RAPPORT DE RECHERCHE

L R I

A STUDY OF MULTISCALE COMMUNICATION AND THE INFLUENCE OF INFORMATION PACE ON PERIPHERAL ATTENTION

GUEDDANA S / ROUSSEL N

Unité Mixte de Recherche 8623
CNRS-Université Paris Sud – LRI

12/2008

Rapport de Recherche N° 1507

CNRS – Université de Paris Sud
Centre d'Orsay
LABORATOIRE DE RECHERCHE EN INFORMATIQUE
Bâtiment 490
91405 ORSAY Cedex (France)

A study of multiscale communication and the influence of information pace on peripheral attention

Sofiane Gueddana & Nicolas Roussel
LRI (Univ. Paris-Sud - CNRS) & INRIA Saclay Ile de France
Bâtiment 490, Université Paris-Sud
91405 Orsay Cedex, France
{gueddana,roussel}@lri.fr

ABSTRACT

The communication infrastructure around us is a rich but fragmented environment made of separated services corresponding to different levels of engagement. The multiscale approach to communication proposes instead to create systems that support a variable degree of engagement and smooth transitions between degrees. This paper reports on the design and evaluation of such a system called Pêle-Mêle. We present a longitudinal study of its use that notably illustrates the importance of providing gradual attention management mechanisms to support transitions between background and foreground communications. We then describe a quantitative experiment that shows the influence of peripheral update rate on subjects' attention in a dual-task situation combining snapshot-based peripheral awareness with a central text correcting task. Overall, our results suggest that control over information pace and salience can help users of communication systems adjust both their local distraction and remote attractiveness.

Author Keywords

Computer-mediated communication, peripheral communication, attention, engagement

ACM Classification Keywords

H.5.3 Group and Organization Interfaces: Collaborative computing

INTRODUCTION

Specific characteristics of interpersonal communication technologies have been studied for quite a while. Studies of video-mediated communication revealed few objective advantages of adding video to audio for focused problem solving tasks [39], for example, but they also showed the value of video for creating shared workspaces and assessing the availability of others. Media space studies particularly demonstrated this last role, emphasizing the importance of long-term and always-on connections and promoting the concept of peripheral awareness of each other's activities [11, 12].

Many of today's communication systems build on these notions of constant accessibility and peripheral awareness. A few additionally support the transformation of a peripheral communication into a primary activity. As an example, instant messaging applications not only provide constant information about people's presence and availability but also support the rapid exchange of text messages. Yet, managing users' transitions between background and foreground activities remains a key challenge of modern communication system design. In Weiser & Brown's terms, the challenge is to create *calm technologies* that engage both the center and the periphery of our attention and move back and forth between the two [38].

Monitoring a peripheral communication while performing another task has a cognitive cost that depends on the perceptual salience of the communication and the distraction it causes. Minimizing this cost is usually desirable and even necessary in situations like car driving where the ability to keep a communication in the background can be critical. But what appears as a cost might quickly turn into a benefit as one starts focusing on the peripheral communication and placing it at the center of attention. This paper reports on the design and evaluation of a system that specifically supports the transitions back and forth between peripheral and focused forms of communication.

Our work followed a triangulation approach [23], combining a theoretical perspective on communication with the design and long-term observation of a prototype and a controlled experiment on the impact of a particular design decision. We studied the case of Pêle-Mêle [15], a video communication system designed according to a multiscale approach [33]. The long-term use of this system notably pointed out the importance of providing gradual attention management mechanisms to support transitions between background and foreground communications. We conducted a quantitative experiment to evaluate the influence of peripheral update rate on subjects' attention in a dual-task situation. Overall, our results suggest that control over information pace and salience can help users of communication systems adjust both their local distraction and remote attractiveness.

This paper is organized as follows. After introducing some related work, we present the design of the Pêle-Mêle system. We then describe the longitudinal study of its use and the quantitative experiment that we conducted and conclude with a discussion that summarizes our findings.

RELATED WORK

Attention is defined by psychologist William James as "*the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought*" [20]. James further explains: "*Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatterbrained state which in French is called* distraction". As we said, a key challenge of modern communication system design is to create systems that do not monopolize user attention but can fade into the background and be promoted on demand to the foreground.

Communication systems designed to fade in the background avoid explicit interaction with users to prevent distraction. They instead resort to presets and automatic capture to determine the information to be communicated, usually of contextual nature. As an example, users of instant messaging applications often communicate about their mood, location and activities by updating a status message [34]. These messages provide good indicators of people's availability and interruptibility at a low cost, which contributes to mutual awareness and can lead to foreground communications. The transmission of images, sounds and other automatically captured data can provide further awareness cues but at the cost of introducing privacy concerns. Filtering techniques have been proposed to help users mitigate these concerns by altering the data to be transmitted [17, 40, 6] or by abstracting it to communicate higher-level information through other means [14, 13, 2].

Communicating in the background also imposes constraints on information rendering. As reported by Pousman & Stasko [31], numerous researchers have investigated ways to create ambient information systems that "*aim at presenting information in a way that is not distracting but aesthetically pleasing and tangible to varying degrees*". Information salience plays an important role in this context, defined as "*the distinct subjective perceptual quality which makes some items in the world stand out from their neighbors and immediately grab our attention*" [19]. Lights, haptics, scent and adapted everyday objects have been used to create low-salience communication devices that blend into the user's environment [35, 7, 10].

The too low salience of a communication might lead users to miss important information or opportunities for more focused interactions, compromising coordination mechanisms and shared understanding. It has thus been suggested that systems should support different degrees of salience [14] and could increase the one of incoming messages that may deserve immediate attention [1]. Outside the specific domain of computer-mediated communication, studies have also investigated how to design peripheral displays so that they provide the most information while having the least impact on the user's performance on a primary task [24, 25, 8]. These studies particularly showed the ambivalent role of animations and the importance of physical characteristics of the display such as its size, position and orientation.

As illustrated by the previous examples, there is a substantial body of literature describing ambient communication devices or ambient information systems that might be used for communication. But creating systems that do not monopolize user attention is only the first part of the aforementioned challenge. These systems should also be capable of promoting the communication on demand to the foreground. Unfortunately, those designed for background use can rarely be used for focused communication, and conversely.

One of the most interesting aspect of early media space studies is that they promoted the idea of gradual and negotiated engagement. As noted by Birnholtz et al., "*paying attention to someone is itself a communicative act – an implicit request for interaction*" and "*interest in interaction on the part of the initiator is expressed by paying attention to his or her target in progressively more intrusive ways*" [4]. Yet, relative little effort has been made to explore ways to actually support this gradual intrusion and the overall collaborative process of contact negotiation [36]. Two recent notable exceptions are Community Bar [26, 32] and OpenMessenger [4, 5], which are probably the closest works to ours.

CASE STUDY: PÊLE-MÊLE

Pêle-Mêle is a multiparty video communication system that supports smooth transitions between various degrees of engagement, from synchronous focused interactions to peripheral and asynchronous communication. Before describing the system itself and how it evolved from its original design [15], we will first introduce the more general approach behind it, which originates from the accumulated experience in the design of other video communication systems over the past ten years [33].

A Multiscale Approach to Communication

Our design approach for Pêle-Mêle uses the *degree of engagement* as a structuring concept, with the following definition: "*the extent to which users are open to others and ready to expose themselves to them* ". The degree of engagement can be seen as the proximity of a user's communication proxy to a remote person (Figure 1), or as the upper bound for the user's attention. It varies over time, depends on the particular context and plays an important part in the choice of communication means. A researcher composing an email message and noticing his co-author just came on-line might want to switch to the instant messaging application for more engaged interactions, for example. After exchanging a few lines of text, they might agree to switch to a phone conversation. A few minutes later, they might want to start a collaborative editor.

Transitions between engagement degrees using existing communication means often introduce potentially complex ar-

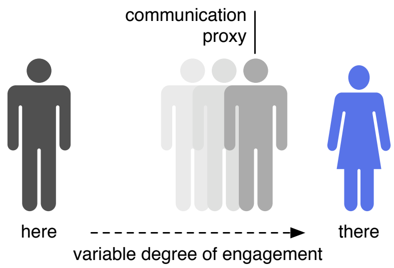

Figure 1. Engagement as the proximity between a communication proxy and a remote person.

ticulation work. In the previous example, although the two authors are already connected through an instant messaging application, there is a good chance one of them will have to find or remember the other's phone number and dial it somehow. And starting the collaborative editor will probably require more complex work. Systems that combine different communication services can help to a certain extent, but even in that case, the transitions might not be so easy. When realizing you just missed a phone call, for example, experience shows it's usually better to wait before calling back the person if you don't want to talk to her answering machine while she talks to yours. Although the reasons why people switch from one service or system to another have been discussed [27, 18], little work has been done on how to improve these transitions.

We believe that more efforts should be made to develop new communication systems that would support a variable degree of engagement and smooth transitions between degrees. Such a system would make it easy for users to reach the degree of engagement most appropriate to their particular context and to perceive other people's engagement. We envision three main ways in which a communication service could support various degrees of engagement: by filtering information, by adjusting its pace, and by facilitating transitions and combinations with other services. In the case of video, filters could alter the size of the images, hide or remove some details but also enhance some others [22, 9], or add information through temporal compositions [17, 16]. The frame rate could also be adjusted and the video streams combined or replaced with text or audio content.

A *multiscale world* is defined by Jul & Furnas as a world "*in which information can exist at multiple levels of detail*" [21]. The degree of engagement as we see it corresponds to a level of detail deemed appropriate for a particular communication context. We therefore propose to use the term *multiscale communication system* to designate a communication system that supports a variable degree of engagement. Smooth transitions between degrees of engagement correspond to smooth variations of the level of detail. In Zoomable User Interface terms [29], we might call them *continuous zooming*. As filtering information and combining or replacing it with another service might change its meaning and not only the level of detail, these operations can be considered as the equivalent of a *semantic zoom*.

As with zoomable interfaces, a first challenge of the multiscale communication approach is to design appropriate interaction techniques to trigger and control the transitions from one level of detail – i.e., one degree of engagement – to another. As one of our goals is to reduce articulation work, these techniques should be as direct and concise as possible. In this context, the camera used by a video communication system is a legitimate candidate for human-computer interaction. Another challenge is to design presentation techniques that make it easy to perceive other people's engagement. We will now describe how we addressed these challenges in the Pêle-Mêle system.

Initial Design of Pêle-Mêle, User Reactions and Redesign

Pêle-Mêle is a multiparty video communication system that uses basic presence, face and motion detection to constantly monitor the activity of its users and classify it according to a three-level scale: *away*, *available* and *engaged*. The activity observed on each site determines the nature of its on-screen representation which can combine live and pre-recorded images. Shared among all instances on a strict WYSIWIS basis, the screen layout follows a *focus-plus-context* approach: live images of people engaged in using the system are overlaid in the middle of the screen while images of available people and past activities are shown on the periphery.

Figure 2 illustrates the layout used by the first implementation of Pêle-Mêle, described in [15]. It shows the images of two persons at the *engaged* level overlaid in the center of the screen (1), someone *available* on the periphery (2) and images from past activities slowly drifting in perspective over time toward the center of the screen (3).

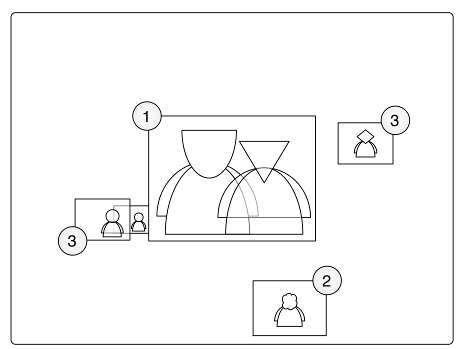

Figure 2. Sketch of the original Pêle-Mêle layout.

This first version of the system applied different spatial and temporal filters on the images depending on the activity level detected. Images from *engaged* people were displayed as-is. Images from *available* people were composed over time to show recent activity and delayed to reduce the risk of unintended privacy exposure. The delayed transmission was decoupled from the activity sensing, making it possible for users to hide what they just did by moving outside the camera's field of view and triggering a transition to the *away* level. Places at that level were represented by the last image they sent degraded over time using an oil-paint filter. Clips of past *engaged* activities were randomly played in the middle of the screen when none of the places was at that level. Smooth animated transitions were used between these representations to ease perception and understanding of state changes.

Informal observations of a first series of Pêle-Mêle prototypes showed that users quickly understood the workings of the activity sensor, its impact on the display and how they could adjust their level of engagement through simple movements. Users said the animations helped them perceive the changes in participants' engagement, including their own. Several complained about the sensitiveness of the activity sensor and the random playbacks that made the animated display quite unstable in some situations. The screen layout was much criticized for its complexity, users having a particular hard time understanding the drifting of images in perspective over time. But even though frustrating at times, interaction with the system was found generally pleasing and effective. Users expressed a great interest in the potential for asynchronous awareness offered by the recorded clips and suggested adding a specific interface for browsing them. They also suggested adding the possibility of establishing an audio link when at the *engaged* level.

Preliminary user feedback led us to redesign the Pêle-Mêle prototypes. We switched from Apple Mac mini computers to iMacs that integrate the necessary hardware pieces – i.e. a computer, a screen and a camera – and come with an infrared remote control. We left the random playback enabled but reimplemented the activity sensor to make it less sensitive and more robust. We smoothed image corners and used sinusoidal paths for the perspective drift to reduce clutter. We graduated the paths and added concentric ellipses to visualize the time scale (Figure 3).

Figure 3. Redesigned layout showing three sites.

To better support foreground communication, we added the possibility of establishing an audio link through a Voice-over-IP application or BlueTooth phone by pressing a button on the remote at the *engaged* level. We also added an alternative view for browsing the clips of past activities. Called, controlled and dismissed using the infrared remote, this view shows a scrollable and zoomable timeline, each site being mapped onto a different line (Figure 4). It automatically plays any clip that intersects a vertical cursor in the middle of the screen. It also constantly shows the current image of each site on the right side of its timeline, keeping users aware of ongoing activities while they explore the past.

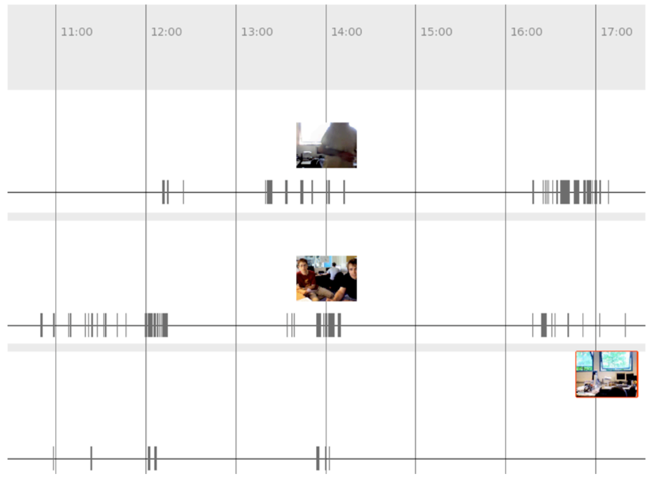

Figure 4. Timeline view showing three sites.

LEARNINGS FROM LONG-TERM USE

After the preliminary testing and redesign phase, we decided to follow an exploratory approach and observe the use of the system from a wide perspective. We conducted two long-term studies, the first one focusing on group interactions and the second on individual use of the system.

Methodology

Two Pêle-Mêle prototypes were installed to connect two of our offices located on separate floors of the same building. The first office, the *studio*, is shared by eight people and gives access to three rooms (X, Y and Z on Figure 5) used by six other people. The second office, the *annex*, is shared by four people who left the studio right before our first study.

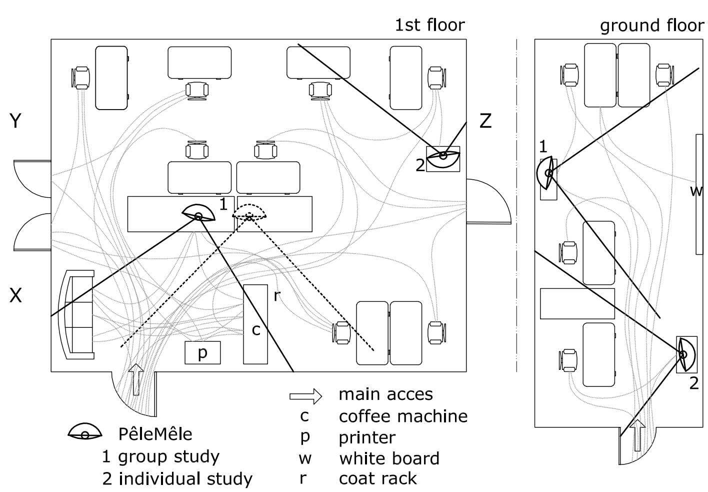

Figure 5. Configurations of the two offices used in both studies.

The first study lasted six months during which the audio link feature remained disabled. The Pêle-Mêle in the studio was positioned so as to face the access door and a coffee machine, a casual meeting space for the group and its visitors. The Pêle-Mêle in the annex was placed facing a whiteboard that three of the four occupants had to walk by to reach their desk. Eighteen members of our group were thus more or less directly involved in this study, with a core of six regular users (three in each office). Their motivation was to reduce the relative isolation of the people who just moved in the annex and to coordinate activities such as lunches and working meetings. The second study lasted three weeks and focused on two particular members of our group, one in each office, who were involved in the same project. We enabled the audio link and introduced it to the participants this time, and the two Pêle-Mêle were repositioned so as to capture their workspace.

Participants' comments and reactions were collected regularly during the two studies. The six core participants of the first one and the two of the second were interviewed at the end, and about ten percent of the recorded clips were reviewed (27286 clips were recorded for the first one and 1163 for the second). As we found the uses of Pêle-Mêle to be quite similar in both studies, we will analyze and discuss them together, pointing out the differences when needed.

Results

Pêle-Mêle has mainly been used for informal communication and the coordination of daily group activities. Participants found it not only useful but playful, qualifying it as "*pleasant*" and comparing it to a "*hallway between the offices*" and a "*little light that welcomes you in the morning*". They typically employed the system in a sequence of articulated uses. They would start by looking at the default view for what happened in both offices while they were away. They would then check who was around in the other office and what they were doing, possibly switching to the timeline for a more detailed view of the recent past. At that point, they might show themselves and try to gain the attention of the distant people. Finally, after establishing contact, they would communicate with gestures, switch to another communication system or use it in combination with Pêle-Mêle.

Our analysis of participants' comments and interviews focused on the influence of the system's multiscale design on the ability for users to keep a communication in the background or to promote it to the foreground: was it easy for them to control the information about them available to others? Was the awareness of other people distracting to them? Did they actually use the system to switch from background to foreground communication?

Background communication – Participants appreciated the ability to interact with the system at a distance and to communicate by simply being in front of the camera and keeping an eye on the display: "*they don't have to make any explicit action to keep me informed*", "*the communication takes place in the use of space*".

Privacy – An occupant of the studio complained at the beginning of the first study that "*privacy is already limited in an open space, and this system takes from the little that's left*". This participant's workspace was the closest to the Pêle-Mêle and the only one in the studio in its field of view (Figure 5, dashed representation). After a few days, he resolved the issue by slightly rotating the device to exclude his desk from its view. No privacy issue was reported during the second study, although the two cameras had been specifically positioned to show the participants' workspace. At the end of the studies, all participants said they didn't feel "*tracked*" by the system. Several explained they didn't see the recorded images as a reliable way of knowing about each others' activities: "*the fact that I can't find someone in the recorded clips doesn't mean he is not there*".

Awareness – Participants maintained general awareness by peeking at the real-time images coming from the remote site from time to time: "*when remote people are in front of the system, I can see who is actually there and what they are doing*". Participants also looked at the images of past activity displayed in the default view, "*little bits of past*" as they called them: "*when I arrive in the morning, I always check how many clips have been recorded*". They reported using the timeline view when looking for precise information about past activity: "*I used the timeline view to check if I was the first to arrive*". They also used the timeline view in the background as a more precise display of past and ongoing activity.

Distraction – Animations were found distracting by three participants at the beginning of the first study. Two of them were able to see the Pêle-Mêle displays from their workspace and reported they were frequently distracted by the transitions and animations caused by the automatic playback of clips. Two other participants also switched the displays to the timeline view on several occasions because of its low update rate at the default time scale. The automatic playback was consequently disabled on the third week of the first study. One of the users commented: "*after this change, I was able to ignore the display so well that I even started missing interesting interaction opportunities*". Although the displays had been explicitly positioned toward them, participants of the second study didn't report any distraction problem. One of them even said: "*I sometimes look at it for distraction when I don't want to concentrate*".

Transitions – The animated transitions implicitly triggered by participants' activities often drew the attention of remote people who considered them as opportunities for shared interactions: "*when things move on the screen, I turn my attention to it and if I see an animated discussion, I sometimes decide to join in*". Participants used simple gestures such as waving hands to explicitly gain remote people's attention and avoided making such gestures inadvertently: "*I avoid stretching in front of the camera to not draw attention for nothing*". They expressed concerns about the remote context in which they appeared: "*when I wave at the device, I know my image is remotely displayed full-screen, but I have no idea if someone is actually seeing me*". Some said they considered Pêle-Mêle as a subtle way of gaining remote attention: "*I used the system to try contacting the remote colleagues without disturbing them*". Others complained it was sometimes hard to draw attention solely with images. They explained they resorted to using the phone or instant messaging in those cases and suggested adding remote auditory notification capabilities. Yet, participants of the second study almost never used the audio link feature.

Discussion

When designing Pêle-Mêle, we assumed that providing users with images of ongoing and past activities would help them keep in touch with distant people. Observations and interviews suggest these two kinds of images were indeed useful in supporting the remote awareness of each other's presence and activities, which confirms the results of previous media space studies. The system augmented the space in which it was placed by creating bridges over distance and time, and activity sensing proved to be quite efficient to make these communication services almost "invisible in use" and integrate them in daily routine [37].

We anticipated that the temporal and spatial filters as well as the different image sizes and positions associated to the activity levels would help mitigate privacy concerns. Although there was an issue about the position and orientation of one of the devices, privacy didn't really came out as a major problem overall. But it is hard to tell whether it was because of the mechanisms we implemented, or because of the specific context of our studies. One might argue that the situation would have been different if we had connected several individual people instead of two groups and then just two people. An interesting point is the fact that the unreliability of the activity sensor contributed to the users' feeling that the system was no threat to their privacy.

The different representations associated to the activity levels and the animated transitions between them proved to be a useful mechanism for drawing people's attention. Participants saw value in it when triggered implicitly by distant people, and also took explicitly advantage of it. They got used to adjust their movements and gestures to be seen or ignored by the Pêle-Mêle and remote people through it. They expressed concerns about how the remote people perceived their actions, about the distraction they might cause. Although they often wanted to minimize it, there were also cases where they wanted to insist on getting attention and video only wasn't enough. This clearly illustrates to us the importance of providing gradual attention management mechanisms to support transitions between background and foreground communications. It also shows that distraction can be considered as a positive factor in certain contexts.

Participants' comments show their ambivalent feelings about their own distraction. Although they usually want to minimize it – again, they also look for some from time to time. Letting users choose between different representations and layouts seems a good way to let them adjust their tolerance to distraction depending on their particular context. Participants' rejection of the automatic playback of clips can be seen as a desire for this control. The images and clips of the past helped users catch up with events they had missed at their own pace, by glancing at the default view or interacting with the timeline. These two views support synchronous and asynchronous communication and differ mainly in the distraction they might cause and the more or less explicit nature of the interactions they support. The fact that participants used and appreciated both can be seen as an indication that a gradual engagement approach can also be beneficial to human-computer interaction.

Pêle-Mêle was designed to provide several new communication services in a single device in order to support various levels of engagement. But as Pagani & Mackay [28], we believe it is important for these new services to be integrated as smoothly as possible with the existing communication environment. The fact that the external audio link available at the *engaged* level was almost never used during the second study might seem disappointing in this respect. The reason for this is probably that since the two offices were in the same building, the two participants preferred meeting in person rather than using a Voice-over-IP application or their mobile phone. Yet, from a multiscale communication perspective, this can be considered as a success rather than a failure since these meetings partly resulted from the casual awareness supported by Pêle-Mêle.

EXPERIMENT

The suggestion from Pêle-Mêle users to cause remote distraction to draw a distant person's attention got us interested in ways to evaluate the attentional cost of peripheral communication displays. To our knowledge, the attention required to peripherically monitor snapshots of a distant person has never been studied following an experimental approach. What is the cost of maintaining this awareness? We conducted an experiment to test if the pace of information exchange influences the attentional cost and thus the expected engagement.

Research Questions

Our goal when designing this experiment was to test the effect of update pace on the attentional cost of a peripheral task. As this cost can not be measured directly, we designed a dual-task experiment that evaluates it indirectly. In this type of experiment, participants share their limited attention between a main (or central) task and a peripheral one. The central task performance degradation was used as a measure of the attentional cost variation in the peripheral and adequately performed task.

The purpose of the experiment is to determine the effect of snapshots update pace variation while monitoring the presence of a distant person on multitasking performance, by comparing two update pace conditions. The experiment tries to answer to the following questions:

- Does peripheral monitoring have an impact on a centrally performed task?
- Does peripheral update rate variation have an effect on central and peripheral task performance?

Task

The central task and the peripheral one appeared on two separate screens. Inspired by the one used by Maglio & Campbell in a similar experiment [24], our central task is a text correcting exercise that involves mainly linguistic capabilities associated with decision making. To make the cognitive load adjustable, we introduced a time limit per sentence. By limiting the time available to read and decide, we turned the task into a "race against the clock" similar to the Tetris game used by Bartram et al. [3].

The image in the middle of Figure 6 shows the text correcting display. The sentence to correct is shown highlighted. At the top of the screen, one can see a progress bar presenting the time left to answer. At the bottom, two "*correct*" and "*incorrect*" buttons can be clicked with the mouse to provide the answer. For each text correction trail of the experiment (i.e., each sentence), participants either clicked one of the buttons or didn't click any in time.

Concerning the peripheral task, we decided to simulate the peripheral awareness of distant friends or colleagues through an image-based communication system. We chose a monitoring task rather than awareness, so that the peripheral task would be sufficiently demanding and thus produce a dual task performance trade-off. We also made this task more difficult in two ways: the priority of the peripheral task over text correction was emphasized, and the remote person's presence changes as well as participants' recalls were very frequent, i.e. every 4 to 12 seconds.

The left image of Figure 6 shows a sample snapshot that was used for the monitoring task. As one can see on the right image of the same Figure, this task was displayed on a peripheral screen. A still picture showing a desk and either a person or an empty chair was displayed for a random duration. Four seconds fade-in transitions were used between pictures. During the dual tasks, participants were randomly interrupted and both displays suspended. Participant were then prompted to recall the presence state of the remote person by pressing the `Return` or `Backspace` key on a keyboard.

Design

The experiment was constructed as a one factor within subject design with a *slow update pace* condition, a *fast update pace* condition and a *single task* condition. Update pace was between 5 to 8 seconds in the fast condition, and between 17 and 21 seconds in the slow one. Participants performed the single task condition as a control condition for the two dual task conditions. The single task consisted in correcting a text document on a central screen with no peripheral task, while the dual tasks included monitoring the presence of a remote colleague through snapshots displayed on a peripheral screen.

Performance on both tasks were compared across the update rate conditions. Each participant performed both dual task conditions and the single task condition. The presentation order of conditions was balanced across two groups of participants (Figure 7). Dual task trials were grouped in two blocks of 75 trials each, one for the fast condition and another for the slow one. The single task condition was divided into three short blocks of 25 trials: before, between and after each dual task condition block presentation.

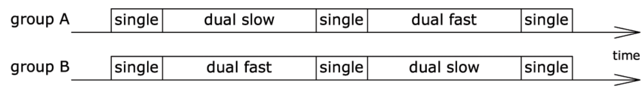

Figure 7. Order of presentation of dual task condition blocks were counterbalanced in two groups A and B. Single task blocks are interleaved with slow and fast blocks.

Two dependent measures were collected for each participant: text correction answers and state monitoring success. Text correcting performance was measured as a nominal variable. For each text correction trail (i.e., each sentence), participant input was classified into three categories: correct, incorrect or missed.

In the dual task conditions, tasks and displays were randomly and frequently interrupted to measure monitoring performance. To avoid introducing a bias, the single task condition execution was also randomly suspended, but participants simply had to press a key to resume it.

The experiment procedure included several phases: training, calibration, test and a post-test questionnaire. The task was orally briefly described, and written detailed instructions were displayed. These instructions emphasized the priority of monitoring the distant colleague over the text correction task. Participants then performed the three conditions during

Figure 6. Experiment tasks and apparatus.

a training phase of 10 minutes. During this training, a visual feedback was displayed helping the participants learn the error types. After the training, as text correction speed differs among participants, a speed calibration test of 15 minutes was performed. During this test, we variated the time per sentence to determine the appropriate speed for each participant to correctly perform the text correction.

After calibration, the time limit was introduced and the test started. The participants performed the single task and dual task blocks. After completing all blocks, participants answered a post-test questionnaire in two parts: participants had first to estimate their linguistic and visual abilities, and then to describe their subjective perception of the differences between the conditions and the strategies they employed in multitasking.

Apparatus and Participants

The text used for the correcting task consisted in french articles with similar readability levels (Kandel & Moles measure ranging from 48 to 52) taken from a popular newspaper. The presentation order of these articles was counterbalanced between participants. Errors of two types were created by hand. Errors were either based on word inversions leading to a syntax error, or gender or number agreement errors. For each participant, zero, one or two errors per sentence were randomly introduced in the text.

A distance of 20 cm separated the screens, two 1280x1024 LCD monitors (17" for the central and 15" for the peripheral, shown on the right image of Figure 6). The software was implemented in Java 1.4 on a 3,4 GHz Pentium 4 computer running Microsoft Windows XP Pro. Snapshots resolution was 512x384 pixels, scaled down from pictures taken at a resolution of 2560x1920 pixels. The text to correct was displayed in 14 point Times New Roman sans serif font.

Twelve adult native french speakers were recruited for the experiment, ten males and two females aged from 22 to 30 (26 on average). All had normal or correct-to-normal vision acuity and perimetry (more than 175°), six of them wearing lenses or glasses.

Results

We first present the effect of monitoring and update rate on the central text correcting task, then on peripheral monitoring. We compared the three conditions (i.e. single, slow, fast) for text correcting performance difference using the chi-square test. Correcting performance was measured as a nominal variable for each text trial. Test result shows a significative difference in the frequency of each response, i.e. success, fail and miss, between the three conditions (chi-square=30,211, $p < .0001$*, Figure 8). This suggests that multitasking and update rate increase lead to more misses, while correct or incorrect trial proportions were less affected. In other words, multitasking and update rate influence the correction time more than its quality.

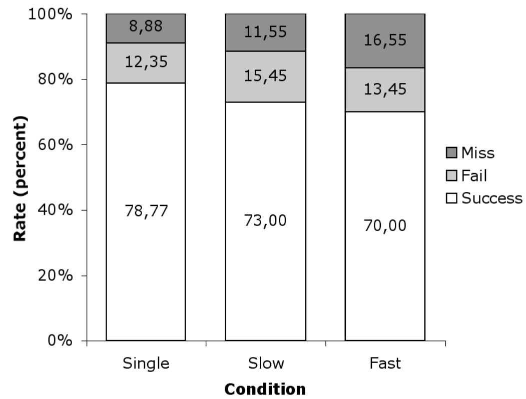

Figure 8. Text correction performance across the three conditions.

The peripheral task execution and its update rate influence the central task performance. The three conditions were compared two by two (Table 1). Additionally, dual task conditions' trials were grouped and compared with single task condition. Significative differences were found between each pair. Difference between single and dual task conditions indicate that multitasking has an effect on central task performance. Difference between slow and fast conditions indicate a significative effect of update rate on central task performance.

Compared conditions	Chi-Square	p<
Single vs. Dual	19,231	.0001*
Fast vs. Slow	9,817	.0074*
Single vs. Fast	25,880	.0001*
Single vs. Slow	8,246	.0162*

Table 1. Two by two comparison of the correcting performance across all conditions using chi-square test.

Update rate has also an effect on peripheral monitoring performance. For the peripheral task, all the participants had to surpass a minimum criterion of monitoring competency to be included in the analysis (more than 90% of success). In the fast condition, participant success rate was at an average of 92,78%, while in the slow one, this rate rose to 96,85%. To compare the update rate conditions, the chi-square test was performed on monitoring success. Test result indicates a significative difference in the frequency of success in monitoring trials between slow and fast update rate condition (chi-square=22,02 , $p < .0001$*).

The post-test questionnaire indicated that participants perceived the negative impact of the multitasking on central task performance, but only five among them perceived the effect of the update rate. This questionnaire indicated also that the participants' strategy was to glance at the peripheral display when they had some free time. Participants reported also that they continued to learn multitasking and each task, even after the training.

Discussion

Several factors can modulate the effect of multitasking and peripheral update pace. The first factor is the cognitive resources: for instance, the peripheral task described by

Maglio & Campbell [24] was a ticker memorization task and its performance was not affected by the dual task situation. In our experiment, the snapshot monitoring task performance was actually affected by the update rate factor. The second factor is learning: in the questionnaire, participants reported learning multitasking during the experiment and that is confirmed by our quantitative results. Participants learn to multitask more efficiently, and timesharing skills may improve with practice reducing the interference between the peripheral and the central task.

The update pace influences the performance of the central task and thus the attentional cost of the peripheral monitoring task. In our experiment, the peripheral task priority was emphasized. The central task performance drop we measured is then caused by motivated and successful monitoring. As we used the central task performance degradation as a measure of the cost of adequately performing the peripheral task, following the dual-task paradigm interpretation, we argue that this drop is representative of the difference of attention cost in peripheral monitoring. The update rate of the display thus influences the attention required to perform the peripheral task.

The effect of update pace on attention is not limited to peripheral monitoring and can be generalized to awareness. Plaue & Stasko explain that motivation makes the difference between an awareness and a monitoring task [30]. In that sense, our peripheral task was a monitoring task. But according to McCrickard & al. [25], an awareness question consists in asking the participant to recall the information that had been displayed, as in our task. We argue that in both awareness and monitoring situations the effort to maintain peripheral attention is influenced by the update rate of the display. But in the case of awareness, no noticeable central performance loss would probably be found.

Performing a peripheral task does not always produce a central performance drop. Our post-test questionnaire indicated that motivated participants tried to schedule their glances to minimize central task performance loss. In the real world, when attention required by the tasks is low, users can be aware of peripheral devices without any loss of performance in a central task. When the cognitive load is high, this ability disappears, and peripheral monitoring impacts on central task performance. Weiser & Brown said that empowering our periphery will allow us to be effortlessly connected to a myriad of information sources [38]. Our results suggest that awareness can be effortless only under the condition that the central and peripheral tasks do not take all the available attentional resources.

SUMMARY

This paper reported on the design and evaluation of Pêle-Mêle, a multiscale communication system. We introduced the multiscale approach, summarized the iterative design of the system and describe a longitudinal study as well as a quantitative experiment that were conducted to evaluate some of its aspects. The study illustrated the importance of providing gradual attention management mechanisms to support transitions between background and foreground communications. The experiment showed that the update rate of a snapshot-based awareness display influences users' attention.

While Romero et al. suggest that future designs should strive for a better balance between distraction, awareness, and screen resources [32], we suggest that users should be given the opportunity to negotiate this balance together. Deliberately raising the cognitive cost of a communication can be interpreted as an increased interest in it. By varying the update rate and salience of a communication, a user might hope gaining remote people's attention more easily and inciting them to engage a little further. As pointed out by Tang [36], current communication systems leave very little room for this kind of negotiation. Our work suggests that these systems should allow the initiator to decide how important and salient a communication is, and not only the recipient.

Pousman & Stasko recently suggested that designers may start building systems supporting a range of notification levels and not just one [31]. Pêle-Mêle is certainly an example of such a system. We plan to further explore this design space by refining the current prototypes and creating new ones.

REFERENCES

1. D. Avrahami and S. E. Hudson. QnA: augmenting an instant messaging client to balance user responsiveness and performance. In *Proc. CSCW'04*, 515–518, New York, NY, USA, 2004. ACM.
2. D. Avrahami and S. E. Hudson. Responsiveness in instant messaging: predictive models supporting inter-personal communication. In *Proc. CHI'06*, 731–740. ACM, 2006.
3. L. Bartram, C. Ware, and T. Calvert. Moticons: detection, distraction and task. *IJHCS*, 58(5):515–545, 2003.
4. J. P. Birnholtz, C. Gutwin, and K. Hawkey. Privacy in the open: how attention mediates awareness and privacy in open-plan offices. In *Proc. Group'07*, 51–60. ACM, 2007.
5. J. P. Birnholtz, C. Gutwin, G. Ramos, and M. Watson. OpenMessenger: gradual initiation of interaction for distributed workgroups. In *Proc. CHI'08*, 1661–1664. ACM, 2008.
6. M. Boyle, C. Edwards, and S. Greenberg. The effects of filtered video on awareness and privacy. In *Proc. CSCW'00*, 1–10. ACM, 2000.
7. S. Brave, H. Ishii, and A. Dahley. Tangible interfaces for remote collaboration and communication. In *Proc. CSCW '98*, 169–178. ACM, 1998.
8. C. S. Campbell and P. P. Maglio. Segmentation of display space interferes with multitasking. In *Proc. Interact'03*, 575–582. IOS Press, 2003.

9. D. J. Chatting, J. S. Galpin, and J. S. Donath. Presence and portrayal: video for casual home dialogues. In *Proc. Multimedia'06*, 395–401. ACM, 2006.

10. A. K. Dey and E. de Guzman. From awareness to connectedness: the design and deployment of presence displays. In *Proc. CHI'06*, 899–908. ACM, 2006.

11. P. Dourish, A. Adler, V. Bellotti, and A. Henderson. Your place or mine ? Learning from long-term use of audio-video communication. *CSCW*, 5(1):33–62, 1996.

12. P. Dourish and S. Bly. Portholes: supporting awareness in a distributed work group. In *Proc. CHI'92*, 541–547. ACM, 1992.

13. J. Fogarty, S. E. Hudson, C. G. Atkeson, D. Avrahami, J. Forlizzi, S. Kiesler, J. C. Lee, J. Yang, and J. Yang. Predicting human interruptibility with sensors. *ACM ToCHI*, 12(1):119–146, 2005.

14. S. Greenberg and H. Kuzuoka. Using digital but physical surrogates to mediate awareness, communication and privacy in media spaces. *Personal and Ubiquitous Computing*, 3(4):182–198, Dec. 1999.

15. S. Gueddana and N. Roussel. Pêle-mêle, a video communication system supporting a variable degree of engagement. In *Proc. CSCW'06*, 423–426. ACM, 2006.

16. C. Gutwin. Traces: Visualizing the Immediate Past to Support Group Interaction. In *Proc. GI'02*, 43–50, May 2002.

17. S. E. Hudson and I. Smith. Techniques for Addressing Fundamental Privacy and Disruption Tradeoffs in Awareness Support Systems. In *Proc. CSCW'96*, 248–257. ACM, Nov. 1996.

18. E. Isaacs, A. Walendowski, S. Whittaker, D. J. Schiano, and C. Kamm. The character, functions, and styles of instant messaging in the workplace. In *Proc. CSCW'02*, 11–20. ACM, 2002.

19. L. Itti. Visual salience. *Scholarpedia*, 2(9):3327, 2007.

20. W. James. *The principles of Psychology*. Henry Holt, 1890.

21. S. Jul and G. W. Furnas. Critical zones in desert fog: aids to multiscale navigation. In *Proc. UIST'98*, 97–106. ACM, 1998.

22. K. Karahalios and J. Donath. Telemurals: linking remote spaces with social catalysts. In *Proc.of CHI'04*, 615–622. ACM, 2004.

23. W. Mackay and A.-L. Fayard. HCI, natural science and design: a framework for triangulation across disciplines. In *Proc. DIS'97*, 223–234. ACM, 1997.

24. P. P. Maglio and C. S. Campbell. Tradeoffs in displaying peripheral information. In *Proc. CHI'00*, 241–248. ACM, 2000.

25. D. S. McCrickard, R. Catrambone, and J. T. Stasko. Evaluating animation in the periphery as a mechanism for maintaining awareness. In *Proc. Interact'01*, 148–156. IOS Press, 2001.

26. G. McEwan and S. Greenberg. Supporting social worlds with the community bar. In *Proc. Group'05*, 21–30. ACM, 2005.

27. B. A. Nardi, S. Whittaker, and E. Bradner. Interaction and outeraction: instant messaging in action. In *Proc. CSCW '00*, 79–88. ACM, 2000.

28. D. S. Pagani and W. E. Mackay. Bringing media spaces into the real world. In *Proc. ECSCW'93*, 341–356. Kluwer Academic, 1993.

29. K. Perlin and D. Fox. Pad: An alternative approach to the computer interface. In *Proc. SIGGRAPH'93*, 57–64. ACM, 1993.

30. C. Plaue and J. T. Stasko. Animation in a peripheral display: distraction, appeal, and information conveyance in varying display configurations. In *Proc. GI'07*, 135–142. ACM, 2007.

31. Z. Pousman and J. T. Stasko. A taxonomy of ambient information systems: four patterns of design. In *Proc. AVI'06*, 67–74. ACM, 2006.

32. N. Romero, G. McEwan, and S. Greenberg. A field study of Community Bar: (mis)-matches between theory and practice. In *Proc. Group'07*, 89–98. ACM, 2007.

33. N. Roussel and S. Gueddana. Beyond "Beyond being there": towards multiscale communication systems. In *Proc. Multimedia'07*, 238–246. ACM, 2007.

34. S. Smale and S. Greenberg. Broadcasting information via display names in instant messaging. In *Proc. Group'05*, 89–98. ACM, 2005.

35. R. Strong and B. Gaver. Feather, scent and shaker: supporting simple intimacy. In *Proc. CSCW'96*, 29–30. ACM, Nov. 1996.

36. J. C. Tang. Approaching and leave-taking: negotiating contact in computer-mediated communication. *ACM ToCHI*, 14(1):5, 2007.

37. P. Tolmie, J. Pycock, T. Diggins, A. MacLean, and A. Karsenty. Unremarkable computing. In *Proc. CHI'02*, 399–406. ACM, 2002.

38. M. Weiser and J. S. Brown. Designing calm technology. *PowerGrid Journal*, 1(01), July 1996.

39. S. Whittaker. Rethinking video as a technology for interpersonal communications: theory and design implications. *IJHCS*, 42(5):501–529, 1995.

40. Q. Zhao and J. T. Stasko. Evaluating Image Filtering Based Techniques in Media Space Applications. In *Proc. CSCW'98*, 11–18. ACM, 1998.