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A Handle on What's Going On: Combining Tangible Interfaces and Ambient Displays for Collaborative Groups

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ABSTRACT
While tangible interfaces open up new possibilities for input and interaction, they are also interesting because of the ways in which they occupy the physical world just as we do. We have been working at the intersection of three research areas – tangible interfaces, ambient displays, and collaboration awareness. Our system, Nimio, uses engaging physical objects as both input devices (capturing aspects of individual activity) and output devices (expressing aspects of group activity). We present our design and experiences, focusing in particular on the tension between legibility and ambiguity and its relevance in collaborative settings.

Author Keywords: Ambient display, passive awareness, group awareness, tangible interfaces, embodied interaction.

ACM Classification Keywords: H5.2 [Information interfaces and presentation]: User Interfaces.

INTRODUCTION
Ubiquitous computing applications reimagine the everyday world as a site for interaction. Where traditional interaction has been bound to personal computers and desktop environments, the move of computation into the world means that the physical environment itself becomes an interface to a diffuse coalition of computational devices and services. The everyday world is, however, populated by other people, objects, and activities. This suggests that one important area for ubiquitous computing system development lies at the intersection of ubiquitous and collaborative systems. Significant research questions in this area remain to be answered. Some of these include, how can ubiquitous technology be used to support group cohesion and interaction? How can people understand the operation of augmented spaces? How can collective behavior emerge in interaction mediated by ubiquitous computing technology?

Motivated by these questions, we have been experimenting with simple devices that can be used to maintain informal contact and interaction for distributed groups. Nimio is a system comprising a series of physical objects designed as individual playthings, but wirelessly networked to act as both input and output devices for a collective visualization of distributed activity (see Fig. 1). These hand-held, translucent silicone toys have embedded sensors (for input) and LEDs (for output) that allow them to be reactive to both sound and touch. Action around one Nimio will cause the others to glow in different patterns and colors. The interaction design is deliberately open-ended, in order to allow the emergence of distinctive patterns of collaborative engagement in real groups. This tension between legibility and ambiguity is a central aspect of our design.

Figure 1: Nimio in its natural habitat.

Background
The research presented here, and the devices that have resulted from it, draw upon and combine previous research into three primary areas – passive awareness, ambient displays, and tangible interfaces.

Passive Awareness
Although early CSCW research focused on the formal, task-oriented aspects of collaboration (e.g.. Glance et al,

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1996, Streitz et al., 1994), it rapidly became clear that computer systems could also usefully support the informal aspects of collective interaction. For instance, IM is not a collaborative technology in itself, but supports collaboration as part of a broader ecology of tools. IM's messaging component supports informal interaction, quick questions, and social chit-chat; at the same time, the presence indicators visualize individual and collective presence (Nardi et al., 2000). The range of mechanisms by which this is achieved have generally been glossed as "awareness."

Embodied action in space is critical to studying how groups maintain an informal connection and understanding of mutual activity. Heath and Luff's (1992) classic study of London Underground controllers shows how they coordinate their actions so as both to display and to monitor the activities in which they are engaged, through the ways in which they share a physical space within which these actions are performed. Audio-video environments have attempt to reproduce aspects of this experience for distributed groups, but everyday interaction takes place in a three-dimensional space, not on a two-dimensional plane, and so communicative gestures, for example, lose their interactional effectiveness on a screen (Heath and Luff, 1991).

Ambient Displays

One approach that attempts to deal with some of these problems is to move the source of interaction back out into the world. A number of researchers have noted the ways in which people interpret the rich cues that they find in the everyday world as a means to understand activities around them, and have begun to explore the ways in which the everyday world can be used as a medium for display. There are two key elements to this work – a focus on passive understandings, and a focus on ambient information. These are related but different concepts. By stressing passive understandings, some research draws attention to the ways in which information may be provided to users without explicit effort on their part, perhaps serendipitously encountered in the course of interaction. This may encompass passive awareness displays based on "push" models (e.g. Dourish and Bly, 1992; Fitzpatrick et al., 1998), or it may suggest approaches that annotate information objects with indicators of activities that others have performed, in much the same way as physical objects carry markers of previous activity (Höök et al., 2003; Hill et al., 1992). Relatedly, a focus on ambient information considers the ways in which information can be conveyed in the environment, through the use of peripheral cues such as background sounds, light levels, etc. The primary consideration here is the way in which information display features as an aspect of the environment. Ambient displays, however, have largely operated as just that – displays, concerned primarily with output. While some have augmented these displays with devices such as video cameras or RFID (e.g. Sawhney et al, 2001), these have largely been efforts in local information customization. In contrast, our focus on collaboration requires that we be concerned also with the displays as input sites.

Tangible Interfaces

One source of inspiration is Brave et al's (1998) "InTouch," which uses wooden rollers connected to both sensors and actuators to create a shared physical experience across distance, and hence to provide a tangible channel for communication between two parties. Its design is simple and compelling, but, while it supports potentially sophisticated interaction between two people, it has no support for broader engagements amongst distributed groups.

Research on tangible interfaces, particularly in collaborative settings of this sort, suggests that they might provide an effective mechanism for combining ambient displays with social connection through activity awareness. The system we have developed, Nimio, is designed for this purpose. Our previous research has suggested that the local environmental and organizational context is a critical issue for ambient display design. We will begin by outlining aspects of this approach, and then discuss our field studies of the group and the space into which Nimio is to be introduced.

CONTEXT-SPECIFIC AMBIENT DISPLAYS

In our previous work we outlined several considerations for the design of ambient displays (Brewer, 2004). Primarily, we stressed the importance of context. Naturally-occurring sources of ambient information are in a sense ideally suited for their situations. Both the sound of rain and shadows from the sun are inherently wed to their location; hearing rainfall means that it is raining *right here*. They are integrated into their surroundings, or rather, they constitute the surroundings. These displays are part and parcel of the information that they convey. However, that information also can be interpreted to have more complex connotations. From seeing many people on the street in the business district of a city, for example, one may infer that it is lunch time or quitting time. This is a crucial feature of these displays: their ability to support inference of more complicated or nuanced situations. Our framework highlights the situated nature of information and inference.

It also emphasizes that the display must address a need, however subtle or currently unacknowledged, while remaining flexible enough to be adopted into the user's lifestyle as they see fit. This is achieved not only by choosing carefully the information to display, but also by understanding *how* that information figures into the users' daily practices. To this end we have developed several design considerations (Table 1), in the form of elucidatory questions, which provide a rationale for choosing certain methods of display based upon the various features of the information.

SITE STUDY

Our principles suggest that any design effort must begin with a detailed examination of current practice. We worked with a group of ten people who manage a multi-disciplinary information technology research institute. They reside in two spacious suites across the hall from each other. Another member of the group has an office on another floor; as facilities manager, his job requires him to roam about the building. This group was the first to occupy the new building, having recently moved from a single, cramped hallway in another building. In their new area, the larger of their two suites contains six offices, a conference room, a reception area, and a multi-purpose copier/coffee/mail room; the

- *Is the Information Dependent Upon the Context?*
- *Is the Information Specific to a Certain Group?*
- *Is the Display Meant to Be Interactive?*
- *How Does the Ambient Information Relate to Other Information and Information Practices?*
- *Is the Primary Purpose of the Display to be Aesthetic or Informative?*
- *How Rapidly Does the Information Change?*
- *Is the Information Already Displayed in Some Way or is it Intangible?*
- *Does Past Information Persist in the Present?*
- *Is the Physical Location Cohesive or Fragmented, Mobile or Static?*

Table 1: Ambient Display Design Considerations

smaller annex has four offices and a reception desk. Impromptu social gatherings tend to happen in the multi-purpose room.

Although the group is influenced by the space they occupy, the social topology of the group is continually changing, as they often work in smaller subgroups depending on the current project schedule. Their office layout is not necessarily optimal for collaboration, so they are highly mobile, traveling both within and outside of the office suites. They estimated their trips across the hall to see colleagues in the other suite in dozens. Thus, the context for the display is primarily influenced by both the group's social and spatial configurations.

We observed patterns of the users interacting with and through the environment, and conducted semi-structured ethnographic interviews with most of the group members. Interview questions focused on daily work routines, collaboration with colleagues, and use of physical artifacts for both work and decorative purposes.

Collaborating around Artifacts. Several people described day-to-day work that was outside of their job descriptions, things they did to "help out" until more staff were hired. One effect of this flexibility of duties was that people did not work with fixed groups. Certainly, some sets of people worked closely and consistently together, but none of these sub-groups worked in isolation. In describing their tasks, some interviewees pulled out calendars, paper documentation, spreadsheets, and floor plans. In one notable instance, a spreadsheet of tasks served not only as a to-do list, but a reminder that she was planning a great deal of collaboration with a particular colleague over the coming weeks. This document that had his name all over it served as a low-tech long-term indicator of his presence.

Collaboration and Interruption. Perhaps more striking than the content of the interviews was the fact that every interview we conducted was interrupted at least once by a colleague checking the availability of the interviewee. Two interviewees reported calling first to see if the other is available, though when this happened during the interview, she let the phone ring and the colleague checked on her in person anyway. Incidents such as these, as well as comments made during interviews, led us to believe that one advantage of their previous cramped quarters was that they allowed peripheral awareness of each other's presence. From one group member:

> "When we were in [our old offices] we were in close proximity, so it was very easy to know where people were or if they were on the phone or if they were talking with somebody else or if they were out of the office... But in here, now that we're separated into two suites, it's difficult because there'll be times where I don't want to call someone on the phone I want to talk to them in person, so I'll walk over there, and I'll have another excuse to go over there for coffee or whatever, and I'll find that they're either on the phone with somebody or they're not there… So that's… you end up making five trips for the one trip."

Furthermore, we were intrigued by the way in which the group chooses to portray itself. They consciously present themselves as a tight-knit and heavily collaborative group. They go out to lunch together, don matching shirts emblazoned with the institute logo for building functions, and tell us in interviews how close they are.

Artifacts and Ornaments. This closeness is also reflected, on occasion, on the physical objects in the environment, which were a particular focus of our attention. At our first visit on site, most group members had similar jasmine blossoms in each of their offices (see Fig. 2). We were told later that one member had brought in several clippings from the same bush to share with her colleagues.

Figure 2: Jasmine Blossom Distributed Display

Though theirs are not technical positions, the members of the group present their organization's innovative technology to visitors on a daily basis. This being the case, it is in their interest to project a certain technophilic image to visitors, which is currently done in part by the office's décor. In the waiting area stands a large plasma disc that responds to voice and touch with moving bolts of colored light. In interviews, several group members expressed an interest in objects or displays that could serve as "talking points" for newcomers, though at the same time they did not wish for distractions from their day-to-day work.

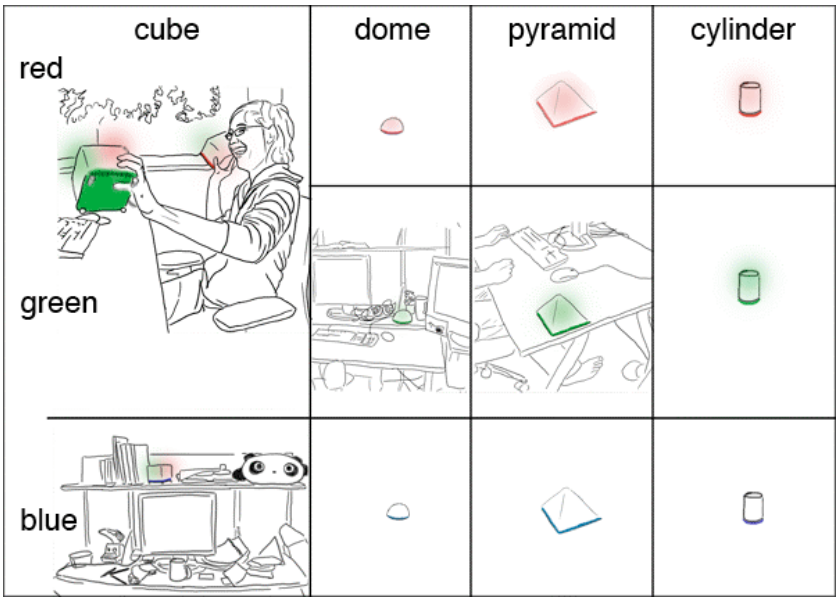

Figure 3: One possible interaction with Nimio

A CONTEXT-SPECIFIC DESIGN

The goal of our observational work was to understand the opportunities and parameters for informal collaboration support in this setting. Clearly, the move from a common space to a larger distributed space has introduced problems for the group. Some of these are purely coordinative, such as knowing when people are around and knowing when they might be available. However, we were struck too by the sense of closeness within the group; an important goal then is to support not just coordination but cohesion. So this less formal element was a critical design issue. It was notable that this cohesion was expressed not least through physical objects. Finally, we noted the importance of providing them with the means to demonstrate to visitors that their organization fosters innovative and aesthetic technology. This trio of coordination, cohesion and comportment became the focus for our design process.

Our studies suggested that the information which would be most beneficial and suitable for display would be the activities of the other group members. Activity, however, is not a trivial thing to capture and express. Some other displays attempt to monitor the amount of work the members of the group are performing and then display the activity as an availability level based upon the work being done. From our observations though, it seems that the users are more attuned to the inverse: they were used to having an awareness not of each others work but of all of each other's attendant activities. They inferred what one another were doing from observing the peripheral cues of each other's actions within the workplace. Understanding how busy or free another person is is not a straightforward operation; one must learn their co-workers patterns of behavior and the peripheral signs which result from those behaviors. Thus, the peripheral information which they previously relied on was not a clear representation of work level, in fact it could vary from person to person, but rather it was a channel through which the group became accustomed to expressing themselves and learning about each other. This channel, then, does not reflect activity level as a scale of interruptibility, and so work done on recovering interruptibility (e.g. Fogarty et al., 2004) is not sufficient for this application as the group is accustomed to communicating and understanding richer information about the nature of each other's activities.

We then set out to examine that information with our framework and to try and develop a method to gather and display it. In this section we will give a detailed account of the way in which Nimio works and highlight, when applicable, the questions of the framework that influenced our design decisions.

How Nimio Works

The system is a set of 12 touchable translucent white silicone toys that can detect when there is sound around them and when they are being moved. They transmit this information to each other wirelessly, and display it via red, green and blue lights.

A single Nimio is defined by its shape and its color. There are four shapes (pyramid, cube, dome and cylinder) and three colors of bases and lights (red, green and blue). Each Nimio can *display* all three colors, but can only *trigger* distributed display of the color on its base. Each toy is a unique combination of a shape and color (e.g., there is only one "red cube" or "blue dome"). These two properties create two types of "family groups," shape groups and color groups (e.g., "dome Nimios" or "blue Nimios"). The family groups and the type of interaction detected govern they way in which information is displayed on the Nimios.

Nimio can detect and display sound and two different levels of movement. If any Nimio detects sound around it, *all* other Nimios pulse their matching light in rhythm with the sound. So, for example, if a cube-shaped Nimio with a red base senses sound *all* other Nimios will display red.

Next, a Nimio detects when it is being moved gently. This activity will *only* be displayed by Nimios of the same color *or* shape as the sensing Nimio, and it will be displayed as a steady pulsing at a frequency of one pulse per second. So, if the red cube is moved gently, all cubes and red-based

Nimios will slowly pulse red, but, for instance, the green-based pyramid will not pulse.

Finally, a Nimio detects when it is shaken vigorously. This activity will also *only* be displayed by Nimios that share its shape or color, as a solid light for 5 seconds. For example, if the red cube is shaken, all cubes and red-based Nimios will light up solid red, but, for instance, the blue-based dome will not be affected.

Example Interaction

Figure 3 depicts an example scenario of how Nimio might be used, showing all of the Nimios in the system and their reactions. Prairie-Dawn has two Nimios in her hands, the green and red cubes. In a moment of whimsy, she gently wiggles both Nimios like maracas. The red and green cubes detect this fidgeting and transmit this signal to the other Nimios. As a result all three of the cube-shaped Nimios begin pulsing red and green because fidgeting is detected within the same "shape group." The red-based pyramid, dome and cylinder pulse red because fidgeting is detected within the same "color group." Likewise, the green-based pyramid, dome and cylinder pulse green. The blue-based pyramid, dome and cylinder *do not* light up because they are not in the same color or shape group with either of the two Nimios that have been fidgeted with. Oscar, who currently has the blue cube atop his desk above his monitor, knows from experience that the steady, rhythmic pulsing he sees means that someone is fidgeting with the red and green cubes. Oscar frequently stops by Prairie-Dawn's desk so he knows that she has the red and green cubes. He chuckles to himself figuring that she is fooling around a bit, and decides he will go and see what she's up to, since he is a bit bored himself.

Design Rationale

Because we were trying to create a socially and spatially situated channel of information, we were acutely aware of the dangers of violating existing social practices. We decided to support inference rather than try to represent something more specific. Instead of supposing that we could know *a priori* what cues and actions were most significant for the other members of the group, we choose to create a medium that would support a more ambiguous set of behaviors. We felt that a limited and explicit modality of input and output would constrain the users in ways that would force them to be more focused on the system itself instead of developing a new way of becoming attuned to one another.

To this end we chose to base our system around a set of toys. Even if they have some predefined mode of interaction, toys are typically re-appropriated by the user for whatever purpose they see fit. It is not taboo or unusual to do so, and by designing a toy we are trying to draw the users away from thinking of our system as a tool which they can only use in a certain way; we are encouraging them to explore the capabilities of the system. Additionally, because the toy is both the means of input and output, the disjunction between monitoring and display is erased. We hoped the users would not feel as if they are being watched, but rather feel similarly to how one feels as they are moving physically through a space, aware of the effects their presence has on others, and in control of those effects.

We chose to allow the users to identify themselves with the toy, rather than identifying the toys with a specific office or user. By allowing the users themselves to constitute the context and negotiate the configuration of that context by means of exchange of the toys, we are giving them the power to represent the workplace as a social space rather than a physical one, and we are transforming the problem of representing individual activity into one of group flow. Also, the fact that the users must actively maintain a mapping between themselves and the space they inhabit supports the behaviors they are accustomed to engaging in.

Our three levels of interaction – sound, fidgeting, and shaking – and the shape and color resonances are meant to support the different types of working relationships to which our participants were accustomed. We treat fidgeting and shaking as a more intimate gesture than the widely broadcast sounds, limiting the display to members of the same color or shape groups. If, for example, the blue-based pyramid is shaken, the owners of the red and green pyramids will be able uniquely to identify the shaker (because only the blue pyramid can make the other pyramids light solid blue), while the owners of other blue shapes will have a more nebulous awareness of the action (because any other blue shape can create that effect in that group). With this property, we tried to reflect the ways in which members of certain close subgroups tend to be more aware of each other's presence, and better able to interpret each others' actions, and give them a means to support that behavior.

We also attempted to design for an experience similar to the way the user's functioned in their old office space. When the area is quiet it may be easier to distinguish between a few sources of activity, but during busy times sounds from the offices of many co-workers are heard by all simultaneously, and become harder to distinguish. Similarly, if sound is present near *multiple* red-based Nimios, those sounds and rhythms will be additively combined and displayed on all of the Nimios. In this way the display draws on the properties of sound in a small office. However, even if the office is busy, the display does not become overwhelming, as there is an upper bound on the complexity of the display. Because the display is somewhat ambiguous, it is adaptable to different *rates of information flow*.

Finally, like the jasmine blossoms found on the desks of the group, Nimio presents an outward display of group cohesiveness, and occupies the workplace alongside the people. The physical presence of an object on the desk serves an additional purpose. When trying to determine *how the ambient information would fit in with other information practices*, we noted the desire of many users to present a high-tech image. A desktop toy fulfills this need since it is usable at the very least as a physical object by anyone, including visitors, who happen to be in the office. Additionally, the group has a preference for tangible representations of information throughout their workday. A "high-tech" toy can strike a balance between the *aesthetics*, informativeness, and usability that the group desired. However, we did not want to create a toy that was so "high-

want to create a toy that was so "high-tech" looking that it would seem fragile or austere. Nimio's physical design attempts to reflect a tech-friendly atmosphere while still remaining intriguing and inviting.

WHAT DID PEOPLE MAKE OF IT?

Nimio was deployed (for 6 months) in a complex social setting, and with very open-ended goals. Accordingly, our assessment is not so much focused on evaluating its fitness for specific instrumental purposes, but rather on examining whether and how it was incorporated into the social life of the group as they settled into their routines in the new building.

Individual Meanings. We were surprised, after witnessing the ease with which group members socialized, that no one ever traded Nimios with each other (as we had hoped). We had not counted on the Nimios being regarded as highly personal objects. Yet in follow-up interviews it became clear that certain shapes had particular meanings to our participants. One women thought the domes were "mysterious" while another man thought they were "boring", but pyramids reminded him of "Egypt and Mexico". People poked, prodded, shook, shouted at, and even disassembled their Nimios. As one woman said of her Nimio, "we became friends".

Performing Group Identity. As noted earlier, the group portrayed itself as tight-knit when we spoke to them shortly after their move to the new building. In the year following the move-in, the group's identity remained cohesive (though not completely undifferentiated) and was articulated in several ways. First, individuals maintained that they worked in a "good group" where "everyone gets along" even as they added several new members to the original core staff. Second, the group's informal style was manifest both in interviews and during participant observation. Meetings tended to be opportunistic and impromptu, rather than formally scheduled; this style was regarded as a more productive use of time, and frequently contrasted in interviews to people's experiences in old jobs and in other groups. Opportunistic interaction meant that the public spaces in the office suite were frequently used, and collaboration was often quite visible. One interviewee asserted that the "tone" of the office "comes from the top", establishing it as a characteristic of everyone working for the group manager. Finally, along with this intensive intragroup collaboration, many group members also interfaced with "outsiders", whether in public relations roles, or collaborating with funded faculty, or meeting with promising undergraduate researchers. Nimio became a part of the image they presented to these outside collaborators, a tangible conversation piece, a visually appropriate and eye-catching office decoration shared by most group members, and an example of the kind of research done at their institute:

> "I think it's visually interesting and unique… I have a lot of people who come and go from my office and so I mean it's an opportunity for me to casually just say… 'oh yeah, we're just part of a research project, just one of many fascinating things we do here'… it seems appropriate in this context."

Generating group identity: shared understandings and interpretable actions. As we had seen in our initial study, people had developed a strong sense of each others' work habits in the course of their interactions. People attended to each others' habits and tailored their communication strategies to relevant personal habits and characteristics of the person they wanted to talk to.

Group members acted visibly or audibly in physical space (leaving office doors open or closed), on the phone (by having audible conversations), on email and on IM (status messages, responsiveness or unresponsiveness). Over time and with trial and error these actions became accurately interpretable to others as meaning specific things like presence at one's desk, or participation in a conference call. We intended Nimio to become another channel in this diverse communication ecology, but encountered several difficulties. The simplest set of difficulties was purely technical. Short battery life left the Nimios sometimes unresponsive, and routing problems cut off a few users who were spatially peripheral. This meant that Nimio's responses to its users and immediate environment were often not consistent enough for people to develop a mental model of what the system was doing. Another sort of difficulty stemmed from the fact that Nimio was a distributed display. A Nimio might be reacting to a distant, otherwise imperceptible event, but precisely because that event was distant there was no way to correlate the distant action with Nimio's reaction. Similarly, after the initial deployment, when we set all the Nimios out in the kitchenette/copy room, no one played with their Nimios in the same place so that they could collectively observe their immediate reactions as we had hoped. This made it more difficult for the participants to understand the effects they had on one another's Nimios while at a distance. Furthermore, Nimio was designed to be unobtrusive; placed out of one's line of sight, the blinking lights did not demand attention the way an audio alert would. But once placed out of sight, it was also out of mind. While Nimio did not become another medium for group-wide accountable action, like physical presence or IM, it was used in ways equally essential for group cohesion.

Subgroup identity: reinforcing strong ties. While it is true that "everyone gets along" and collaborations are fluid, some ties within the group were stronger than others. One participant noted, with regard to potential collaborations "each of us is the center of a bell curve of possibilities": one *might* collaborate with anyone, but would be more likely to work with some than others. Another noted that these ties are mutually reinforcing; opportunistic face-to-face meetings with collaborators were also moments where one might get "sucked into" yet another project. Strong ties might mean nearly constant face-to-face interaction:

> "we literally just get up, and you can see, we are coming and going out of each other's offices all the time, so it's very personal contact."

Strong ties tended to coincide with physical proximity, since people had offices in the main suite or the annex ac-

cording to their job duties and organizational positions. In these cases, some people were able to find enough correlations to render Nimio interpretable. There were two main ways in which this happened: awareness of Nimio as a physical object in a coworker's office, and awareness of a coworker's activity through Nimio. In the first case, people were seldom aware of who possessed which shapes and colors among their weak ties, but could identify those possessed by a few of their close collaborators. Three women who worked closely together (identified by one as "the three talkers") chose their Nimios together, grabbing the three pyramids as soon as they were available, making a conscious decision to use a set of Nimios that could communicate most closely, making their affiliation visible. In their case, Nimio could call their attention to what had been a merely background awareness of their closest coworkers' activities:

> "I'd see the red lighting up and then if I listen – like I can tune everybody out, but then if I stopped and listened yeah it would be her."

The tiered interaction model we had designed using a gradient of communication between similar shapes, similar colors, and the whole group did indeed reflect the varying levels of collaboration within the group. While Nimio did not strengthen ties uniformly throughout the group, it made stronger and weaker ties more visible to us.

Three themes emerge from these observations. First, Nimio was highly interpretable to individuals. Some seemed to have a better grasp than others of "how it works", and many interpreted the system in ways we wouldn't have expected, though explanations were available either from the researchers or from other coworkers. To some degree, misunderstandings were due to some of the aforementioned technical and interactional difficulties with the system, yet some interpretations were incredibly specific and surprisingly accurate. Second, awareness of Nimio and other people was gained largely through face-to-face interaction. For the most part, people were aware of what their most frequent face-to-face collaborators possessed. At the same time most participants were aware of the two receptionists, whose desks and Nimios were publicly accessible. Lastly, Nimio highlighted and clarified some of the social complexities of the group, providing a lens that helped us understand how these coworkers collaborated. While participants expressed a desire to be more aware of *all* their colleagues, in practice that awareness emerges from their communications over primary work activities, and each reinforces the other. Nimio made this process more visible to us but did not break the feedback loop.

CONCLUSIONS

In recent years, the topic of "play" has become a regular topic of design inspiration in interactive systems (e.g. Blythe et al., 2003; Gaver et al., 2004). Our design here has been driven by a set of concerns that reflect two different readings of the word "play."

The first reading of "play" is the human reading, as something amusing, fun, and playful. This is the sense of play explored by Gaver and colleagues exploring "ludic design" (Gaver et al., 2004). This element of play is obvious in our design, which specifically attempts to make Nimio engaging on an individual level. The physical form of the objects, and even the material from which they are constructed, are aspects of this playful engagement, as are its use of color and the ambiguous aspects of interaction. Further, they are designed as distinct from the conventional "work" space. An activity monitor could be implemented as a traditional PC application, living on screen alongside traditional productivity applications and the other electronic elements of the work day. The physical embodiment that we have chosen, though, and its form factor, allows the device to occupy the edge of the desk, alongside toys and personal items, negotiating between the spheres of work and play. Nimio clearly does not strike anyone as a productivity tool.

The second reading of "play" is the mechanical meaning, suggesting "wiggle room" – something loose, flexible, or not quite fixed in place. This aspect of play is central to our interaction model. Nimio provides an abstract channel for communication, with little or no structure by which the meaning of the messages might be determined. By deliberately leaving their interpretation open to question and investigation, our goal was to allow for the creation of collective understandings. Our intent was to allow people to develop a set of visual and embodied patterns that come to have some meaning for participants through their continued engagement. Gaver et al. (2003) discuss the importance of ambiguity in design, noting: "the everyday world itself is inherently ambiguous: most things in it have multiple possible meanings. Allowing this ambiguity to be reflected in design has several advantages. Most importantly, it allows designers to engage users with issues without constraining how they respond. In addition, it allows the designers' point of view to be expressed while enabling users of different sociocultural backgrounds to find their own interpretations." (p. 233). To these advantages, we would add another, critical, point; technologies and technology use take their meaning not simply from individual encounters; rather, they evolve over time through collective use, through the ways in which people adopt and adapt them, just as our participants' visible actions became legible to each other over time and through collective participation. These collective experiences are inherently varied, open-ended, and situated in practice. Wenger (1999) describes practice as a process by which we can find the world and our encounters with it as meaningful; in this view, practice and meaning reside within communities.

Elsewhere, we have considered these issues as they relate to the broader program of embodied interaction (Dourish, 2001). Here, we want to elaborate on the twin central concerns we encountered with Nimio: legibility and ambiguity, and identity and anonymity. The legibility/ambiguity tension concerns the extent to which the device is broadly understandable but retains enough mystery both to be engaging and to allow users to project their own meanings onto it. When translated from interaction to collaboration, a similar issue arises in the tension between identity and anonymity. This arises because the goal of Nimio is to foster group

cohesion rather than interpersonal communication, and yet, in order to be meaningful and legible, people must be able to associate visible actions with people, and to distinguish between the actions of different actors or groups.

Our tiered interaction design – based on color groups and shape groups – is a response to this tension. They do not allow for a precise identification of objects or activities, but allow participation "affinity groups" to develop. While the Nimio devices do not reflect the activity of specific individuals, neither are they simply reflections of the group as a whole; activities can be associated with different subsets of individuals, and so they allow for people to make distinctions between activities. Distinctions – between activities, and between groups – are critical here, since they are the foundation of distinguishable meaning and therefore patterns of collective signaling and interpretation.

Critically, the focus here is on collectives and their interactions. Traditionally, collaborative technologies, and most particularly awareness technologies, have focused on individual interactions or on group presence, and have articulated these in terms of predefined forms of expression. Here, we have left the forms of expression open, and we have used different visual and interactional forms to delineate different social groups. What is central to the design is the overlap between different groups (color groups and shape groups), precisely because of the ambiguity that they introduce in the interpretation of the actions of any particular object.

The central concern that our design demonstrates is a sensitivity towards the ways in which these devices can be meaningful to users only in the contexts of their own practices. This is not simply an argument for customization; instead, it reflects the observation that these devices must be designed for appropriation. A jasmine blossom is not a device for social cohesion except when used as one; similarly, the ways in which patterns of connection and engagement arise around ubiquitous computing technologies suggest that the meanings of advanced technologies are also going to arise only through real use. We have attempted to illustrate here how the tension between legibility and ambiguity has been a central element of our design. For embodied devices, this is a key technology challenge.

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