Peripheral Telecommunications: Supporting Distributed Awareness and Seamless Transitions to the Foreground

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Abstract. We consider two problems related to communication between geographically distributed family members. First, we examine the problem of supporting peripheral awareness, in order to improve both emotional well-being and awareness of family activity. This is based on a field study to determine the role and importance of various peripheral cues in different aspects of everyday activities. The results from the study were used to guide the design of our proposed augmented communications environment. Second, we consider the choice of mechanism to facilitate the on-demand transition to foreground communication in such an environment. The design suggests an expansion of Buxton's taxonomy of foreground and background interaction technologies to encompass a third class of *peripheral* communications.

Keywords: Telecommunications, peripheral cues, geographically distributed family.

1 Introduction

The number of families that live apart, either by choice or necessity, has been increasing due to various social circumstances. In the United States, the proportion of nuclear family households (two married parents and a child) dropped from 40% of all households in 1970 to 23% in 2005, while in the same period, the number of single-adult households climbed from 16% to 28% in 2005 [1][2]. Similarly, in Japan, between 1995 and 2005, there was a drop of 2.5% in the percentage of nuclear family households, while the percentage of people living alone increased by a staggering 28.6% [3]. Additional trends, in part due to greater longevity, indicate a growing elderly population [4], often living in isolation from the rest of their families. These dramatic shifts in household composition entail significant changes in the nature of family relationships and, we argue, place increased importance on the role of communications technology for social benefit.

Telephone conversations and videoconferencing provide the means for voice or video communication, but these are often brief in duration, sporadic, and fail to convey much of the rich background or peripheral information we experience about each other when living together. Furthermore, family members, in particular seniors, may be hesitant to initiate contact using telecommunications technologies, even when they wish to see or speak with their loved ones.

This paper describes our initial effort to compensate for these limitations and engender a greater sense of social proximity to distributed family members. The research to date consists of a field study of peripheral communication cues in family relationships and the design phase of an augmented communications environment that facilitates the exchange of certain peripheral information and allows seamless transitions between peripheral and foreground communications.

1.1 Peripheral Communication

In everyday life, people who live together consciously or unconsciously convey, perceive, and share various peripheral information. Examples include the cues of tone of voice, singing in the kitchen or shower, the pace of footsteps, doors being opened or slammed shut, light or music leaking through a door, movement of personal belongings such as bags and keys, and the aroma of coffee brewing or cookies baking. Of course, such cues may have divergent interpretations and significance to different family members and across different families. It is thus necessary to understand how individuals might interpret and use specific cues, perhaps subconsciously, to gain awareness of the mood or physical presence of other family members.

When family members move apart, these cues are no longer shared, which, we believe, diminishes the sense of close contact the family previously enjoyed. Our research project is investigating how technology can help convey these subtle, but important elements of peripheral information to family members or partners living apart for extended periods. Our hypothesis is that the exchange of appropriate peripheral cues will lead to an improved awareness of each others' mental and emotional states, and in turn, reduce the burden on individuals when they wish to initiate communication, thereby leading to improved contact between family members. If implemented correctly, this may improve emotional connectedness, decrease feelings of loneliness and separation, and augment conventional (foreground) communications technology, leading to more productive and fulfilling interactions.

1.2 Previous Literature

Home technologies that aim to assist family members living apart, in particular, seniors, have been investigated by other HCI researchers. Efforts in this area include the use of various digital props, for example, life-size cardboard cutouts of family members [5], family portraits [6], Internet teapot [7], Message Center [4], interactive light table [15] and the installation of an augmented "planter" [8] that senses and

conveys physical motion and touch of remote family members. Despite the apparent simplicity of these devices, family members reported powerful emotional affects resulting from their placement in the home.

The major research question relates to the determination of whether more significant cues are sensed and conveyed to remote family members in a meaningful form so as to increase peripheral awareness of the state of loved ones without the technology becoming intrusive or overly demanding of foreground attention.

2 Studying Peripheral Cues among Family

Field studies of technology use in the home have been conducted for a variety of purposes include natural observational studies of family awareness [9] and information organizing systems in the home [10][11]. Social and emotional factors have also been considered within the eldercare experience of "aging in place" [12]. However, there have been comparatively few studies on the details of background communication among close individuals [8]. In the design of an effective communications environment for close individuals who live apart, we think it is important to understand how various communication cues are used by these individuals while living together.

2.1 Method and Research Settings

As a first step, we conducted a field study consisting of a series of empirical sessions, involving interactive semi-structured interviews, a set of questionnaires, in-situ contextual inquiry sessions, and open-ended discussion. The aims were to understand the participants' current use of communications media, determine important peripheral cues for sensing presence and mood of family members, memory triggers that evoke feelings of missing one another, and verify that our assumptions concerning the use of peripheral communication were valid.

Seven respondents (two male and five female), ranging between 19 and 26 years of age, participated. Table 1 summarizes the profile data of these individuals (indicated by initials) as well as a breakdown of their use of peripheral cues in relating to other family members. With only one exception, the participants described their relationships with family members as open, relaxed, devoted, and involving frequent communication. The field study took place in Montreal, Canada between July and September of 2006 and involved approximately nineteen hours over nineteen sessions in total. The sessions, spread over several weeks, were conducted on an individual basis to assure participants' privacy and divided into three components. Each such component involved a period of discussion, completion of a questionnaire, and a take-home data gathering exercise.

The aim of the introductory session was to facilitate for participants a better understanding and awareness of their everyday background communications with family members and establish an appropriate rapport. The initial questionnaire (Q1) involved topics of family members' profiles, feelings regarding relationships with

family members, and current use of communications media. Prior to the second session, participants were asked to complete a second form (Q2) by listing a number of cues related to everyday background communications with family members at their home. In order to gain specific information regarding the various roles that peripheral communication plays in everyday activities, these were divided into categories of gaining awareness of (a) mood and (b) physical presence of family members, as well as (c) memory triggers that evoke feelings of missing family members.

During the second session, typically one week later, we began with a debriefing of the responses to Q2 and followed this with another questionnaire (Q3) concerning participants' current feeling of loneliness and well-being. This was done to understand their potential motivation of further contacts with family and the context for their peripheral communication cues. Prior to the third session, participants were asked to complete another form (Q4, which was an elaboration of Q2), listing as many peripheral cues as possible. Participants were also asked to draw floor plans of their home and capture video or photographic examples as helpful to illustrate their list of cues. These were expected to provide a basis for understanding the spatial relationships of peripheral cues and assist our design of a prototype augmented environment for peripheral communication.

During the third session, again, typically one week later, we conducted semi-structured in-situ contextual interviews to evaluate the level of emotional responses and their importance, as related to the list of cues obtained from Q2 and Q4.

Table 1. Profiles of respondents and summary of peripheral communication cues.

	Gender	Age	Living apart from which family members	Living with	Peripheral communication cues					
					Visual	Audio	Somato sensory	Olfactory	Taste	Other
FR	M	26	brother, parents	n/a	14	14	0	0	0	0
NR	M	23	brother	parents	17	16	0	1	0	0
MK	F	19	parents	n/a	9	16	1	0	0	3
TR	F	22	partner, parents	n/a	4	3	0	1	0	0
IM	F	22	partner	roommate	13	9	2	0	0	4
CY	F	23	partner	n/a	9	13	0	3	0	2
LP	F	23	partner	parents	4	3	0	0	0	0

2.2 Results

Use of Conventional Communications Media. From the comments and discussion with study participants, several shortcomings of conventional (foreground) communications media were noted. In general, emotional characteristics of communications, including one's overall mood and expressions of sarcasm or humor, were felt to be not as easily conveyed through communications media as in person. The two most popular forms of communications media used by our study participants were clearly telephone and email, with the former being preferred, when available, almost exclusively. Nevertheless, one participant commented explicitly on the

inadequacy of email for expressing feelings, in particular as she spoke a different mother tongue from her partner, while another noted that misunderstandings may arise from the lack of visual cues available in telephone conversation. Additional issues raised regarding telephone communication concerned the restrictions on engaging in parallel activities, such as washing dishes, due to background noise. The danger of misinterpretation, in particular for jokes or sarcasm, was also raised in regard to instant messaging. As has been described in numerous other studies, social communication relies to a great deal on visual cues to provide context for verbal remarks.

Peripheral Cues. A total of 161 distinct peripheral communication cues were obtained from the responses to our questionnaires Q2 and Q4. These were analyzed according to the primary modality of individual cues and classified into six categories of visual, audio, somatosensory, olfactory, taste and others (Table 1).

The results indicate that audio (46%) and visual (43%) were the two dominant modalities of peripheral communication cues with family. Very few cues were reported for the other modalities of somatosensory (1.9%), olfactory (3.1%) and taste (0%) information. A small number of cues involved the description of an overall experience, typically a non-instantaneous event such as going for a walk, or to a dim sum restaurant. As these involved multiple modalities over a particular interval, or did not involve any particular modality information, these were classified in a separate category of "others" (5.6%).

An analysis of the distribution of cues by category (Table 2) suggests that the two dominant modalities of audio and visual cues may play different roles in peripheral communication. Audio seems to be particularly relevant for gaining awareness of the mood of other family members, whereas visual cues were more strongly related to triggering memories that evoke feelings of missing one another. Both modalities were equally significant in relation to cues of physical presence of other family members.

Table 2. Peripheral cues summarized by category.

	state of mind	physical presence	thinking of family	Sum
Visual	12	26	32	70
Audio	33	26	15	74
Somatosensory	0	0	3	3
Olfactory	0	2	3	5
Taste	0	0	0	0
Others	2	0	7	9

3 Peripheral Communications Prototype

Based on the results of our initial field study, we attempted to specify the design of an augmented environment for the transmission of peripheral cues between geographically separated family members.

3.1 Modality Considerations

The preceding analysis of cues suggests the dominance of visual and audio modalities in peripheral communication, with audio particularly important for conveying a sense of feelings or emotions of family members. Since our primary intent is to support a greater awareness of the well being and feelings of distant family members, it therefore makes sense to focus on the extraction of relevant auditory cues from the environment and the manner in which these are delivered to the remote party. An additional benefit of working with the auditory, rather than visual, modality is that rich information may be conveyed without requiring family members to be in a particular room where a display is visible.

Relevant audio cues cited by our study participants included the gait of footsteps, doors being slammed shut, music played, and the sounds of a meal being prepared, typically as indicators of presence of other family members. Similarly, the tone, inflection, and rate of speech were mentioned as strong cues of emotional state, even if individual spoken words cannot be recognized. These observations are significant, as they suggest that audio may afford a high degree of peripheral communication even if reproduced in a low-fidelity manner, provided that the salient characteristics are preserved. At the same time, it is necessary to ensure that our system neither conveys foreground information, such as clearly discernable speech, nor commands explicit attention. This may be achieved by some form of active content filtering, or by mapping audio input to some other modality, for example, an abstract graphic visualization, similar to those provided by music player software. Miyajima et al. provide such a mapping between the input of touching a terminal and the corresponding output sounds produced at the remote location [8]. In contrast, we are motivated to convey cues in their original modality, preserving as much richness as possible in the communication. In either case, it is humans, rather than technology, that are responsible for the interpretation of these cues. However, we believe that such interpretation is severely limited when it cannot benefit from the skills that family members develop through years of experiencing cues in their original form.

3.2 Peripheral Audio

Our design aims to convey the maximum information content without crossing into the domain of foreground communication. To do so, we propose to transmit muffled audio between the two sites, simulating the perceptual effect of hearing the sounds made by family members several rooms away; in other words, virtually extending the house in the manner of a geographically distributed soundscape. This may be

accomplished easily by damping the microphones in order to mimic the acoustic effects one would experience as sound travels through walls. This would offer the benefit of relegating what may be a complex computational filtering task to natural physics. To preserve meaningful semantics, we believe that sound source location and directionality are important, in the sense that sounds from the kitchen may not be perceived in the same context if they are reproduced in a different room at the remote location. Thus, use of multiple microphones and speakers is required, with an attempt to match the sources and sinks to socially equivalent locations at the two sites. Automated gain control might be utilized to balance reproduced audio cues with the local ambient volume level. In addition, manual gain control may prove important to users, at least for acceptability of the technology as deployed in a home environment. Similarly, privacy concerns are reduced because muffled speech remains unintelligible.

4 Transitions Between Periphery and Foreground (and back)

Buxton [13] proposed a taxonomy for classifying communications technologies, divided into human-human/human-computer along one axis, and foreground/background along the other. His definition of *background,* like ours, relates directly to activities that take place in the periphery of human attention. While Buxton's model includes smart-house and the "Portholes" system [14] as examples of background human-computer and human-human interaction, respectively, these nevertheless demand a certain level of focused user attention to issue commands or queries, but also, in the case of Portholes, at least, to interpret current state. Moreover, exploiting the (computer-mediated) human-human technologies, even in a purely background context, rely on a centralized element of information technology, typically a computer display, which assumes a relatively stationary user. This may be acceptable in an office scenario, but is unlikely typical of a home environment, the primary domain of our interest. We believe that truly *background* technology must be able to convey meaningful state information without conscious effort on the part of its users *and* allow accessibility to this information from a wide variety of locations within one's environment. Portholes does not necessarily meet either of these definitions, while the Ambient Scribbles of the RemoteHome [15] violates the latter definition as it can only be viewed by users facing the correct direction. To distinguish between these cases, we propose the following refinement of Buxton's taxonomy, in which technologies that operate *entirely* in the user's periphery of attention are deemed *peripheral* (Figure 1).[1]

Buxton's model not only provides a taxonomy but describes the transitions between states in response to various events. Keeping with this approach, our system, placed in the newly added third column, supports transitions as follows. A user who is currently receiving peripheral audio from a remote family member may

[1] Such a definition might equally well be considered as pervasive or ubiquitous computing, but given the proliferation of technologies under this label that fail to meet our requirements, we prefer to avoid potential confusion.

request initiation of foreground human-human communication with that individual by entering the specific room from which the sounds are currently heard, and performing an appropriate gesture or speaking a passphrase. This information is received by the distributed technology (peripheral human-computer interaction). The gesture might take the form of an arm wave, as if trying to capture someone's visual attention, while the passphrase could be an explicit "Hi, Dave!" Clearly, these options would require additional system components such as image processing or speech recognition, and would need to be robust to potential false positive recognition. A simpler alternative would be to equip each room with a tangible interface, for example, a mock-up of a telephone, which, when picked up, or perhaps, simply touched (background human-computer interaction), would serve as the indication of user intent to establish a foreground connection with the other family member.

Figure 1. Revised model of communications technologies (based on Buxton [13])

	Foreground	**Background**	**Peripheral**
Human-Human	Face-to-face conversation, telephone, video conference, email	Communicating background information using a centralized interaction device (e.g. Portholes, Digital Family Portrait, Family Planter)	Communicating background information using peripheral interactions anywhere within an environment (e.g. pervasive sounds of remote family members)
Human-Computer	GUIs	Smart-house technology, or indicating intention by manipulation (e.g. by lifting a telephone handset)	Communicating intentions using natural indicators (e.g. intent to establish foreground connection to remote family member)

At the remote end, either an iconic sound (e.g. "ringing") or visual cue that reminds a receiver of the caller (background human-computer interaction) could be generated to indicate that someone wishes to speak with them. However, it is worth reflecting on Weiser and Seely Brown's definition of calm technology as that which "engages both the center and the periphery of our attention, and in fact moves back and forth between the two" [16]. Ideally, we would like the *calling cue* to fit this role, rather than being a disruptive signal, although this entails the risk that the caller may be inadvertently ignored. One option would be to convey the unfiltered sound of the caller's voice, at an appropriately discrete level, as they speak the passphrase, thereby signaling the caller's intent. With sufficient audio resources, this might be enhanced by spatializing the sound so that the caller appears to have moved closer to the intended receiver. The actual connection (foreground human-human interaction) would only be established if the called party accepts the request, as indicated by a corresponding gesture, action, or utterance. At that point, the communications technology would temporarily stop filtering the transmission of audio between the two sites, at least for the two rooms currently occupied by the family members at each

end, and the communication link becomes a conventional speakerphone.[2] It may be desirable for the system to permit users to move around their respective environments, while maintaining the foreground communication they have already established, although privacy considerations must be kept in mind when other family members are also present.

Similarly, a transition from foreground back to peripheral communication could be effected by a wave or utterance "goodbye," or equally, the action of returning the mock telephone handset to its base. In either case, the transition between states is easily established, making use of similar cues to those employed in the everyday world.

5 Concluding Remarks

With the overall design now completed, we are beginning the effort of translating these ideas into a practical implementation that will be deployed in the homes of some of our initial study participants. These individuals will remain actively involved in the development process by providing continued feedback as the design evolves, Of particular interest, we wish to experiment with the various options for initiating transitions between states, as described in the previous section, in order to evaluate their ease- and frequency of use. We expect to conduct multiple evaluations of family interaction, before, during, and after deployment, in order to assess the effectiveness of our prototype. This feedback will, in turn, drive successive iterations of the technology. We hope that this effort will prove beneficial in helping distributed family members maintain awareness of each other's state and emotional well-being in a manner that goes beyond the capabilities of current foreground communications technology.

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