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Managing lightweight interactions.....

## **TeleNotes: Managing lightweight interactions in the desktop**

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**Keywords: Interpersonal communications, computer mediated communication, task management, audio, video, conversation management, lightweight interaction**

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# TeleNotes: managing lightweight interactions in the desktop

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## ABSTRACT

Communication theories and technology have tended to focus on extended, formal meetings and neglected a prevalent and vital form of workplace communication, namely lightweight communication. Unlike formal, extended meetings, lightweight interaction is brief, informal, unplanned and intermittent. We analyse naturalistic data from a study of workplace communication, and derive five design criteria for lightweight interaction systems. These criteria require that systems for lightweight interaction support: *conversational tracking*, *rapid connection*, the ability to *leave a message*, *context management* and *shared real-time objects*. Using the criteria, we evaluate existing interpersonal communications technologies. We then describe an implementation of a system TeleNotes, that is designed to support lightweight interaction by meeting these criteria. The interface metaphor allows communications to be based around desktop objects, resembling "sticky notes". These objects are also organised into "desktop piles" to support conversational threads and provide mechanisms for initiating real-time audio, video and application sharing. We conducted informal user testing of several system prototypes. Based on our findings, we outline outstanding issues concerning theory and systems design for communication systems, in particular with regard to the issue of managing conversations over time.

## LIGHTWEIGHT COMMUNICATIONS

Studies of workplace activity show the *pervasiveness* of interpersonal communications. Office workers spend between 25% and 70% of time in face-to-face conversations with others, depending on job specification (Kraut, Fish, Root & Chalfonte, 1993, Panko, 1992, Whittaker, Frohlich & Daly-Jones, 1984). In addition to being frequent, interpersonal communication is also *vital* for achieving certain types of work-related tasks. Frequent, opportunistic face-to-face communications are crucial for rapidly resolving ambiguity during the planning and negotiation phases of projects, and they also support organisational learning (Finholt, Sproull & Kiesler, 1990, Kraut, Egido & Galegher, 1990, Kraut *et al.*, 1993, Kraut & Streeter, 1996, Suchman & Wynn, 1984). However, apart from a few recent exceptions (Bly, Harrison & Irwin, 1993, Fish, Kraut, Root & Rice, 1992, Gaver, Moran, MacLean, Lovstrand, Dourish, Carter & Buxton, 1992, Isaacs, Tang & Morris, in press, Tang, Isaacs & Rua, 1994), past systems and theoretical work have tended to focus on only one class of interpersonal communication. This is the class of interactions that are *extended*, *multiparty*, *formal* and *one-shot* (Egido, 1988, 1990, Isaacs, Morris & Rodriguez, 1994, Johansen, 1984, Nunamaker, Dennis, Valacich, Vogel & George, 1993, Olson, Olson, Carter & Storrosen, 1992, Stefik, Foster, Bobrow, Kahn & Suchman, 1987, Tang, 1991). Recent research shows, however, that such extended, multiparty, formal, one-shot interactions are the exception, rather than the rule in interpersonal communications. The majority

of office interactions consist of brief informal two person exchanges, for example, to answer colleague's question, to remind a coworker about a deadline, to hand over a document or discuss a social issue (Frohlich & O'Conaill, 1995, Isaacs, Whittaker, Frohlich & O'Conaill, in press, Kraut *et al.*, 1993, Suchman & Wynn, 1984, Whittaker *et al.*, 1994). Here we therefore focus on brief, two person, informal, repeated communications which we call *lightweight interactions*.

Research on scientific collaboration has shown that physical distance is the strongest predictor of whether two researchers will collaborate, precisely because physical proximity promotes lightweight interaction (Kraut *et al.*, 1990, Kraut *et al.*, 1993). The data we report below shows exactly how a shared physical environment leads to these types of interaction. However, trends towards telework, mobile work and the globalisation of business are geographically separating workers, making collocated lightweight interaction less frequent, and harder to achieve. In addition the use of technologies such as email and workflow may be decreasing the lightweight interaction that in the past took place around face-to-face document distribution and meeting scheduling (Whittaker, in press).

What is needed to support effective lightweight interaction at distance? Technologies to support lightweight interaction will need to support its key features. Empirical work shows interpersonal communication<sup>2</sup> is: (a) usually *two-person* rather than multiparty, so that for professional workers 84% of meetings are dyadic (Whittaker *et al.*, 1994); (b) *brief*, with conversations generally lasting no more than a few minutes (Kraut *et al.*, 1993, Whittaker *et al.*, 1994); (c) *opportunistic* rather than scheduled, with professionals having around 90% unscheduled meetings (Kraut *et al.*, 1993, Whittaker *et al.*, 1994), with figures of around 60% unscheduled meetings for managers (Panko, 1992); (d) focussed around *shared objects* such as documents or designs (Luff, Heath & Greatbatch, 1992, Tang, 1991), in our data we found documents were involved in 53% of interactions (Whittaker *et al.*, 1994); (e) *repeated* rather than one-shot. Repeated communications are often necessary because the purposes of lightweight interactions are seldom achieved in one interchange, with the result that such conversations are frequent and intermittent (Whittaker *et al.*, 1994), with participants on average interacting with each other 2.5 times per day (Kraut *et al.*, 1993).

To illustrate the character of lightweight interaction, we present two illustrative examples, taken from an extensive analysis of real workplace interactions. The data come from an observational study in which knowledge workers were "shadowed" for a week. We recorded all their interactions using a combination of video and audio. We generated a corpus of 294 conversations, involving a total of 99 different interactants. This research method and more detailed results are presented in Whittaker *et al.* (1994) and Frohlich (1995). Both the current examples involve the same two participants, R. and F., who work together in a surveyor's<sup>3</sup> office.

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<sup>2</sup>The data we report here cover *all* forms of interaction and not just lightweight interaction. They therefore include instances of more extended, formal, arranged meetings. By including all forms of interaction, these summary data thus *underestimate* some of the major characteristics of lightweight interaction, namely their dyadic nature, brevity, opportunism, and repeated nature.

<sup>3</sup> In US English, a surveyor is referred to as a real estate appraiser.

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In Example 1, the entire whole two person interaction is completed in 4 utterances and lasts only 8 seconds. R. sees that F. is moving around the office and hence is not currently engaged directly in work. R. therefore opportunistically solicits F.'s help. The fact that they share a common physical environment affords R. this information about F.'s availability and allows F. and R. to jointly look at, and then physically exchange, the document. Note also the brevity of the interaction and the absence of formal conversational openings or closings, such as greetings or farewells.

The fragment in Example 2 represents 28 seconds of a second interaction lasting 96 seconds. Although it again features R. and F., it shows an unplanned conversation about a *different* topic, one that occurred immediately after F. had finished a phone call to a client. It arose spontaneously because R. heard F.'s phone call and opportunistically wanted to monitor the outcome (Line 1). Again the fact that participants share a common physical environment promotes this type of impromptu interaction. It continues with R. offering unsolicited advice and assistance. Again the interaction starts without formal initiation, with R. beginning with a direct question to F. The interaction also has a *history* as revealed by the implicit shared context between the participants: without being told, R. knows the identity of F.'s caller (Line 1), and details of the case (Line 3), although R cannot remember all these details. R. also proceeds to supply background information which F. may not already have known (Line 7), and some advice (Lines 9 and 11). The shared context results in a condensed and cryptic conversational style. This conversation continued for several more utterances after the extract: R. gave more details and offered a warning about acting for both client and tenant. Thus an unplanned conversation led to a detailed task oriented discussion, initiated by R. that was of benefit to F. Further analyses of these conversations, along with a demonstration of their functions and mutual benefits to the interactants are given in Frohlich (1995) and O'Conaill & Frohlich (1995).

These results suggest a characterisation of work in which people are engaged in multiple intermittent interleaved collaborative tasks. Workers seek out and are frequently sought out, by their coworkers for *brief synchronous* opportunistic interactions. Each conversation may have a history of prior interactions and workers are often concurrently engaged in multiple interaction threads. Furthermore, a worker may be engaged in multiple concurrent conversational threads with the same coworker. This gives rise to the problems of *context-regeneration* and *tracking conversational threads*. Given that workers are engaged in multiple concurrent tasks, and that conversations are usually impromptu, how are workers able to switch context from their current task and immediately refocus on the topic that their coworker has just asked about? Furthermore, when the brief interaction is over, how do they switch back to their prior interrupted task (O'Conaill & Frohlich, 1995)? How also do they keep track of the relationships between different fragments of the same intermittent conversation, when there are often long delays between related interactions?

We will argue that people currently exploit the presence of work-related artifacts (such as papers, drawings, notes and folders) to help manage the history and context of these intermittent interactions. When task-related documents are co-present and visible, they can serve to "hold the context" of multiple ongoing conversations. Indirect support for this notion comes from our observation that 53% of workplace interactions involved a document (Whittaker *et al.*, 1994).

Additional evidence for the context management function of documents is the frequently observed "messy desktop" (Barreau & Nardi, 1995, Frohlich, 1995, Kidd, 1994, Malone, 1984, Mander, Salomon, & Wong, 1992, Rouncefield, Hughes, Rodden, & Viller 1994). Office workers scatter their physical desktops with clusters of notes, documents and folders relating to ongoing projects. As a consequence, this information is readily at hand as a retrieval cue when an external interruption occurs. The "messy desktop" therefore allows people to regenerate the history of a prior conversation, even when substantial time has elapsed since the topic was last discussed<sup>4</sup>.

Other work has described people's attempts to use the computer desktop in an analogous way: electronic documents and folders are sometimes left visible in the user's electronic workspace to serve as reminders and context-holders for urgent work in progress (Barreau & Nardi, 1995). Similarly, users often retain undischarged email messages in their inboxes to serve as reminders about tasks or conversations that are still in progress (Whittaker & Sidner, 1996). Despite this, few systems provide direct support for context maintenance<sup>5</sup>. Furthermore, a number of recent studies have emphasised the utility of paper documents in providing an external visible record of current ongoing activity, and contrasted this with the relative inaccessibility of screen-based information for context tracking (Bowers, 1994, Luff *et al.*, 1992, Whittaker & Schwarz, 1995).

These paper documents and notes also serve a second role. Once an interaction is underway they function as *shared objects*. They operate as part of a shared workspace and provide a shared physical context for the conversational participants. They also act as a resource for looking up information, recording information and as a target for gesturing, marking and note-taking (Frohlich, 1995, Luff *et al.*, 1992, Tang, 1991, Whittaker *et al.*, 1994). Studies of remote synchronous communication using audio and shared workspace have also documented these functions for electronic documents and shared materials as "context holders" and memory aids in real time discussions (Bly, 1988, Brinck & Gomez 1992, Minneman & Bly, 1991, Whittaker, Brennan & Clark, 1991, Whittaker, Geelhoed & Robinson, 1993, Whittaker, 1995a). Similar benefits occur when groups are provided with a shared *dynamic* image to support collaboration at distance (Gaver, Sellen, Heath & Luff, 1993, Nardi, Schwarz, Kuchinsky, Leichner, Whittaker & Sclabassi, 1993, Nardi, Kuchinsky, Whittaker, Leichner & Schwarz, 1996, Whittaker, 1995a, 1995b). In these applications video supports a shared workspace by providing joint access to video images of work objects that are critical to the collaborative task of the distributed group. In a neurosurgery application (Nardi *et al.*, 1993, 1996; Whittaker, 1995a, 1995b), remote members of a distributed surgical team were able to view video images from the operating theatre, of the patient's brain or spine. They were therefore able to see the state of the operation "at a glance" by

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<sup>4</sup> An alternative perspective is that the "messy" desktop is actually dysfunctional, resulting from a lack of time or inclination to carry out filing and that it is an ineffective way to organise ongoing tasks. While we know of no study that has quantitatively compared the success of "messy" and "neat" desktops, there is strong evidence of the reminding functions of visible materials (Whittaker & Schwarz, 1995, Whittaker & Sidner, 1996), as well as the ability of users to find information in "messy" piles (Barreau & Nardi, 1995, Malone, 1983).

<sup>5</sup> One exception is a system by Henderson and Card (1986) that uses the metaphor of "rooms" into which users can place related documents or applications, where it is easy to switch rooms and hence contexts.

looking at the image. This enabled them to co-ordinate their remote actions and provide advice to the team in the operating theatre.

Using artifacts as reminders and context-holders for ongoing tasks, is also important in the event of *failed attempts* to initiate lightweight interaction. We refer to this as the *connection problem*. The *opportunistic* nature of lightweight interaction means that attempts to initiate communication often fail, because the intended conversational participant is not currently available for conversation. Thus we found that attempts to initiate impromptu communications using the telephone failed on 62% of occasions, because the intended recipients were away from their desks or otherwise engaged in communicating with another person (Whittaker *et al.*, 1994). Similar failure rates are reported by other studies (Rice & Shook, 1990). This suggests two new communication requirements: *one way drop* and *communication reminders*. For many communication purposes, one way information transmission may be sufficient: surveys report that users feel that leaving a message is adequate for over half of business telephone conversations (Rice & Shook, 1990). For this reason, office workers often leave each other brief notes accompanying documents ("here's the most recent draft, can you look at pages 3-5?"). On other occasions, however, one way drop of information may be insufficient. It may therefore be necessary to have synchronous communication, in which case a *communication reminder* may be important: leaving a message ("call me before 11, on 123 4567") can be used to co-ordinate a future synchronous connection (Tang *et al.*, 1994). Following from this, a further function of desktop notes, documents and folders may also be to *remind* the worker of the fact that a connection attempt failed and that a synchronous conversation still needs to take place. Furthermore artifacts can *hold context* during the period that one is waiting to communicate synchronously with another person. Thus when the connection is successfully made, the original conversational context can be more easily regenerated, because the presence of the documents serves as a retrieval cue for memory access.

This analysis of workplace communications indicate that effective support for lightweight interaction requires five related components:

- v (a) **Conversational threading:** *Participants are engaged in multiple intermittent communications tasks, often with different individuals. The system must therefore keep track of interactions, storing elements of the same conversation together so that they can rapidly be accessed as a unit, allowing participants to check the status of a given conversation*
- v (b) **One-way drop:** *The system should support the ability to leave a brief asynchronous message, given the fact that attempts to achieve opportunistic connections frequently fail, and valuable information exchange can often take place without synchronous communications.*
- v (c) **Quick Connection:** *Given the brevity of lightweight interaction, the system should support rapid flexible communications and participants should be able to quickly connect with others.*
- v (d) **Context preservation and regeneration:** *Given the intermittent but repeated nature of lightweight interaction, where there are often long delays between elements of the same conversation, the system should support methods for straightforwardly accessing prior parts of ongoing conversations, including the materials or artifacts that are involved in that interaction.*

v (e) **Shared objects:** *The system should support real-time shared objects as props and conversational resources, because of the frequency with which documents feature in lightweight interaction, and their supporting role in mediating conversation.*

Principles (a) and (d) and to a lesser extent (b) require the management of interactions across time, a problem which has characteristically been ignored in theoretical, empirical and technology oriented work (O’Conaill & Frohlich, 1995, Whittaker *et al.*, 1994, Whittaker & Sidner, 1996). In contrast (c) and (e) are more concerned with real time interaction, which has received more attention. Overall we need to support both synchronous and asynchronous communication methods, as part of an *integrated* set of communications applications for lightweight interaction (Tang *et al.*, 1994). Users can then choose the appropriate communication method as the situation demands.

**CURRENT TECHNOLOGIES FOR SUPPORTING LIGHTWEIGHT COMMUNICATIONS: STRENGTHS AND WEAKNESSES**

Our discussion has mainly focussed on analysing lightweight communications in workgroups who share the same physical location. We now evaluate current technologies used for remote communication to see how well they support the lightweight interaction characteristics identified above. Table 1 shows that no current technology support all the features of lightweight interaction. Technologies tend to focus on purely synchronous communications (eg. telephone, shared workspace, videophone) without support for context regeneration or task threading. Alternatively, they are focussed on asynchronous communication (eg. email, workflow and voicemail), which is highly effective for information drop-off but does not support real-time exchanges. Furthermore we will argue that with the possible exception of workflow, most asynchronous technologies do not support context regeneration and task threading effectively.

	PHONE	VOICEMAIL	EMAIL	WORKFLOW	PAGER	MEDIA SPACES	Video phone/ Video-conference	Shared workspaces
TASK THREADING	No	No	Weak support in some systems	Yes	No	No	No	No
ONE WAY DROP	No	Yes	Yes	Yes	Yes	Not supported in most systems	No	No
QUICK SYNCHRONOUS CONNECT	Yes	No	No	No	No	Yes	Yes	Yes
CONTEXT REGENERATION	No	No	Weak support in some systems	Yes	No	No	No	No
REAL-TIME SHARED OBJECTS	No	No	No	No	No	Not supported in most systems	Not supported in most systems	Yes

*Table 1: Evaluating current communications technologies for lightweight interaction features*

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The *phone* supports synchronous connection, but it has no document integration or asynchronous components. It therefore provides no support for managing the history of an intermittent extended conversation by offering features such as *context regeneration*, and *task threading*. It also provides no capability for *real-time object sharing*. Phone alone does not support *one-way drop* of information, although combined with an answering machine it does so.

*Voicemail* does not support *synchronous communications* or real-time *shared objects*. Voicemail supports *one-way drop* of information, often as a means to promote synchronous communications, eg. "this is X, call me back on 123 4567". Although there is message storage in voicemail, most systems limit storage to small numbers of messages which have to be deleted on a frequent basis<sup>6</sup>, and no commercial systems provide users with ways to manage messages according to *thread* (Rice & Shook, 1990). Again this means that the prior *context* of a voicemail message is often lost.

*Email* does not support *synchronous connection*. It also does not allow users to *share objects* in real-time. Given its asynchronous nature, email supports *one-way drop* of information. Most email systems also provide minimal features for *context regeneration*, in that they allow users to save messages. However the majority of systems lack features that explicitly facilitate context management, such as the automatic categorisation of messages by conversational task. For example, one might wish to view originating messages and responses to those messages together to determine the conversational context for a response one is generating, or track the state of an ongoing conversational thread (Whittaker & Sidner, 1996). Most email systems provide folders, for the categorisation of messages, and hence provide weak support for *context management*, but categorisation requires the user to execute each action manually, rather than being an intrinsic system feature<sup>7</sup>.

*Workflow* systems do not allow *synchronous connection*, or *shared objects*, but their primary aim is to allow users to track the set of interactions that are associated with complex transactions occurring over extended periods of time. They therefore support aspects of *threading* and *context regeneration* (Abbott & Sarin, 1994, Winograd & Flores, 1986). Workflow systems are asynchronous and in principle support *one-way drop*, although they tend not to be used this way as they are intended to manage more extended interactions.

*Pagers* do not support any of the above features, being solely a means to *drop* information, such as a short message or phone number. They do not support any other communication features.

*Media spaces* are recently prototyped technologies that provide users with permanently open video/audio links or methods to quickly establish synchronous video/audio links (Bly *et al.*, 1993, Fish *et al.*, 1992, Gaver *et al.*, 1992, Mantei *et al.*, 1991, Tang *et al.*, 1994). Recent

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<sup>6</sup>Part of the problem here is that the size of audio files makes it costly to store large numbers of messages, which precludes the creation of message archives.

<sup>7</sup>Email systems such as Notesmail, Eudora and ccMail allow users to *program* automatic message classification, but some expertise is required to set this up.

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systems provide some integration with *real-time shared applications* to allow object sharing<sup>8</sup> (Tang *et al.*, 1994). Two systems (Gaver *et al.*, 1992, Tang *et al.*, 1994) also provide support for *one-way drop*, but none of these systems helps with *context regeneration* or *task threads*.

*Videophones* (and their multiparty equivalent *videoconferencing*) are predominantly synchronous technologies, supporting *quick connections*. A few implementations have included *shared objects* (Tang & Isaacs, 1993), but most do not. None of the other features such as *one way drop*, *context regeneration* or *threading* are supported by *videophones*.

*Shared workspaces* support real-time *object sharing* and a number of products exist, eg. Proshare<sup>TM</sup>, ShowMe<sup>TM</sup>, and Omnishare<sup>TM</sup>, although none is ubiquitous. These systems are intended to support *rapid connection*. There are no explicit features in these systems for *context regeneration*, *threading* or *one-way drop* of information.

It is clear from the above that no current technologies support all five lightweight interaction features. TeleNotes was designed to rectify this situation.

## DESIGN

The observational data from face-to-face lightweight interaction, enabled us to generate a set of five critical lightweight interaction requirements, to guide the design of TeleNotes. The aim was to present a unifying user interface metaphor for the applications that would support these five requirements.

### *Presentation metaphor*

The TeleNotes user interface is designed to be analogous to aspects of real world paper-based interactions, to offer our users a familiar metaphor for system interaction. We present electronic equivalents of work-related objects such as documents, notes and folders to offer office workers familiar tools with which to manage their lightweight interaction over time. TeleNotes is intended to resemble a real world "messy desktop" containing papers which are laid out at specific spatial locations, with related information being arranged in stacks (Frohlich, 1995, Kidd, 1994, Malone, 1983, Mander *et al.*, 1993). Information in TeleNotes is therefore spatially arranged around the computer desktop, with each stack being relevant to a separate ongoing lightweight communication task. Each stack is automatically sorted so that it contains information relating to each ongoing conversation such as prior messages and relevant documents. These messages and documents are intended to serve as "context holders" for each separate intermittent interaction. As with their real world equivalents, each stack can be physically arranged and relocated anywhere on the desktop by the user. Moving one item in the stack is sufficient to relocate the whole stack, given that TeleNotes automatically maintains the relations between stack items. The stacks "float" on top of other applications making them highly

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<sup>8</sup> One can obviously "share" objects in a rudimentary manner by pointing a video camera at them (Gaver *et al.*, 1993, Nardi *et al.*, 1993, 1996, Whittaker, 1996a, 1996b), but currently video does not provide high enough resolution to allow text to be easily read this way, nor does this method allow both partners equal ability to modify the document.

visible<sup>9</sup>. This constant visibility means the stacks can remind the user about what communication tasks are currently in progress. The fact that stacks are readily accessible allows rapid context regeneration of materials related to a specific interaction by simply "opening" the stack of materials. The stacks are shown in Figures 1, and 2<sup>10</sup>. Figure 1 is a schematic of the computer desktops of two users Steve and Jerry, who each have three ongoing communications represented by three different stacks. Figure 2 is a screen dump from TeleNotes showing a user's desktop with multiple stacks, as well as an open message which is part of one of the stacks (shown in the upper right hand corner of the figure). We discuss the detailed features of the stacks later, when we examine *threading* and *context regeneration*.

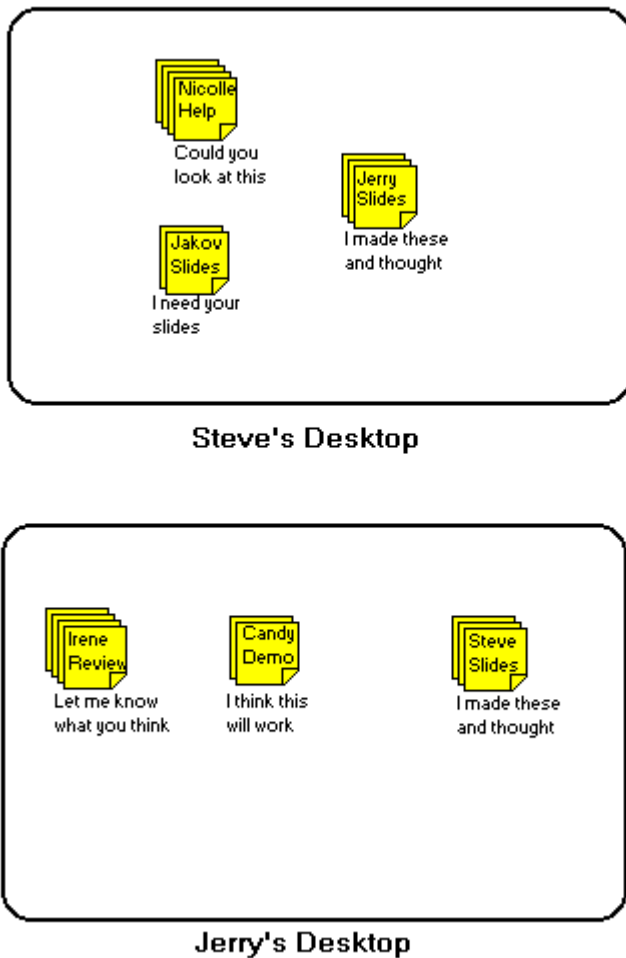


Figure 1 - Schematic showing management of three conversations using stacks, for two different users' desktops.

<sup>9</sup>Some of our users actually found the constant visibility too distracting, a problem we discuss later.

<sup>10</sup>Our Figures are a mix of screen dumps and schematics, we use the latter for clarity of depiction.

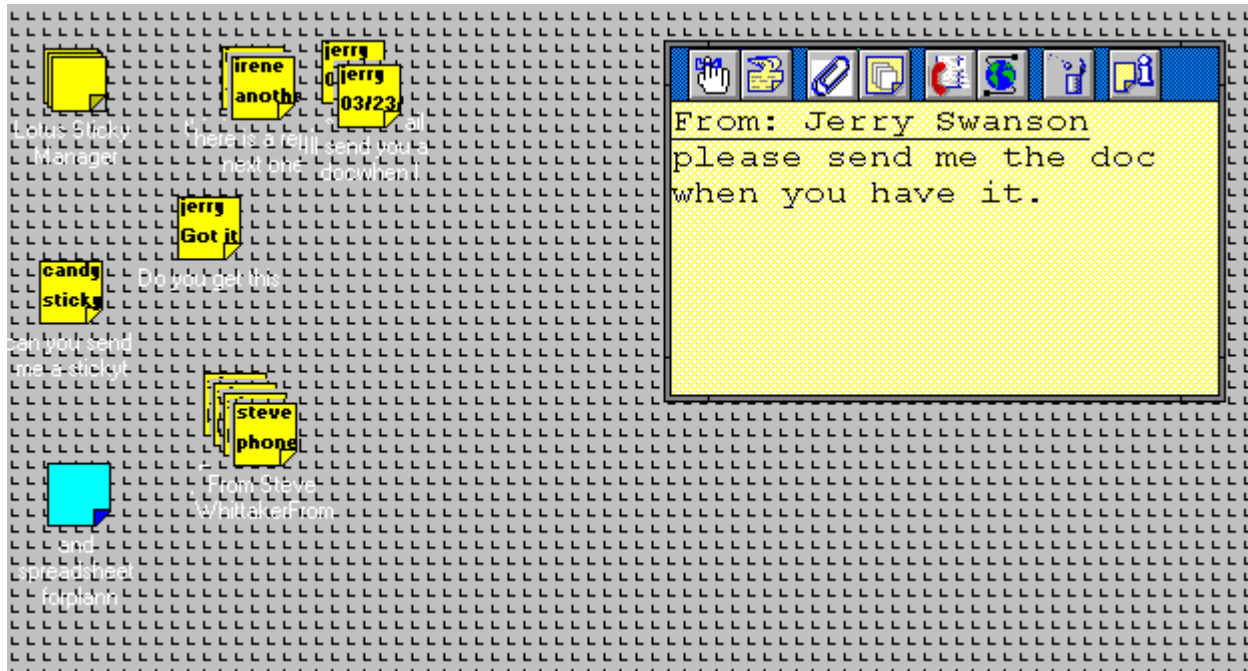


Figure 2 - Screen dump showing multiple stacks with one of the component communication messages of one thread shown "open".

How then does TeleNotes support communication? A second key notion is that of the "sticky"<sup>11</sup>. Communications in TeleNotes are centred around "stickies" designed to be analogous with physical postits<sup>TM</sup>. Stickies are small "document-like" objects, on which the user can type brief messages. Each communication stack or thread is constituted by a collection of sticky notes, that all relate to a common conversational topic. The thread is therefore made up of a series of brief typed conversations about a related topic that are ordered in temporal sequence. When a sticky is sent to another user it appears on the remote desktop in a way that catches the recipient's attention, both because it appears on top of other applications and because it flashes periodically until it is read. If the sticky is part of a pre-existing thread it will automatically appear at the same location as other stickies from that thread, as the uppermost element on the stack (as depicted in Figure 1). TeleNotes does more than support message threads, however: sticky notes also serve as methods for both rapidly launching different types of synchronous communications and also as ways of encapsulating or attaching documents and other applications. TeleNotes can be used to initiate synchronous voice and video communications and real-time object sharing, because stickies hold connection and addressing information about the sender. Whenever users send a

<sup>11</sup> A number of other recent programs have used the stickies metaphor, but in ways that are different from what we have done here. Apple devised a program in System 7.5, which is intended to support a personal reminding function, eg. allowing people to leave brief notes for themselves. It does not allow for communication with others however. Our application also contrasts with applications running under X Windows, which allow users to send short messages. These applications do not support many of the features we developed here such as threading, attachments, synchronous audio/video communications, or object sharing. The most similar application is the "stickup" notes which are part of the Montage prototype (Tang et al., 1994). Montage "stickups" support many of the communications functions described above but not the *threading* or *context regeneration* functions addressed in TeleNotes.

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sticky, information about their email, phone, videophone and network address are also implicitly encapsulated in the message, and this information can be used to make real-time connections. Finally, stickies serve as "cover notes", so that they can be attached to application files to allow for the attachment of materials such as documents or slides. Stickies are therefore containers for any class of material that is relevant to the ongoing interaction.

We now describe how TeleNotes addresses each of the five lightweight interaction design requirements:

***Conversational threading:*** *Participants are engaged in multiple intermittent communications tasks, often with different individuals. The system must therefore keep track of interactions, storing elements of the same conversation together so that they can rapidly be accessed as a unit, allowing participants to check the status of a given conversation*

Office workers are often engaged in multiple simultaneous projects about different topics, and threading can help them track each independent set of communication tasks. Figure 1 shows two user's separate desktops. Each separate conversation is represented in a different threaded stack appearing at a distinct location on the user's desktop. Whenever the user initiates a new sticky conversation (which is achieved by clicking on the StickyManager icon to generate a new sticky), a new stack or thread is created. Any response to that initial sticky will then be threaded onto the initial message, as will any subsequent message that is part of the same thread. We describe the technical details of how threading is implemented in the next section. Stacks are automatically labelled with the name of the communicating partners and users can also add their own task labels to a stack. TeleNotes also displays the first 20 characters of the uppermost sticky message under the stack.

Figure 1 shows that Jerry is currently working on three tasks (labelled Review, Demo and Slides), each represented by a different stack. These are with Irene, Candy and Steve, respectively. Steve is also working on three tasks, one of which (Slides) is also with Jerry. Thus if Irene asks Jerry a question about their ongoing conversation, Jerry will rapidly be able to identify the set of messages relevant to his interaction with her, along with their associated materials such as documents or slides. The stack metaphor therefore enables users to easily switch between different ongoing communications tasks, as the situation requires, and thus manage multiple intermittent conversations.

***One-way drop:*** *The system should support the ability to leave a brief asynchronous message, given the fact that attempts to achieve opportunistic connections frequently fail, and valuable information exchange can often take place without synchronous communications.*

Stickies provide a way to deliver an asynchronous quick message. Figure 2 shows user Steve's desktop with an opened sticky, which is an asynchronous request from Jerry Swanson. New sticky threads are straightforward to create. They are initiated by the single simple action of clicking on the StickyManager (top left hand corner of the screen), and brief messages can then

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be typed in. Addressing<sup>12</sup> and delivery are achieved through Notes Mail™. Stickies are delivered rapidly in a LAN environment. They appear on the recipient's desktop a few seconds after sending, threaded onto the relevant stack if they are part of an ongoing conversation. Furthermore, each sticky that is sent is automatically copied onto the sender's desktop, to serve as a record of that part of the ongoing conversation including the documents that are relevant to each point in the conversation. This copy is intended to *remind* users about current communication tasks: both *that* the task is in progress and also about the content of the conversation.

***Context preservation and regeneration:*** *Given the intermittent but repeated nature of lightweight interaction, where there are often long delays between elements of the same conversation, the system should support methods for straightforwardly accessing prior parts of an ongoing conversations, including the materials or artifacts that are involved in that interaction.*

Users are often interrupted in the context of one conversational task and required to converse about another task. How does TeleNotes support this? Each stack is a record of prior elements of the conversation, and is therefore a method of regenerating the context of the ongoing conversation. Figure 3 depicts the desktop of a user who has exchanged four sticky messages in the course of revising a document. Here the user has "opened" the stack (by a single menu selection) to show the history of one conversational thread. He can now access any prior part of the conversation with Jerry Swanson by consulting the relevant sticky.

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<sup>12</sup>The system uses the central Name and Address book in Notes Mail for addressing, so that the user only has to remember the name of the person for the sticky to be correctly addressed, and not their email address, username or domain.

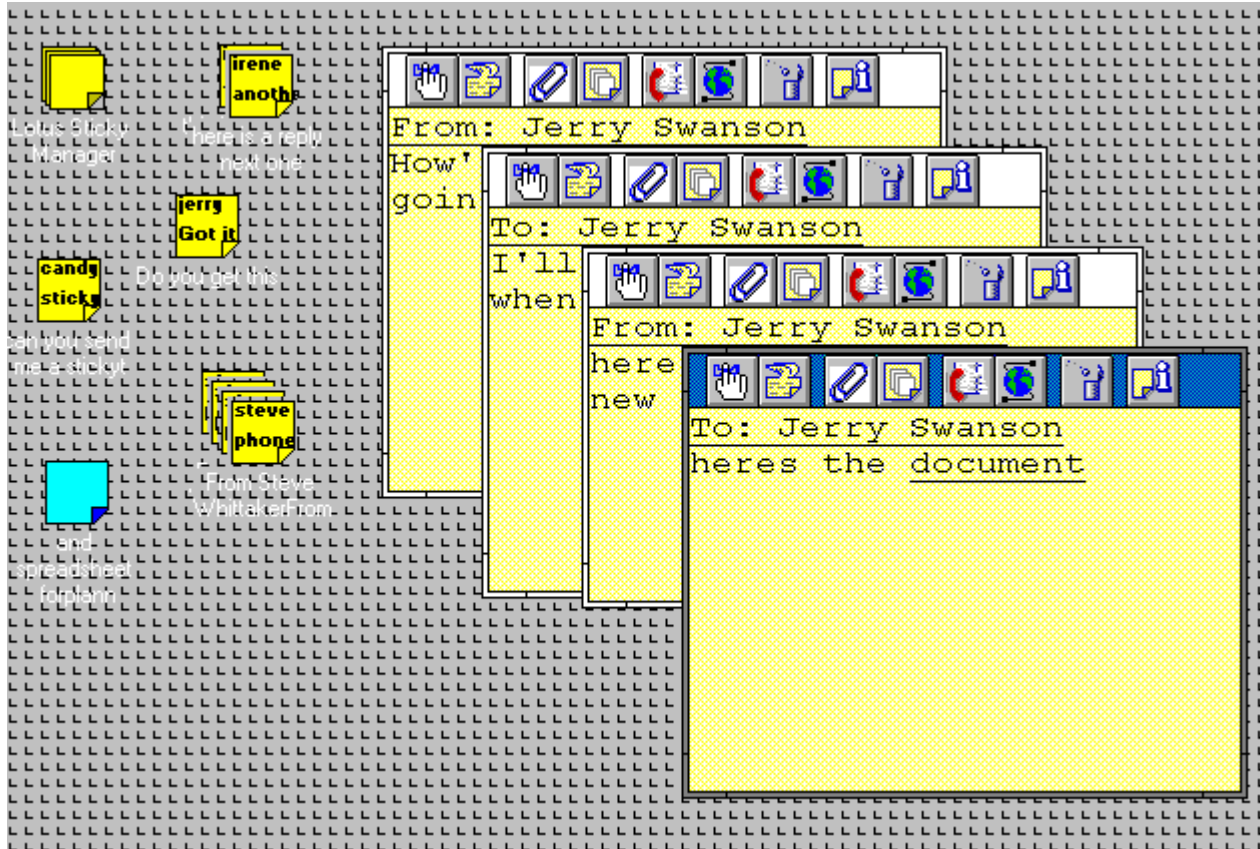


Figure 3 - An extended sticky conversation, showing conversational history

Context is not only constituted by the prior sticky messages in a conversation, it also involves other types of documents and materials generated and used in the course of the conversational interaction. Stickies therefore also support the attachment of documents or applications, and allow these to be included in the conversation context. In this way stickies serve as "cover notes" or containers for the attached documents. Figure 4 shows a conversation related to document editing, where the presence of an attached document is depicted by the underlining of the word document in the sticky showing a hypertext link. By clicking on the link, the user can access the attached object, in this case the document shown in the lower part of Figure 4. Clicking on a link automatically launches the relevant application, which can be any desktop program. At this point the application is displayed only on the user's machine, but we describe below (*Shared objects* section) how two users can share the same object simultaneously using the communications options. The process of creating hypertext links is also straightforward: the user selects a menu option or icon and clicks on the relevant document. The hypertext link is placed under whatever text the user has highlighted or failing this the word which was nearest the position of the user's cursor, when the menu option was selected.

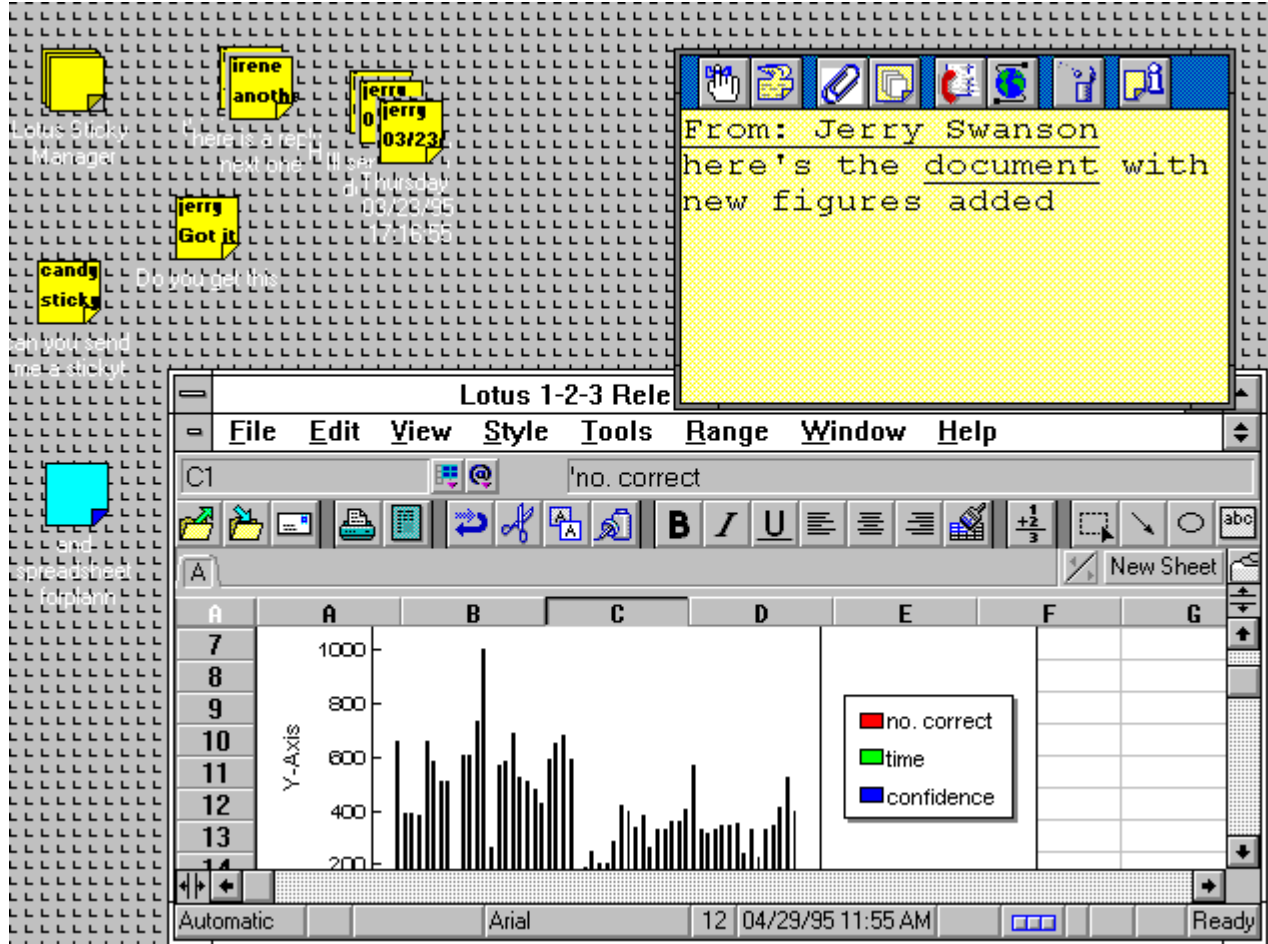


Figure 4 - Accessing a document from a hypertext link in a sticky

Stickies with attached documents can also be used to support one method of document versioning. Thus, if users are unsure of the precise state of the document at a prior stage of an extended editing process involving multiple exchanges of documents, they can straightforwardly access prior versions of the document from the relevant prior stickies. They do this by identifying the relevant earlier stickies and clicking on the document link within each sticky. They can then make the relevant comparisons, with other later stickies and document versions. By using the stacked stickies as pointers to the attached documents, the user is therefore provided with a lightweight method of document versioning: by looking back through the stack the user can view the document at different stages of the revision process. This use of TeleNotes for versioning is schematically depicted in Figure 5.

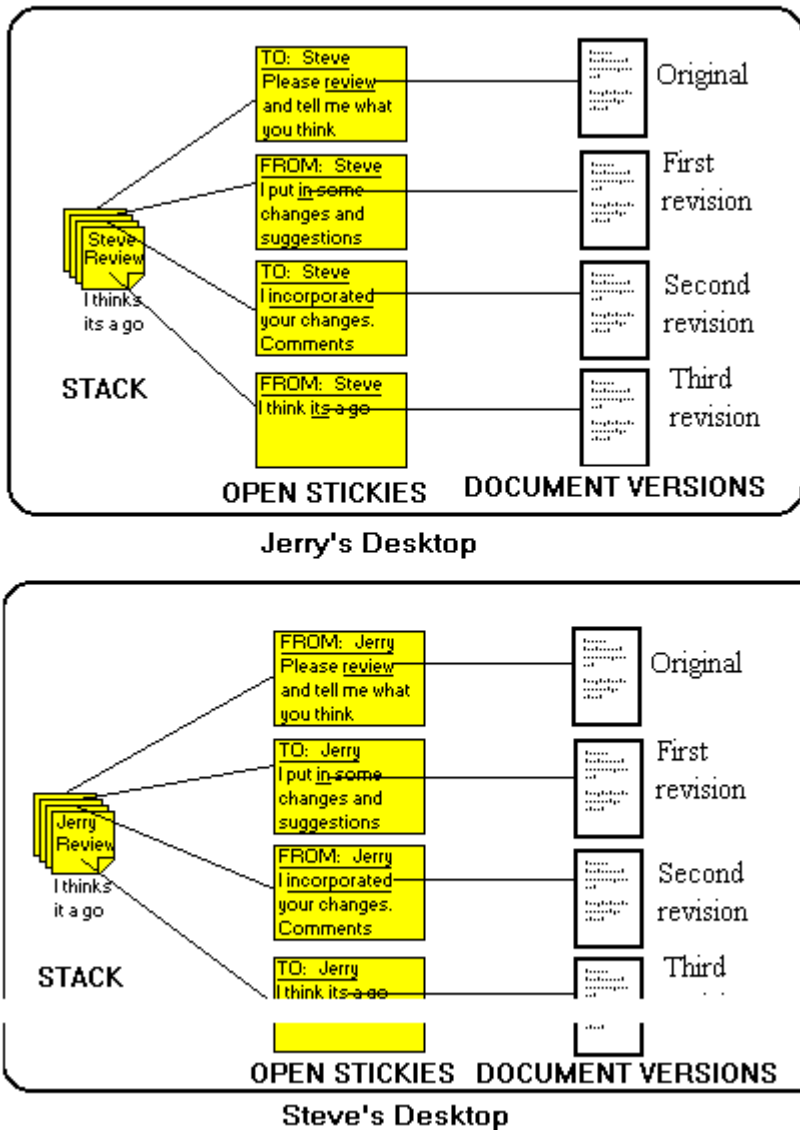


Figure 5 - Schematic showing how stickies can be used for versioning

We have so far described one aspect of the problem of retrieving the context of a prior conversation, namely regenerating the information that is of immediate relevance to an interrupting coworker. There is also a complementary problem: after the interruption is over, people then have to regenerate the context of *their original task*, ie. the one that the coworker interrupted. We have implemented a feature that enables users to save the context of current activity when interrupted. A user might therefore be compiling a document based on spreadsheet data, when a coworker interrupts asking a question about a different problem. By selecting the relevant menu option, the user creates a sticky which automatically incorporates hypertext links to all open applications and their most recently accessed files. By typing a quick description onto the sticky - "Q3 report and spreadsheet data", the user can save the context of all the current applications, which can then be re-instated when the interruption is over.

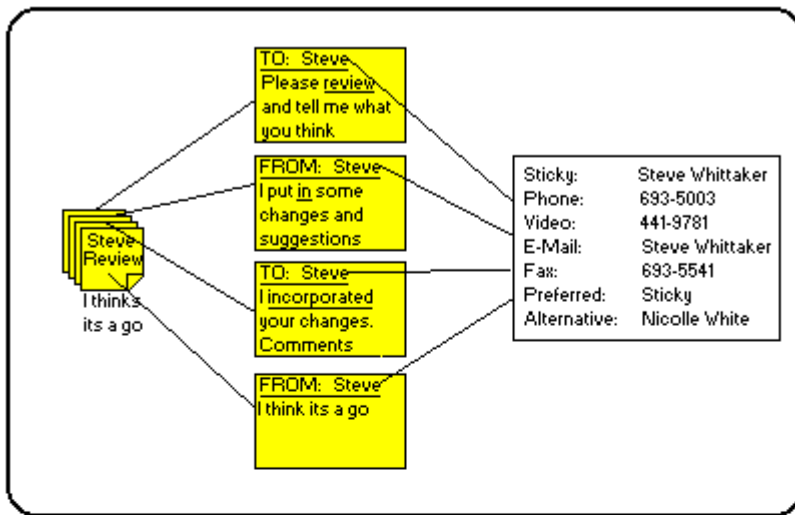
***Quick Connection:*** *Given the brevity of lightweight interaction, the system should support rapid flexible communications and participants should be able to quickly connect with others.*

TeleNotes can also be used to initiate lightweight *synchronous* conversations. Stickies are a method of achieving rapid connection to other users, because stickies encapsulate connection and addressing information from the sender. Users can respond to a sticky by choosing one of a variety of communication media. Clicking on the sender's name<sup>13</sup> generates a series of connection options. These are shown schematically on the right hand side of Figure 6, and are sticky, phone, videophone, email, and fax. On selecting the "phone" menu option, TeleNotes automatically dials the sender's phone number and establishes a real-time audio link. In this sense, a sticky operates like a multimedia "business card", because it contains all the addressing information necessary to connect back to the sender. Note also, that because the connection information is embedded in the original sticky, this removes from the user the cognitive overhead of finding relevant addressing information and manually initiating connections, by typing or dialling numbers. The result is that connection is fast<sup>14</sup> and lightweight, addressing one of our initial design goals.

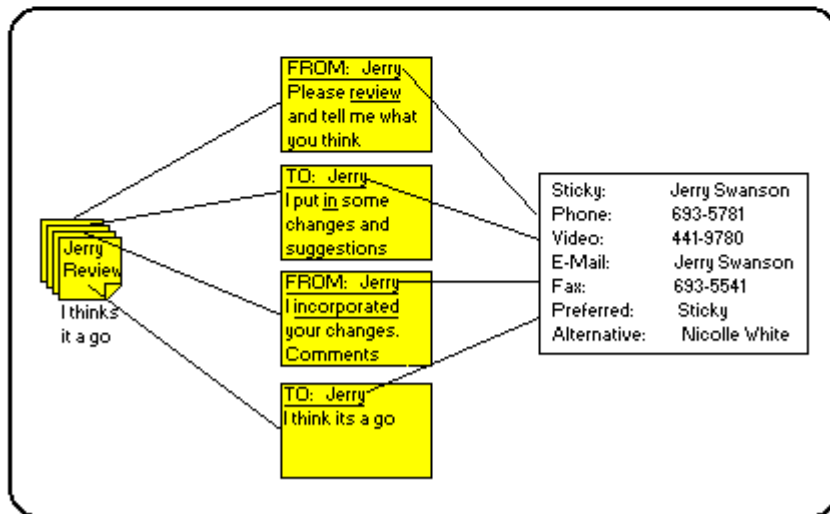
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<sup>13</sup>The underlining again depicts a hypertext link.

<sup>14</sup>This was true unless the video option was chosen, when videolinks often took 11s or more to establish, given the limitations of the ProShare conferencing protocol and the restricted ISDN bandwidth it used.



Jerry's Desktop



Steve's Desktop

Figure 6 - An extended sticky conversation between two users showing connection alternatives accessible from a sticky

**Shared objects:** Given the document focussed nature of lightweight interaction, the system should support real-time shared objects as props and conversational resources, because of the frequency with which documents feature in lightweight interaction, and their supporting role in mediating conversation.

If users wish to synchronously share or edit a document (or any other application) they can do so in TeleNotes. Sharing is just another communication option depicted in Figure 6. For those users who have video hardware, TeleNotes will open an audio and video connection to the recipient. Once the connection is open the user can include the application, using the dedicated datasharing

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program. For users without video, datasharing is accompanied by an audio link only. Once the channel is established, then object sharing can take place, again using the datasharing program. Again because the originating sticky holds recipient addressing information, the user does not have to remember such information, so that selecting the relevant menu option automatically makes the connection. Again this means that object sharing is a lightweight and rapid process.

## IMPLEMENTATION

The prototype uses the stacks and sticky notes metaphors to support the multiple facets of lightweight interaction. In order to assure the prototype could be used by users in their everyday work, we based the implementation on existing software infrastructure. TeleNotes therefore relies on Notes Mail™ for communication transport and storage, and ProShare™ for audio/video and real-time datasharing connections. Audio only connection is achieved using CallCom™ software to switch ROLM dataphones. The novel components of TeleNotes are (a) the UI and the hypertext editor for the stickies themselves; (b) the Sticky Manager which handles threads and desktop presentation of related stickies; (c) the transport protocol for the stickies.

The TeleNotes application runs in a networked Microsoft Windows™ environment (Version 3.1). The architecture of the application involves two executables, StickiesManager and StickyInstance, and a shared DLL (Dynamic Linked Library), CommonTransport. The application was developed in C++ using Microsoft Foundation Classes™ and the Microsoft Visual C++ Environment. The CommonTransport DLL uses the Lotus Notes™ API.

### *StickyManager and StickyInstance*

The StickiesManager executable manages each StickyInstance executable, the threading and presentation of StickyInstance task stacks, and the communication between all StickyInstances. The StickyInstance executable provides a text editor for composing stickies, and manages the hypertext links, including the methods to attach and launch application files.

When a task or stack of stickies is begun, the StickyInstance registers with StickiesManager which in turn allocates each new StickyInstance by a Unique Task ID (UTI). Subsequent StickyInstances related to this stack or task (ie. responses to the originating sticky) have the same UTI. The UTI is used by the StickiesManager to manipulate and track related StickyInstances. Any sticky that is generated by responding to a prior sticky automatically inherits the original sticky's UTI. The StickyManager uses this information in the spatial presentation of stacks and the set of manipulations that can be globally applied to a stack (eg. "opening" all stickies or dragging a stack to a new location). The StickyManager also stores the connection information associated with each stack, such as the sender's phone or ISDN connection information.

### *The Transport Process.*

When user1 sends a message to user2, user1's StickyInstance encodes the message (as well as hypertext attachments if there are any) and hands the encoded message to the StickiesManager. The StickiesManager embeds certain state and user connection information, and the UTI. The

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CommonTransport DLL provides for the transport of StickyInstance text and attached documents using Lotus Notes Mail as the transport mechanism. The message is passed to the CommonTransport DLL which adds a Sticky signature (or key) and then uses Notes Mail to send the message to user2's Notes Mail database. The message is transmitted as compressed ASCII.

User2's StickiesManager polls its Notes email through the CommonTransport DLL protocol, looking for new mail messages with a Sticky signature. The StickiesManager moves these messages to a new Notes database and creates a new StickyInstance. The StickyInstance decodes the message, and presents it to the user. When an incoming message is part of an existing thread, the StickiesManager detects this and presents it at the relevant spatial location, based on the location of the relevant stack. The Notes database used for the persistent storage of stickies can be either local, or on a Notes server. In either case, users can work while not directly connected to a server. In addition, TeleNotes can be accessed and run over modems and analogue telephone lines, because of the use of the underlying Notes transport.

#### *Audio/Video and datasharing connections*

The audio/video connection between Sticky users is accomplished using Intel ProShare™ Personal Conferencing Video System 200 (Version 1.8), connecting over ISDN (Integrated Services Digital Network) lines. For audio/video connections, the Sticky application uses Microsoft DDE to communicate with the ProShare application. The datasharing conferencing uses Intel ProShare Premier edition software. In either case, the Sticky application communicates with the ProShare software by various Windows messages to pass relevant information about which connection options (audio, video, shared data) are requested along with (a) addressing information, and (b) attached application information. When users request audio only communication, we use a separate phone application. Here phone control is achieved using DDE to pass requests for phone connection along with addressing information to the ROLM Callcom™ application, and then to the ROLM dataphone.

#### **OBSERVATIONS AND USER FEEDBACK**

A number of different versions of the prototype have been deployed and used by eight people in the course of their everyday work over a period of two months. The users consisted of researchers, administrative assistants, managers, and software engineers. Feedback and usage patterns were gathered by informal user interviews and comments elicited by email.

#### *How was it used?*

The informal field trial showed that the prototype was used for the types of brief communications that we had originally intended. Typical sticky messages were "Here's a quick draft of proposal X, comments please"<sup>15</sup>, "I left the hardware you need on your office chair", "the files are on the server at location Y". Messages were short: few were more than two sentences long. These generated equivalently brief replies. Stacks were predominantly short, consisting of no more than

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<sup>15</sup>This had a document attached to the message

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three messages. Senders also frequently exploited the fact that TeleNotes enabled them to include documents as part of the message context.

Comments from users showed that for certain classes of communication, the stickies were preferred to email. They were described by users as "quicker to start up". Also because TeleNotes achieved fast message delivery and stickies appeared almost instantaneously on the other person's desktop, it led to more "quickfire" exchanges than with email communication. As a result, people commented that they had "more of a sense" about what a collaborator was doing than when using email.

People also exploited the spatial aspects of stacks in TeleNotes, to engage in task management. They placed different communication task threads at different desktop locations to manage different ongoing communications. Users seldom maintained more than four different stacks at any one time for reasons we return to later. In addition, TeleNotes was used for *personal* reminding, with people using it for sending "messages to themselves", eg. "remember to confirm flight", relying on the visibility of stickies to guarantee they saw the message. Again these reminders were highly brief, consisting of a few words only. One unforeseen usage was to display large untransmitted stickies on one's *own* machine to communicate information to others. Thus one user left a sticky on her computer desktop saying "I'm out of the office today, contact phone, 123 4567", so that others could see it when they came into her office. The advantage she stated was that she could create this message from offsite, and still have it displayed in her office, where people would expect to find her.

### *Design feedback*

The functionality of the application was apparent to users and the UI presented them with few difficulties, so that people were able to use it after a demonstration lasting only a few minutes. Users made a number of comments about our design.

People said that on occasion the threading mechanism could be confusing, especially when there were several ongoing communications tasks. This may explain why users generally restricted themselves to four or fewer threads. Confusion was most pronounced when people were engaged in multiple different threads with the same person. Although we provided the facility for users to specify task labels which should have differentiated the different threads, there were occasions when users gave tasks similar labels. One solution here might be to "colour code" threads from the same user to reduce the chance of confusion. Two users observed that one of their threads become sufficiently complex that they wished to generate subthreads. In the current TeleNotes model, however this is not possible, although the design could be modified to incorporate it. Another problem was caused by a user generating two successive stickies without waiting for a response. Few users exploited the context preservation feature that enabled them to save all current objects and applications inside a sticky to preserve current work when being interrupted. It required them to select a special class of sticky and then type a descriptive label. This was perceived to be too cumbersome by users whose main priority on being interrupted was to address the interruption itself, rather than saving their current work.

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Several users observed that there were restricted sets of people to whom they would send a sticky, ie. that the acceptability of this communication method depends on the relation between the interactants. Our users felt that stickies were appropriate for peer to peer communication, but did not want to send stickies to strangers or high level management. This may indicate of the fact that we had succeeded in our objective of supporting informal rather than formal communications, as stranger- or status-oriented communications are characterised by their formality. A related issue concerned the "alerting" function when a sticky arrives, as signalled by a flashing desktop icon, overlaying the application that the user is currently working in. Users such as Administrative Assistants commented on the utility of this feature in enabling them to be responsive in their jobs. They noted the advantages of stickies over email in giving them immediate visual access to urgent messages. They pointed out that the arrival of the sticky could be detected whatever application the person was using, and also when they were on the phone. In contrast, urgent email messages may not be read for some time if the user is not currently using the email application. However other users did not like the intrusiveness of the alerting function. They commented that it distracted them from their current activity. Together these results suggest that the utility of the application and aspects of its design may have to be sensitive both to the job type of the users and the relationship between the interactants. The design implication is that certain features such as alerting need to be user configurable. In addition, we need more research to determine which sets of users and workgroups most require this form of informal quickfire communication.

A different type of problem arose indirectly from the fact that TeleNotes is a communications application. With communications applications, it is necessary to design for the possibility that not all users are guaranteed to be running the application: One user might therefore send a sticky, but if the recipient is not running the application, it is still to guarantee that the recipient received the message. In our first prototype, we did not design for this eventuality. A re-designed version of TeleNotes provided a mechanism whereby sticky messages were delivered into email, if the application was not running. Email delivery obviously compromised the desktop delivery and "urgency" aspects of the application, but meant at least that messages were not lost altogether. One unexpected problem arising from this is that some users wanted to recompose their message if they knew it would be delivered in email rather than as a sticky.

Similar problems arising from the nature of communication applications were encountered with different hardware configurations. Not all users had the installed hardware to support all the communications options, eg. application sharing and videophone. The fact that the hardware was not ubiquitous meant that our evaluation data are restricted for both audio, video and application sharing features. Again, this is independent of the design of TeleNotes, but nevertheless has an impact on whether and how the application was used. To this end, we constructed a version of TeleNotes which supported communication via stickies and email only, so that users could participate in TeleNotes communications, but without multimedia and application sharing capabilities.

The available data on the connection options show that the audio connection was perceived as being valuable. Audio connection to the sender of a sticky was almost instantaneous which was seen as being highly useful in allowing people to ask a quick synchronous verbal question about

a sticky or attached document they had received. Connection time was much longer for video and data sharing however. Given that connection sometimes took as long as 11s, video and datasharing connections were considered to be too slow when the resulting conversations were intended to be brief.

People also expressed concerns about screen real estate. Stickies are deliberately designed to persist and remain visible on the user's desktop, as "reminders" about communication tasks in progress, and people stated that this was a useful feature. A difficulty, however, is that stickies also consume space on the desktop: by the time several conversational threads are underway, the space for viewing other desktop applications is much reduced. We therefore provided a method for users to "save" threads into a Notes database, thus removing them from the desktop. We also provided users with two presentation modes of running TeleNotes, in which stickies could "float" on top of the current application, or below it. The problem with putting stickies in databases, or having them submerged beneath applications, however, is that they reduce the visibility of these materials and compromise reminding and rapid context regeneration functions. For this reason, the visibility of stickies needs to be user configurable.

## CONCLUSIONS

We built a system to support key aspects of lightweight interaction. The system addresses some of the limitations of other communications technologies in supporting *connection*, *context management*, *conversational tracking*, *shared objects*, and *one-way information drop*. Our early prototypes were successfully used by people in the execution of their everyday work. Nevertheless, there are still a series of intriguing questions concerning possible extensions to TeleNotes. These should be premissed on more theory and data about lightweight interactions, which should help better focus future design choices. This section first compares our results with related systems built to support lightweight interaction. We outline existing theories of lightweight interaction, suggesting where questions remain, and then discuss the implications of these theories for future lightweight interaction system design.

### *Related Systems*

A number of systems have been built that partially address aspects of lightweight interaction (Bly *et al.*, 1993, Fish *et al.*, 1992, Gaver *et al.*, 1992, Harrison, Mantei, Beirne & Narine, 1994, Mantei *et al.*, 1991, Tang *et al.*, 1994). A key difference between the approach taken by all these other systems and the one taken here, is that a major focus of our design was to support the construction and maintenance of shared context across repeated but intermittent interactions. To this end, we explicitly constructed tools to support the *prior history* of the interaction, and the set of *shared objects generated in prior interactions*, as well as to allow real-time interactions to take place. The threading features and real-time communication capabilities in TeleNotes were also intended to address some of the perceived problems with asynchronous technologies like email, such as lack of explicit support for managing conversational history and poor responsiveness (Whittaker & Sidner, 1996).

Another issue concerns the relationship between the lightweight interactions we supported here and systems built to support *awareness*. Awareness arises from implicit information about the

actions of coworkers, and its function is often to help determine their availability for interaction (Bly et al., 1993, Dourish & Bly, 1992). While we did not attempt to explicitly support awareness in TeleNotes, our users' comments indicated a heightened sense of the activities of coworkers. This may have arisen from the simple fact that stickies tended to be exchanged very frequently, giving them more rapid updates and more timely information about the current actions of colleagues.

### *Theories of communication*

We need to extend our understanding of lightweight interaction, both by building better theories and collecting more data. With certain exceptions (Isaacs, 1989), current conversational theories have so far focussed on *one-shot* interactions, having identifiable beginnings and endings, with conversational context evolving *throughout* the discussion (Clark & Brennan, 1991, Clark & Schaefer, 1988, Grosz & Sidner, 1986, Sacks, Schegloff & Jefferson, 1974). In contrast our observational data showed that lightweight interactions often seem to consist of *multiple distinct* unplanned fragments. Context has to be reconstructed on the *reinstigation* of an ongoing conversation after long periods have elapsed, or other activities intervened. Conversational theories therefore need to be extended to address these new problems of *connection*, *context regeneration* and *conversational tracking*, to determine how people successfully initiate conversations, how they reconstitute context when there are long intervals between interactions, and how they keep separate the multiple simultaneous workplace conversations they engage in.

Such theory needs to be specific about what variables affect these processes. In our initial observational study (Whittaker *et al.*, 1994), and in testing our prototype, we found that *connection* and *initiation* were affected by the *relationship* between the communicating participants, and by their job type. Thus administrative assistants felt that having arriving sticky notes "flash" on the desktop was crucial, because they did not wish to miss incoming urgent information. In contrast, other users found this type of alerting intrusive, and disruptive of their current work. Other research also indicates that connection is highly sensitive to the relation between participants (Fish *et al.*, 1992, Tang *et al.*, 1994). In addition, the *medium* of initiation can influence the initiation process, for example video initiations may be radically different from those happening face-to-face (Heath & Luff, 1991). Having clearer principles about the factors that influence initiation will allow us to determine how to implement the necessary different styles of *connection*.

We also need to better understand what affects *context regeneration* and *conversational tracking*. Thus the *number of simultaneous conversations* that the user is trying to track may reflect this difficulty. The more conversations a person is engaged in, the harder it may be to effectively switch between them. The fact that our users in TeleNotes tried to restrict the number of current threads is also of relevance here. In addition, the *temporal pattern of interactions* may also be crucial: longer intervals between successive elements of a given interaction may make it more difficult to regenerate context. Another parameter is the *complexity* of each conversational task: so that tasks involving highly complex sets of materials may therefore be much harder to retain and remember than simple ones (Whittaker *et al.*, 1993). Our observations of usage were

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consistent with this, showing that stickies were often used for attachments of complex materials such as documents, which helped to manage the context of complex interactions.

We also need to know more about the processes by which people regenerate context. Research from discourse theory may be relevant here. Do people rely on linguistic cues to regenerate context (Grosz & Sidner, 1986, Isaacs, 1989, Litman & Hirschberg, 1987, Reichman, 1985, Walker, 1992, 1993, in press, Walker & Whittaker, 1990, Whittaker & Stenton, 1988)? We have argued here that people also rely on the presence of relevant physical materials for context regeneration, although this claim needs more systematic quantitative evaluation (Whittaker *et al.*, 1994, Whittaker & Schwarz, 1995, Whittaker & Sidner, 1996). There are other outstanding problems with regard to conversation management (Isaacs, 1989). How do people distinguish between different conversations especially when they are engaged in multiple interactions with a single person? How do people manage interruptions? On being interrupted, do they ever intentionally prepare for context regeneration by leaving themselves reminders for when they return to a task, ie. how do they prepare for future retrieval?

Current communication theories have also tended to focus almost exclusively on synchronous communications, although we have seen here both that there are *connection* problems in trying to establish such communications opportunistically and also that *one way drop* of information can be highly effective in the event of failed attempts to connect (Rice & Shook, 1990). There is some theoretical work showing the importance of synchronous communication in tasks that require ambiguity resolution and consensus, such as planning or negotiation (Finholt *et al.*, 1990, Kraut *et al.*, 1990). However, more research is required to clarify the respective benefits of synchronous and asynchronous communication and determine how users make choices between these communication methods, when both are available.

### *System extensions*

Answers to the above questions will be invaluable in making design decisions about a set of possible extensions to our prototype. More detailed information on *connection* should help us to determine how best to implement the alerting function when a sticky arrives on a person's desktop. It should also determine whether we need to add the ability to start a conversation by visual "glancing" at a potential recipient using video, a technique which has been suggested as one solution to the connection problem (Bly *et al.*, 1993, Fish *et al.*, 1993, Gaver *et al.*, 1992, Tang *et al.*, 1994). Alternatively "open channels" (Bly *et al.*, 1993) or "awareness servers" (Dourish & Bly, 1992) may partially address the connection problem, by providing continuous updates about coworkers' activities. Clearer understanding of conversation tracking and context should also inform us about the utility of some of the novel features that we are currently designing, which are described below. We also need to know how *fast* connections need to be made. Our observations are consistent with other research in finding that delays of several seconds in achieving connection can compromise the utility of this type of application for brief communications (Tang *et al.*, 1994). This requirement for rapid connection presents considerable technical problems for wide-area applications.

The novel features we are exploring include the idea of *automatically* supporting aspects of context regeneration, to provide direct access to relevant prior contexts when a user experiences an external interruption, such as a phone call. One possibility is to exploit information about the *identity* of the interrupter to trigger relevant contextual information. Incoming videophone, phone or network "caller-ID" information could be used by the system to automatically access relevant conversational threads. The current TeleNotes implementation has a database entry associating caller phone numbers with their names (see Figure 6). Thus individual stickies or whole threads associated with a incoming caller could be triggered and automatically accessed and presented to the user making relevant documents and messages from prior interactions immediately available.

On other occasions, the user might want to be reminded of a particular context at a *specific time*. This may be applicable for a series of organised meetings, where a user might wish to retrieve the minutes of the prior meeting in the series, immediately prior to going into the next meeting. One technique might be to program individual stickies, so that context regeneration could be triggered by TeleNotes, at the time it is relevant for the user to have that information. One might therefore request a sticky to "reappear on Tuesday 7th at 9.45 am", to give the user 15 minutes to peruse the relevant contextual information immediately prior to the 10.00 meeting. Programmable stickies could also be used to promote connection: thus one user might send another user a sticky saying "call me at 4.00", which if accepted by the recipient would execute the relevant action. Programmable stickies might also address part of the problem of screen real estate. As our users commented, the more sticky stacks that one has concurrently displayed on one's computer desktop the less effective they become as visual reminders. Programmed stickies can be designed to only appear when the user has determined it is relevant for them to be visible, and hence reduce the total number of visible stacks.

In addition to more theory and evaluations of possible new design extensions, we need to understand the *role* of the lightweight interactions more precisely. We need to determine *the classes of conversation* for which the different aspects of the tool are most suitable. Thus our users' comments indicated that there were only certain types of situations in which they would use the stickies component of TeleNotes. A clear factor here was the perceived *informality* of stickies. Various people stated they wouldn't use stickies to communicate with strangers or high level management, ie. for more formal types of interaction. This suggests a role for stickies within distributed workgroups who already know each other. In more formal settings the other communications options (phone, FAX, email) may have to be used, given the perceived informality of stickies. Other necessary requirements for the effective deployment of the whole TeleNotes system, are that the workgroup's interactions are *repeated but intermittent*: TeleNotes offers fewer benefits if the conversation consists of a single interaction. Furthermore, if the conversational materials are simple and straightforward, then context regeneration may be unproblematic, so that TeleNotes may again offer reduced benefits, over phone or email.

Finally the design of TeleNotes reflects a recent trend in systems that attempt to exploit some of the features of paper-based systems, and their associated work practices, by incorporating these features into electronic applications. Recent empirical work has emphasised the benefits of paper, drawing attention to its visible nature, the fact that it can be easily spatially organised, and its context-holding function (Bowers, 1994, Bentley, Rodden, Sawyer, Sommerville, Hughes,

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Randall, & Shapiro, 1992, Luff *et al.*, 1992, Whittaker & Schwarz, 1995). Systems have also been designed that attempt to provide synergy between paper and electronic worlds, eg. "augmented reality" (Johnson, Card, Jellinek, Klotz & Rao, 1993, Newman & Wellner, 1992, Mackay & Pagnini, 1994). Other electronic systems have explicitly been designed to model aspects of the paper world (O'Conaill, Geelhoed & Toft, 1994, Wang, 1989, Whittaker *et al.*, 1993, Wolf, Rhyne & Ellozy 1989). We need more work investigating the impact of some of the features of the paper world investigated here, such as visibility and ease of arrangement, Future electronic systems can therefore better exploit the affordances of the world of paper, including its utility in managing extended intermittent interactions that we investigated here.

## ACKNOWLEDGEMENTS

Thanks to Irene Greif, Sal Mazotta, John Patterson, Lyn Walker, Nicole White and Brid O'Conaill for conversations about this work. Thanks also to the people who participated in the field trials.

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