general topics of conversations. We are also interested in your familiarity with the system as explained to you previously and your knowledge of the other participants in the group.

Background Information

Question 1: Table 1 shows characteristics of introversion and extroversion.

Extroversion	Introversion
Social	Private
Expressive	Quiet
Many	Few
Broad	Deep
Interaction	Concentration
Outward	Inward
Action before thought	Thought before action

Based on these characteristics, would you classify yourself as?

□	□	□	□	□
Very Extroverted	Mildly Extroverted	Neutral	Mildly Introverted	Very Introverted

---

Question 2: In your everyday leisure conversations, what do you usually talk about?

□ Sports I play	□ Sports I watch	□ Economy	Others (specify)
□ Television	□ Local politics	□ My activities	□ ____________
□ Other friends	□ World politics	□ My Family	□ ____________
□ Movies I've seen	□ Local weather	□ School / Work	□ ____________
□ Books I've read	□ Holidays	□ Food	□ ____________

Question 3: Do you use any of the following devices regularly? (Check applicable boxes)

- ☐ Handheld computer (including calculator, Palm, PocketPC, etc.)
- ☐ Cellular phone
- ☐ Pager
- ☐ Digital wrist watch

Question 4: Do you often wear any of the following pieces of clothing/fashion accessories?

- ☐ Ribbons for charitable causes (e.g. AIDS, breast cancer)
- ☐ Remembrance day poppy
- ☐ Sport team jerseys
- ☐ Tattoos (permanent or temporary)
- ☐ Jewelry (Earings, Rings, Necklaces etc.)

Familiarity with the group

This section asks you about your relationship with the rest of the participants.

Question 5: In the boxes below indicate the number of people in the group that fit in the criteria described.

Number of people I have not met before in this group	
Number of people I know briefly in this group	
Number of people I sort of know in this group	
Number of people I know well in this group	

Appendix C

Wine and Cheese Interview Sheet

Did you have fun at the party?

What did you think of the food?

What do you think of Sfu so far?

Was it difficult meeting new people at the party?

Why do you think that is so?

Did you know a lot of people there previously?

Did you tend to stick close to them?

Who introduced you to others?

What topics did you chat about with other people?

What do you think about the other students in the department so far?

What did you like/dislike about the party?

Do you like to go to other parties?

Did you feel left out of conversations, or have nothing to say?

What do you think about the poll questions on the large screen?

Are there any questions you would have liked to see on the large screen?

Are you interested in how people answered the questions?

Do you wonder how people answered each question?

Did you ask people you were chatting with how they answered the questions?

How often did you notice the questions changing?

Roughly how many minutes do you think between questions changes?

Did the poll questions interfere with your normal interactions?

Were you distracted by it?

Were the people talking to you distracted by it?

At what times do you notice the question changing on the screen?

Appendix D
Pizza Party Questionnaire

This post trial questionnaire is used to understand your reactions to the use of the system in the study.

Response to the system

This section asks you about your understanding of the various components of the system after prolonged usage. It could be more extensive use has a negative or positive effect on your reactions.

Please respond to each of the following statements in terms of the degree to which you agree or disagree with the assumptions made. Please indicate your choice by circling the number that most accurately reflects your feelings about each statement.

Question		**Strongly Disagree**			**Neutral**			**Strongly Agree**
1.	I find Pollsrus-on-the-web is easy to use.	1	2	3	4	5	6	7
2.	I understand how to use Pollsrus-on-the-web.	1	2	3	4	5	6	7
3.	Pollsrus-on-the-web is fun to use.	1	2	3	4	5	6	7
4.	I find the Cybiko handheld computer easy to use.	1	2	3	4	5	6	7
5.	I understand how to use the Cybiko handheld computer.	1	2	3	4	5	6	7
6.	The Cybiko handheld computer is fun to use.	1	2	3	4	5	6	7

Question		Strongly Disagree			Neutral			Strongly Agree
7.	I find the Cybiko Pollsrus application easy to use.	1	2	3	4	5	6	7
8.	I understand how to use the Cybiko Pollsrus application.	1	2	3	4	5	6	7
9.	The Cybiko Pollsrus application is fun to use.	1	2	3	4	5	6	7

Familiarity with the group

This section asks you about your relationship with the rest of the participants. It is possible that you have become more familiar with the group after this prolonged interaction.

Question 10: In the boxes below indicate the number of people in the group that fit in the criteria described.

Number of people I have not met before in this group	
Number of people I know briefly in this group	
Number of people I sort of know in this group	
Number of people I know well in this group	

Response to the environment

This section asks you about your response to the environment where lights conveyed information about yourself to others in the room.

Please respond to each of the following statements in terms of the degree to which you agree or disagree with the assumptions made. Please indicate your choice by circling the number that most accurately reflects your feelings about each statement.

Question		**Strongly Disagree**			**Neutral**			**Strongly Agree**
11.	I liked wearing the lights. **Comments**	1	2	3	4	5	6	7
12.	I liked answering the poll questions. **Comments**	1	2	3	4	5	6	7
13.	The answers represented by the lights were easy to understand. **Comments**	1	2	3	4	5	6	7
14.	I felt comfortable answering the questions. **Comments**	1	2	3	4	5	6	7
15.	I liked being able to submit new poll questions to the Pollsrus system. **Comments**	1	2	3	4	5	6	7
16.	I liked being able to queue questions to the Pollsrus system. **Comments**	1	2	3	4	5	6	7

Question		Strongly Disagree			Neutral			Strongly Agree
17.	I would like to use the system again. **Comments**	1	2	3	4	5	6	7
18.	The lights made it easier for me to start conversations with people I already know. **Comments**	1	2	3	4	5	6	7
19.	The lights made it easier for me to start conversations with people I did not know very well. **Comments**	1	2	3	4	5	6	7
20.	I am comfortable showing information about myself using the lights. **Comments**	1	2	3	4	5	6	7
21.	The system made the event more enjoyable. **Comments**	1	2	3	4	5	6	7
22.	The system helped me to interact at the event **Comments**	1	2	3	4	5	6	7
23.	I would use a commercial system if it was available. **Comments**	1	2	3	4	5	6	7

Appendix E

Pizza Party Interview Sheet

How do you feel about wearing the lights?

Was it comfortable?

Do you understand the purpose of the wearable hardware? Can you explain it to me?

Was it effective?

Could you tell what each colour meant?

Did you use notice the lights on other people?

Did their colour affect how you interacted with them?

Did the large display help?

What effect did the large display have on your interaction?

Did the overall statistics interest you at all?

What about individual answers?

Did you answer all the questions on the site? Why not?

How do you feel when the lights tell others people, things about you?

Did you always feel conscious of the light being there?

Was the light distracting? Did it take your focus away from the conversation?

Do you think it helps you to meet people?

Do you think it helps shy people approach you?

Would you be comfortable wearing this light in other settings?

Where do you see something like this being useful?

Was the light in your way? Did it make it difficult for you to move?

Did the beeping annoy you or disturb your conversations?

Did you talk about the same things you did when at the wine and cheese party?

How was this different?

Do you think it would work with a different group of people?

Would you wear something like this everyday?

Did the size of the device bother you?

How else would you improve the device?

What are there things you enjoy / did not enjoy about using the device?

Can you see something like this used in the future?

Tell me something that happened at the party.

Can you tell me the name of each person at the party and something about them you discovered during the party.

Appendix F
Light Controller Implementation Details

The microprocessor reads the signals from the serial port TX line and sets the output lines (RB0 – RB7) appropriately. It receives a single byte, which consists of eight binary digits (bit). Each bit corresponds to a line on the microprocessor. When the bit is high (1) the line is set to the off position. When the bit is low (0) the line is in the on position. The four lines connected to the coloured lights are at position 1, 3, 5, and 7. The microprocessor is capable of controlling up to eight triacs. Each triac in the triac bank is connected to the inverter and the EL-wire. When the input to the triac is set, the triac allows AC current to flow through it from the inverter into the EL-wire. The resistor regulates the power to the triac.

The optoisolator circuit separates the Cybiko from the light system. The optoisolator contains an LED and a photodiode. The LED is driven by the serial port data line (TX line). The photodiode receives light pulses from the LED and allows current to flow through it instead of through the logical inverter. This sets the logical inverter input to 0V and the output to 5V. This signal is then passed into the microcontroller.

Appendix G

Questionnaire Data

Questionnaire data from the Wine and Cheese gathering.

	ID	1	2	3	4	5	6	7**	8**		
	Introvertness *	3	3	3	5	3	5	4	1	3.375	Mean
Topics of Conversation	Sports I play	■		■				■	■	4	Count
	Television	■	■	■						3	
	Other friends	■					■	■	■	4	
	Movies	■	■	■	■			■		5	
	Books	■						■		2	
	Sport I watch			■						1	
	Local politics	■		■				■		3	
	World politics	■		■		■	■	■		5	
	Local weather	■		■				■		3	
	Holidays	■						■		2	
	Economy		■	■		■				3	
	My activities	■	■		■	■		■		5	
	My family	■		■		■		■		4	
	School/work	■	■	■	■	■	■	■	■	8	
	Food	■						■	■	3	
Comp. devices	Handheld					■		■		2	
	Pager									0	
	Cell phone				■		■			2	
	Watch			■	■					2	
Fashion Items	Ribbons									0	
	Poppy						■	■	■	3	
	Team Jersey									0	
	Tattoo									0	
	Jewelry		■		■		■	■		4	
Group Familarit	Not met	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A		
	Briefly	3	1	2	0	8	2	N/A	N/A		
	Sort of know	3	3	2	0	2	8	N/A	N/A		
	Know well	2	2	3	0	0	11	N/A	N/A		

* Higher values mean more introverted. (5 Very Introverted, 1 Very Extroverted)

** Participants 7 and 8 were not obtained until after the wine and cheese gathering. They were asked to fill out this questionnaire after the second event (pizza party).

Questionnaire data from the Pizza Party

ID	1	2	3	4	5	6	7	8	Mean		
1	7	7	6	6	7	6	6	7	6.50	Website	Easy
2	7	7	6	6	7	7	6	7	6.63		Understand
3	4	6	4	6	4	6	5	4	4.88		Fun
4	4	5	3	6	7	6	5	5	5.13	Cybiko	Easy
5	7	6	4	6	6	7	6	7	6.13		Understand
6	5	6	2	6	6	5	4	5	4.88		Fun
7	7	6	4	6	7	6	5	3	5.50	Pollsrus Cybiko	Easy
8	7	7	4	6	7	7	6	7	6.38		Understand
9	5	7	5	6	6	6	5	4	5.50		Fun
10	2	6	2	7	4	3	3	3	3.75	Don't know	
	1	1	1	3	2	0	0	0	1.00	Briefly	
	2	0	0	4	0	3	1	3	1.63	Sort of know	
	2	0	4	0	0	5	3	1	1.88	Know well	
11	6	5	3	4	4	7	4	3	4.50	Liked wearing the Lights	
12	7	7	5	5	5	5	5	5	5.50	Liked answering poll questions	
13	7	7	5	5	6	4	3	7	5.50	Answers were easy to understand	
14	7	6	6	6	7	6	5	7	6.25	Felt comfortable answering the questions	
15	7	7	6	4	1	4	5	n/a	4.86	* Like to submit poll questions	
16	n/a	7	4	4	4	5	5	n/a	4.83	* Liked to queue questions	
17	4	6	4	4	6	6	3	4	4.63	Use the system again	
18	6	7	3	4	5	7	5	5	5.25	Easier to start conversations with people I already know	
19	5	7	4	6	4	7	5	7	5.63	Easier to start conversations with people I don't know	
20	6	5	3	6	4	6	5	7	5.25	Comfortable showing lights	
21	6	7	4	6	6	6	3	5	5.38	More enjoyable	
22	6	7	4	6	5	7	5	5	5.63	Helped me to interact at the event	
23	3	6	4	4	4	6	4	2	4.13	Commercial system	

* Questions 15 and 16 are not applicable if participants did not use the kiosk/web system.

Appendix H

Implementation Issues and Problems

Hardware

Triac resistor configuration – The logic triac is not a common component in electronic textbooks. The configuration of the triac had to be carefully discovered through calculation or by a trial and error method. We learned that in some cases, designing circuits is more of an art than an exact science. We came up with the correct resistor triac configuration after many failed attempts at trying to understand what was really going on.

EL light hook-up – Soldering a delicate hair-thin wire to a thicker wire properly takes a lot of practice. Making this connection survive the abuse it receives as part of the wearable display is even more difficult. Different soldering techniques were tried. We adapted some of these technique and found a process that worked adequately.

PCB design mistake – A mistake in defining the PCB layouts caused one of the components to fit the PCB board poorly. We had to drill the board to make the holes larger so that the pins of the component could pass through the board and be soldered securely. This caused a bit of anxiety but we learned that this is a common problem when designing PCBs and our solution was effective.

Floating ground – The floating ground problem usually occurs when two circuits interfere with one another. These circuits need to be isolated from each other. The problem was not immediately diagnosed in our system. Even after the cause was discovered, some of the solutions proposed were costly and required major modifications to the hardware. We researched similar floating ground problems with different communications protocols such as MIDI and found a way of isolating the Cybiko from the wearable hardware using a basic optoisolator.

Enclosure problem – Hardware enclosures were used to protect our users from damaging the delicate hardware components of our wearable display and light controller. We also needed to protect our users from mild electric shocks that could be discharged from the inverter if wires became loose. We had to fit out hardware components into a plastic case that was slightly too small after the addition of the optoisolator circuit. We learned that we had to design our circuit to fit the enclosure. Since we were not using a custom enclosure the choice of enclosure must be made before layout out components on the PCB.

Faulty triac problem – We found that the triacs had reliability issues due to poor resistor selection or a poor soldering technique. Sometimes the triac would fail causing two lines to be selected at once, or no lines at to be selected. Replacing the faulty triacs solved this problem.

Green/Blue light - During initial user testing we determined that the green on the wearable display was not a pure green. To alleviate confusion, we changed the colour of the bar on the CD Community Display from a pure green to a lighter green, which was more similar to the colour on the wearable display. Testing also revealed some confusion between the Green and Blue light. Some users revealed that the colours looked similar from a distance.

Cybiko

Port socket size – We wanted to use custom cables to connect the Cybiko to the wearable hardware. However we could not source the port socket on the Cybiko. We had to use the serial port cables provided with the Cybiko and remove the DB-9 plug to save on space on the hardware enclosure.

Threading problem – We had problems trying to multithread the Cybiko. We used a timeout while waiting on the message queue in order to divert processor time to polling the serial port.

Server discovery problem – Client Cybikos need a way to find the Server Cybiko. The clients must be able to distinguish the server from other Cybikos around them. We tried several techniques to solve this problem and settled on an undocumented API call used by other Cybiko programs.

Bandwidth problem – The bandwidth problem, discovered from our pilot studies and system demonstrations caused us to rethink the design of the thin-client. We decided to support a minimal set of functions on the client and eliminate some of the features on the Cybiko client for the purposes of our user study. The *Browse* and *Queue* functions were removed, leaving only the *Answer* function. The client was still notified when a new question became active. Our move to a smaller feature set, helped the system's robustness. We could test the system with minimal user interaction. Our tests showed that we could change the active poll question once every minute while supporting eight clients with no bandwidth issues. Other ways to increase bandwidth include using multiple servers to serve more Cybikos or using an intelligent caching and predictive data retrieval mechanism to optimize bandwidth usage.

Appendix I

Sample Interview Data

Interview	User	Time	How we meet people 1	Motivation for meeting people 2	Previous relationship 3	Topics of conversation 4	Poll system Indirect reference 5	Stereotypes 6	Individual preference 7	Misc Interesting 8	Future reference 9	Group size 10	End of conversations 11	Attention to poll system 12	Physical Comfort 13	Psychological comfort 14	Usability 15	System 16	Opinions 17	Suggestions 18	Context 19	Story anecdote 20	Useful 21	Success 21	Text
2	2	3:00																	X				X		Was interested in peoples answers
2	2	5:35																	X				X		Helped me meet other people, Its a good reason to start a conversation.
2	2	5:45																	X				X		Yes it helps shy people.
2	2	6:05																	X				X		Gives you a reason to talk to them.
2	2	10:00																	X				X		but i don't mind.. because if there are other things happening
2	2	10:40				X																	X		Didn't talk about the same things... more academic related. Mostly topic relate
2	2	11:15				X																	X		Common things still happened ; nobody asked about how many courses we'r
2	2	13:20																					X		could be useful
2	1	2:20																					X	X	my attitude didn't change but it gave a starting point for the discussion
2	1	5:50																	X				X		I am shy, i didn't approach any people a lot, it didn't really help me. Other peo
2	1	13:00																			X	X	X	X	computer people tend to be shy and not talkive. and it worked well so for less
2	5	4:05																					X	X	Yeah at one point i spoke to ken because he liked hiking. I started joking abou
2	5	5:05																X					X		I'm somewhat interested in it but not all the time.
2	5	5:10																					X		Individual answers are more interesting to me
2	5	5:30																					X		I didn't answer all the questions, maybe i didn't have enough time. I was just p
2	5	5:50								X								X					X		I was kinda surprised. I didn't know what those lights were for before. Ken told
2	5	8:45																					X	X	Me personally, it would help me meet other people.
2	5	10:20								X						X							X		[would you feel uncomfortable if you were the only one with the light off] No. T
2	3	1:20																					X		more or less it helped people to talk. its new stuff to me, so its helpful i think.
2	3	1:45															X				X		X		When you see someones answer is different from your own, you will ask and
2	3	4:25																X					X		You can see the graphic representation. How many people choose the same
2	3	5:00																	X				X		overal statistics interest me... individual answers.. its ok but people will talk ab
2	3	5:40																X	X		X	X	X		[topic is more interesting than the answer] sometimes they will talk about a sto
2	3	8:50																	X				X	X	yes it helped me meet people.
2	3	21:25																	X				X		i think probably useful in the future. i just don't know what application its gonn
2	6	1:15																					X		yup effective
2	6	1:25																					X	X	its suited very well in initiating conversations, tells you something about that p
2	6	1:50																					X		it succeeded.
2	6	3:55																				X	X		I was quite interested in the statistics. How many picked the same answer as
2	6	4:24															X			X			X		Yes its one thing to know 1 out of th 8 choose a particular answer... its also in
2	6	6:10							X	X											X		X		it helped me meet other people. I think of myself as a little shy.. so with the lig
2	6	12:20			X														X				X	X	i knew 5 of those people from before... i know their name but i don't know thei
2	6	13:30																	X		X		X		i think it would still work the same way.. as well with a different group. people
2	7	1:20																X	X	X	X		X		just to make starting conversations with strangers easier... i think so... there is
2	7	4:35																X		X			X		i guess it (the overall statistics) could have been more interesting if i thought i
2	7	4:50																			X	X	X	X	in general no, the questions were too vague but thats why its a good conversa
2	7	8:20																X			X		X		it didn't help me MEET people but helped me interact with strangers
2	4	4:20																					X		if you know the other person is interested in bicycling or snowboarding then yo
2	4	10:10																			X		X		the reason why i was there, was the project, so it helped yes...
2	8	1:05																					X		yeah i think it helped people to start conversations, it gave them something to
2	8	1:45															X	X					X		knowing the answer to the question allowed you to ask something about their
2	8	3:45																					X		(peoples individual answers) yeah because that allowed me to learn more abo
2	8	8:00																					X		yeah i think so, sort gives you something new to talk about
2	8	9:10																					X		yeah i think so (wearing the lights in other settings)
2	8	14:05																				X	X		the shy guy i didn't get to know...
2	8	18:30																					X		yeah i think so, i could see it being used

Sample Interview data
Each interview was transcribed with timestamps. Each line represents an interesting interview snippet and is categorized along 21 categories of interest. These snippets can be sorted by category and then examined together. When an interesting quote is discovered, the audio for the interview is retrieved from an mp3 version of the interview and transcribed fully.