

Supporting Group Collaboration with Interpersonal Awareness Devices

Lars Erik Holmquist, Jennica Falk and Joakim Wigström

PLAY: Applied research on art and technology, Viktoria Institute, Gothenburg, Sweden

Abstract: An Interpersonal Awareness Device, or IPAD, is a hand-held or wearable device designed to support awareness and collaboration between people who are in the physical vicinity of each other. An IPAD is designed to supply constant awareness information to users in any location without relying on an underlying infrastructure. We have constructed one such device, the Hummingbird, which gives members of a group continuous aural and visual indications when other group members are close. We have used the Hummingbirds in several different situations to explore how they affect group awareness. These experiences indicated that the Hummingbird increased awareness between group members, and that it could complement other forms of communication such as phone and email. In particular, we found the Hummingbird to be useful when a group of people were in an unfamiliar location, for instance during a trip, where no other communication support was available. We argue that IPADs such as the Hummingbird may fulfil important functions in modern work situations.

Keywords: Augmented reality; Awareness; Handheld CSCW; Mobile computing; Ubiquitous computing; Wearable computing

1. Introduction

The work situation in a modern office can be very different from the setting of only a few decades ago. Many workers are not obliged to come to work at specified hours and spend their whole time working at the same desk; instead, they are often much more flexible in working hours and location. Employees may keep variable hours and much time can be spent in meetings, visiting customers, performing fieldwork, or working from home (telecommuting). Some may also have several workplaces that they move between, e.g. an office and a laboratory. At the same time, spontaneous meetings and group discussions continue to be an important factor in work, especially in creative professions. While much communication can now be carried out remotely, via telephone or email, informal face-to-face communication is still very important [1].

A problem with initiating face-to-face communication is the matter of simply knowing where people are. Much time can be spent looking for people in order to initiate communication or call a group meeting. This also makes it important to utilise fully the situations when people really *are* present. Many desktop-based groupware systems support informal communication by conveying awareness of other people's activities, through constantly streaming video images or other means. An illustrative example is the Portholes application [2], where video-images of members of a working group

were transmitted to the participants' desktop workstations at 5-minute intervals, thus providing a continuous awareness of the activities of others. The recent success of a commercial awareness-promoting product, ICQ (<http://www.icq.com>), is an indication of the desire of people to be aware of the (online) presence of colleagues and friends. ICQ users can be notified whenever certain other users are online, and the system, which also supports the sending of short messages, is said to have more than 20 million registered users.

However, solutions such as ICQ and Portholes assume that people spend most of their time at a desktop workstation. If people start moving around, or working from several places, perhaps using laptop computers or Personal Digital Assistants (PDAs), such workstation-based solutions will not work for initiating face-to-face communication or group meetings. Beepers and mobile phones are tools that work regardless of where the user is situated, but these do not provide continuous awareness information. Using a beeper or a mobile phone requires an explicit action by the user, making their effect quite different from a continuously running application such as Portholes, and furthermore they usually only support communication between two persons, not larger groups. A call via mobile phone or beeper can also be disruptive, since there is no way of knowing what activity the person at the other end is engaged in, and for this reason many people are wary of using them when not absolutely necessary.

Based on these observations, we argue that there is a need for an awareness solution that combines the advantages of desktop-based awareness applications – constant, non-disruptive awareness – with the freedom provided with mobile devices such as beepers and mobile phones. We propose that a new class of IT devices, Interpersonal Awareness Devices, or IPADs, be introduced as a solution to the problems outlined above. In the following, we will define the IPAD concept and describe our first experimental implementation of such a device, the Hummingbird. We will then describe some experiences of using the Hummingbird prototypes. Finally, we will summarise the findings and outline some future work in this area.

2. Interpersonal Awareness Devices

An IPAD works as a contact facilitator rather than a mediator. This means that the IPAD is used to help initiate a contact, but not for sustaining the actual communication. IPADs extend the range of awareness provided by our ordinary senses, so that for instance a user may know that a colleague is nearby even though he or she is not close enough to be directly heard or seen. Many groupware applications already perform the same function, but as mentioned they are tied to the location of a user's desktop workstation rather than to the user herself.

From the name, an IPAD can be defined as having the following properties:

- *Inter*: it utilises the relationship *between* itself and other IPADs (such as the distance), thus taking advantage of the user's inherent mobility
- *Personal*: it is *personal*, i.e. an IPAD is identified with its user, and carried or worn at all times when in use
- *Awareness*: an IPAD is used to convey *awareness of others*. It is not used for mediation of the actual communication that may result from this awareness
- *Device*: an IPAD is a self-sufficient *device*, not reliant on any infrastructure except that provided by the presence of other IPADs.

An important basis for the IPAD concept comes from the observation that informal communication may occur whenever people are in the *same* place, but that it does not necessarily matter *which* place they happen to be in. For instance, noticing and talking to a co-worker in a café may be as important

as meeting him or her at the office. Therefore, any solution constructed with the intention of promoting informal communication should, if possible, be usable independently of the physical location.

IPADs do not depend on any installed infrastructure and thus the communication between IPADs will be inherently bi-directional. For such a system to work effectively, every IPAD must send and receive the same type of information, and devices should be able to enter and leave the system as users come and go. Thus, there cannot be any single device that has a crucial function, because if the users move out of range the system would stop working if it depended on any one of the components to function. It would of course be possible to construct a special IPAD that only sends, or only receives, certain information, but this would be closer to a traditional tracking or surveillance system and would not fit our current definition of IPADs.

Note that the IPAD definition is quite open-ended when it comes to functionality; for instance, it does not specify what *kind* of awareness should be conveyed. Typical examples of awareness to convey might be that of a person's level of activity, her mood, if she is available for contact or does not want to be disturbed, what her current task is, etc. Such information may be either set by the user or inferred automatically through some method. Also, the definition does not specify how the awareness information should be presented; it may for instance be through subtle audio, lights, tactile displays, etc.

Apart from the practical function of facilitating communication, the use of IPADs can be comforting. They can be used to convey the sense that a user is not alone or cut off from the group, even when the other members cannot be directly heard or seen. This might for instance be when the user is situated alone in her room or in a crowded public place with many unfamiliar people around. Our usage experiences have shown that this is an important function of our current prototype.

3. Related Work

There is increasing evidence that important workplace collaboration takes place at many places other than at the users' desks [3]. Despite this, applications designed to promote informal communication by increasing awareness have so far been primarily tied to a desktop computer or some other stationary display, although badges that tell a

centralised system about the user's location have been developed (e.g. Active Badges, below). In the desktop-based Portholes system video images of the members of a group were transmitted at 5-minute intervals to increase awareness of the others' activities [2]. @Work provided a combination of video snapshots and other awareness information, some of which was made available via the web [4]. Systems with the purpose of supporting informal communication and awareness but which are not based on video communication include Peepholes [5] and commercial services such as ICQ (<http://www.icq.com>).

Several devices have been developed that use similar working principles to our IPAD prototype, the Hummingbird, but we are not aware of any that can perform the same function. The Lovegety [6] is a commercial "ice-breaking device", intended to match users of the opposite sex, currently mainly available in Japan. The devices come in two different varieties, "male" and "female", and when two devices of different kind are close (c. 5 metres apart) they emit a piercing sound. Additionally, users can choose the preferred type of interaction, e.g. "talk" or "karaoke", and a visual signal indicates when there is a match. The Lovegetys have become a commercial success, but since they only work in "pairs" and support a very short range, they are not very suitable for use as interpersonal awareness devices. A similar system in the research community, GroupWear [7] matched users' interest (as defined by their answers to a questionnaire) and gave a visual indication of how well two users' profiles matched. Meme Tags [8], another application evolved from the GroupWear concept, was used to spread "memes" – short ideas in the form of text, input by the users – in a social setting. GroupWear and Meme Tags do not rely on any infrastructure, but since they communicate using infrared light, they require users to be in direct view of each other, thus not extending the physical range of awareness.

The Active Badge system [9] located users in a building, relying on an infrastructure of sensors. The badges themselves do not communicate directly with each other, making it impossible to use them outside buildings that have the required infrastructure, thus losing much of the flexibility of the IPAD concept. Another system with computationally augmented badges, SmartBadges [10], has been proposed for use as a matching system similar to the GroupWear, with user profiles stored on servers. Although these badges are able to communicate via the Internet, a (nearly) ubiquitous

infrastructure, wireless gateways to the network still need to be in place, making the system in practice only useful in areas where these gateways exist.

4. IPADs in Practice: the Hummingbird

To explore the concept of IPADs we have developed a prototype called the Hummingbird. The Hummingbird is an interpersonal awareness device that supports the *awareness of presence* between individuals in a group. It does this by providing users with an aural and visual indication of which other Hummingbird users are in the vicinity. The Hummingbird functions according to the following simple principles:

- A Hummingbird does not do anything on its own
- If two or more Hummingbirds belonging to users in the same group are close (currently less than roughly 100 metres apart) they will produce a sound – they "hum"
- In addition to the sound, a display supplies the identity of the other Hummingbird users in the vicinity (since there may be more than one user nearby at the same time).

In this way, the Hummingbirds can extend the awareness of presence between users even through physical obstacles like walls and closed doors. With Hummingbirds, it would for instance be possible for a group of users at the same workplace to be aware of each other's coming and going, even if their individual workplaces are not located in such a way that they can always see or hear each other. This might be very useful in modern work situations, where people keep flexible hours and are not tied to a specific location, but where there can still be a need for both formal and informal meetings when the opportunity arises. Hummingbirds might also promote informal communication outside the workplace, since they do not rely on any infrastructure and can thus be used at all times.

After determining the desired functionality of the Hummingbird, we needed a way of realising the concept through a prototype. Direct short-range radio communication between the devices seemed to be the best option. As a proof-of-concept, we built a first generation of prototypes. These were large, unwieldy circuit boards that did just one thing: when they got within a certain distance of each other, they produced a sound.

These prototypes were too large to be comfortably carried but they did demonstrate the viability of the concept. The prototypes also gave us the opportunity to experiment with operating ranges, which would be very important for a successful realisation of the Hummingbird concept. We soon found that standard radio components have such a high operating range that we had to artificially lower it, by measuring the strength of the signal and introducing a cut-off point. In this way, we could adjust the range of the prototype so that it was anything from a couple of metres to several hundred metres. After some experimentation, we settled on a range of about 100 metres as suitable for triggering the Hummingbirds.

We now had sufficient knowledge to build a second generation of prototypes, of which four were constructed for evaluations purposes. This device was now much smaller (Fig. 1); even with the addition of a power source it was no larger than a modern mobile phone. The prototype consisted of a circuit board with a micro-controller, a 2×8 character LCD screen, a miniature speaker, and a radio transceiver operating on the 433.92 MHz-band. It was powered by a set of rechargeable batteries, and would operate for 10–15 hours on each charge. For convenience, we used a type of “holster” designed for mobile phones as carrying cases (Fig. 2). Two switches were provided: one for turning off the sound without affecting other functionality; and one for turning the device on and off completely. Each Hummingbird was programmed to continuously transmit an identification code, while simultaneously listening for the codes of other Hummingbirds in the vicinity. It would have been possible to program the devices to transmit different codes to form several separate groups, but with only four prototypes we saw little reason to do it at this stage.



Fig. 1. The Hummingbird prototype.



Fig. 2. The Hummingbird in its carrying case.



Fig. 3. The Hummingbird display. This device, a, has detected devices b and d. The arrow indicates that device d was the latest one to be detected. The numbers are an indication of signal strength, used for debugging purposes.

Since the size of the display forced us to keep the names of the devices short, we named them a, b, c and d. Figure 3 shows a close-up of the Hummingbird display, in this case indicating that two other Hummingbird users can currently be found in the vicinity. (Some numerical information on signal strength and an arrow pointing to the letter of the latest detected device, which was made available for debugging purposes, can also be seen in Fig. 3.) Users would be given a specific Hummingbird, so that when the devices were active, each user was associated with the name of the corresponding Hummingbird. We found that when

properly briefed, users very quickly started to associate the letters with the person carrying the corresponding Hummingbird. The display proved especially useful when the surroundings were too noisy for the Hummingbird sound to be heard, or when users were in a situation where they had to turn off the sound so as not to disturb other people.

5. Usage Experience

With four working prototypes, we were able to use the system in a number of different settings. Our aim was to attempt to incorporate the Hummingbirds into everyday situations, to find initial indications of how well they performed their intended purpose. It should be pointed out that the experiences described below were not intended as strict evaluations of the Hummingbirds. But although these results can at most be viewed as anecdotal evidence, they are examples of the system in real use, and we think they give some interesting indications of the effect IPADs may have on group communication.

In all situations described below, the user groups consisted of both people familiar with the Hummingbirds and novice subjects with no prior experience with the prototypes. We have grouped the experiences in two frameworks, which we call *familiar* and *unfamiliar* settings, respectively. We are aware that these definitions are not exhaustive and that there are many borderline cases, but they work reasonably well for the experiences that we will describe in the following.

- *Familiar setting.* We define a familiar setting as an environment in which a person spends a significant amount of time, together with mainly the same group of people. In a familiar setting users will know most of the people around them, and keep in casual contact with them throughout the day. Typical examples are in the home, together with family and friends, and at an office or school, with colleagues or classmates.
- *Unfamiliar setting.* We characterise an unfamiliar setting as a place or situation in which a person has rarely or never been. In an unfamiliar setting it is easy to get lost, physically or mentally, and for this reason it may sometimes require a great deal of effort to maintain contact with accompanying friends. Examples of this may include travelling abroad, visiting someone else's workplace, or at a large gathering of people such as a conference.

5.1. Familiar setting

The office: In the building where the authors work, the offices are scattered across several floors. This makes it difficult to know when others are present, and people are often reluctant to make a trip through several floors or to the other end of a long corridor just to find out if someone is present. Emailing or using the telephone can often help, but further complications are added by the fact that people may be at work but not in their rooms – they might be in meetings, tinkering in the laboratory, having coffee in the kitchen, etc. For these reasons, we thought that our own offices would provide an interesting opportunity for using the Hummingbirds in a familiar setting.

Four test participants carried Hummingbirds for a full working day, bringing them with them when they arrived at work in the morning and using them as they saw fit throughout the day. The only requirement was to keep the Hummingbirds powered-on at all times. Despite working on the same project, the participants had offices located on three different floors in the building, a condition that we already knew decreased their awareness of each other. The strength of the Hummingbird signal was sufficient for users to know of the others' presence in the building, even when they were separated by several floors.

At the beginning of the day, users tended to actively monitor their Hummingbirds. There was a novelty value just in looking at the display to see who was present, and to take little walks around the building to see the effects. Soon, however, the first surge of interest waned and the Hummingbird would drift to the background of the user's attention. When in their offices working and concentrating on other things, the participants did not actively watch their Hummingbirds (Fig. 4). Only when there were distinct changes in activity would the Hummingbird be moved into the foreground of attention, for instance during hours of the day when people moved in and out of the building more frequently.

We found that in a familiar setting, the awareness information from the Hummingbirds was useful but not crucial. Users do not necessarily expect to meet the person they have established "Hummingbird contact" with. However, when they do need to find out if another user is present the Hummingbird allows them instantly to do so. Even if the other user is not in his or her office, just the ability to know if someone is in the building makes it easier to initiate contact, since there are



Fig. 4. In the office the Hummingbird was mostly in the background of the user's attention.

only so many places in which to look. We did see some tendency for the four users to increase their informal interaction during the day, which we credit partly to the Hummingbird functionality and partly to the novelty of the experiment itself. Further long-term studies would be needed to confirm this effect.

From this study, we saw evidence that in a familiar setting Hummingbirds can work as a form of “calm technology” [11], which does not demand the user's undivided attention, but can be acted upon when needed. However, although we saw some effects on the interaction between users, these were nowhere near as strong as those found in the unfamiliar settings.

5.2. Unfamiliar settings

We used the Hummingbirds in two settings that we classify as unfamiliar: at a large rock music festival, and at a major academic conference.

The rock festival: The annual rock festival in Roskilde, Denmark attracts around 80 000 visitors from all over the world. The event lasts for 4 days and offers a great variety of live music and other attractions. The festival is set in a very large and at times extremely crowded outdoor area, where it can be hard to maintain contact with companions. Here, we wanted to test the range and rate of contact of the Hummingbirds in a realistic outdoor environment and under realistic but semi-controlled conditions.

We considered it necessary to introduce some limitations in both time and space. The time limit was partly due to battery performance and the fact that once the batteries were discharged, we had no possibilities of recharging them on site. We also realised we could not let users carry the Hummingbirds with them at all times, since the devices would probably break or disappear as soon as a user decided to watch a crowded performance or engage in some other typical festival activity. We limited the test to a predefined subsection of the festival area, to increase the chances of establishing contact during the experiment. A roughly defined space, about 1.5 kilometres in diameter, was designated as our test area. The area was quite crowded in places and contained a variety of different attractions. The test was carried out during one afternoon, for a total time of 4 hours. Participants were told to wander around the test area and take notes of the time and place when a Hummingbird contact was established. Apart from this, the participants were free to use the information provided by the Hummingbirds in any way they wanted to.

After the test, some users said that the Hummingbird seemed to promote a feeling of “connection” that was quite unusual and not easy to explain or describe. The participants reported a clear sensation of connection with other users whenever their Hummingbirds established contact. When the Hummingbird contact was interrupted, and the other person disappeared out of range, the sensation of disconnection was just as evident. The participants often attempted to establish visual contact with other users that they knew were nearby, but soon found that a Hummingbird in itself does not always give enough information to locate a person. The users expressed occasional frustration when a person who was visible on the Hummingbird display could not easily be found. However, the Hummingbirds did give an indication whether it was worth looking for a person or not, which in most cases seemed to be enough, especially when contact was established in a fairly open space. Despite the occasional frustration, however, users were not certain that they wanted the Hummingbirds to give away any more information about distance and location, since they felt that this might be a breach of privacy.

Importantly, it was very evident that all of the participants enjoyed using the Hummingbirds! All participants talked positively about the experience, confirming that using the system has entertaining as well as practical benefits. Our conclusion from

this experience was that Hummingbirds can work quite well in an outdoor setting where a group of people want to act independently, yet keep some contact with each other. We will avoid any attempts to explain the feeling of “connection” between users, and only note that it was quite evident that the Hummingbirds affected the communication in the group in a positive way. These findings were further substantiated by our final experience with the prototypes.

The conference: The annual ACM SIGGRAPH conference on computer graphics and interactive techniques is a combined academic conference and commercial exhibition, which attracts 30 000–50 000 visitors. In many ways it is surprisingly similar to a rock festival, since it too is a huge, sprawling environment with many things happening simultaneously. We brought three Hummingbirds to SIGGRAPH’98 in Orlando, Florida (the fourth device being in a state of early retirement after the Roskilde experience). The test subjects were staying at three different hotels, but met regularly during the conference. They used the Hummingbirds extensively during the first few days of the conference, until the prototypes started to falter from the Florida heat and humidity.

As with the rock festival experience, the users found the Hummingbirds great fun to use, and started to rely on them to a surprising extent. When carrying a Hummingbird in the conference area, users would often check the display to see if someone else was close. When coming to a predetermined meeting point, users would check their Hummingbirds to see if anyone else was there already. Although obviously a novelty even after several days of constant use, users soon allowed the Hummingbirds to complement other activities in a quite natural way.

The most interesting situation turned out to be when all three users attended a conference reception without having made any decision on which time to arrive. The first user who arrived at the reception could instantly determine that the others were not there yet, and rather than wasting time looking for his friends in the crowd, could concentrate on eating good food and chatting with other acquaintances. When the second user arrived, he immediately knew whom to look for, and found the first user almost immediately. When the third user arrived, she could see that both of the others were already there, and described the feeling as very comforting – “Oh good, I’m not alone!” – even though she had not yet seen any of her friends.

We found that in this setting the Hummingbirds added noticeably to the enjoyment of the evening.

This test strengthened our impressions from the festival experience, in that it showed that Hummingbirds were both enjoyable and practical to use in an unfamiliar setting. Although the devices eventually broke down and we had to cut the experiment short, we felt that this experience indicated that long-term use of the Hummingbirds is viable. When the Hummingbirds started to malfunction and the experiment had to be abandoned, we found that the users genuinely missed the little “birds”!

5.3. Conclusions from the usage experiences

The most obvious conclusion from using the Hummingbirds was that although they seemed to have the potential to be useful in the office environment, users did not find them as immediately compelling to use in the familiar setting as in the unfamiliar settings. A reason for this could be that in the unfamiliar settings there was little other support for communication, even though such situations may be exactly those where users feel the need to communicate the most. With Hummingbirds, a comforting “link” to other people was created, which gave the devices a much higher short-term impact in this setting than when there was more communication support available and where the users felt more at home.

There was less initial enthusiasm for using the Hummingbirds in the office setting, but this test was very limited and we believe there is much potential for using IPADs in a variety of work situations. It is possible that if IPADs were to be used over a longer period of time, thus providing users with the opportunity to rely more fully on them in their day-to-day activities, they could prove a useful supplement to stationary awareness applications such as ICQ.

6. Future Work

We have already constructed a new generation of Hummingbirds, which is more robust and flexible. These are based around a pre-existing hand-held computing device, the Nintendo GameBoy, which has been equipped with a radio transceiver and custom software. This construction, which is easier to produce and modify, will allow for some long-term

and large-scale evaluations of the IPAD concept. We also intend to integrate the IPADs with traditional data networks, including the Internet, so that services such as ICQ may be complemented with IPAD functionality and vice-versa. Increased functionality will also allow for more advanced uses of the devices, including the specification of several different groups who can use the IPADs independently, allowing for much larger groups of users without conflict.

Formal evaluations will be needed to establish the potential usefulness of the Hummingbird and other IPADs, and to understand fully the effect that such devices can have on the communication within a group. These evaluations should include both close studies of groups of people using IPADs in unfamiliar settings, such as during travel, and long-term studies of the use of IPADs in familiar settings, such as an office or other workplace. Some kind of ethnographical method might be suitable for observing users in these settings, complemented with interviews to gauge their subjective reactions to the experience.

For a device that is to be carried and used at all times, the form factor is very important. We are currently working with an industrial designer and a jewellery designer to find new forms that would allow IPADs to be seamlessly integrated with personal clothing and accessories. Figure 5 shows some proposed shapes. It is worth noting that these designs are noticeably smaller than any form of currently available mobile communication technology, something made possible by the fact that an IPAD should require very little user interaction apart from an on/off switch. In relation to the design aspect it might be interesting to work with other modalities than sound and vision, in particular haptics. Novel concepts for haptic communication such as HandJive [12] and inTOUCH [13] might provide inspiration for new forms of IPAD interfaces.

In a broader perspective, it will be important to examine how the use of IPADs might change the way we work and communicate. Will constant



Fig. 5. Concepts for future IPADs (design by Jona J. Bjur).

awareness information lead to “technostress”, or will people learn to turn their IPADs off? If IPADs become popular, the development of their usage will most probably mirror that of the mobile phone, which is still in the stage of becoming naturally integrated in the daily life. A convergence of PDAs, mobile phones and IPADs may be a likely future for mobile work.

7. Conclusion

We think that it is important to open up our thinking about awareness in collaborative work, and move from traditional desktop-based applications to the mobile solutions provided by IPADs and other handheld CSCW devices. Since people will work in different places and the line between work and social life will probably blur even more in the future, the solutions that are provided should be flexible and not just tied to a specific workplace. We believe that the IPAD concept represents an avenue worth pursuing when continuous awareness of others is needed, both in traditional settings such as an office and in mobile settings. IPADs also provide solutions to some of the privacy and security issues that arise from other similar solutions, such as Active Badge, since they are not reliant on any centralised information processing and there is no persistence of the location information they provide.

Our experience with the Hummingbird prototype shows that IPADs can be useful in a variety of situations. In our preliminary experiences, Hummingbirds were more appreciated when used in unfamiliar situations such as trips and conferences than in traditional office situations. This may be in line with the changing nature of work and the increased mobility that technology is making possible, and we think that it is quite natural that our experiences indicated that the devices fit well into such situations. However, we also think that IPADs also have the potential to become useful in many current workplaces, especially since these often permit a high degree of local “micro-mobility” that means that alternatives to desktop-based solutions will be needed. We believe that Hummingbirds and other IPADs may prove to be a useful tool for supporting group collaboration in the future.

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Correspondence to: Lars Erik Holmquist, PLAY: Applied research on art and technology, Viktoria Institute, Box 620, S-405 30 Gothenburg, Sweden. URL: <http://www.viktoria.informatik.gu.se/groups/play/> Email: leh@viktoria.informatik.gu.se