UNIVERSITY OF CALIFORNIA, SAN DIEGO

The Role of External Resources in the Management of Multiple Activities

A dissertation submitted in partial satisfaction of the
requirements for the degree of Doctor of Philosophy
in Cognitive Science

by

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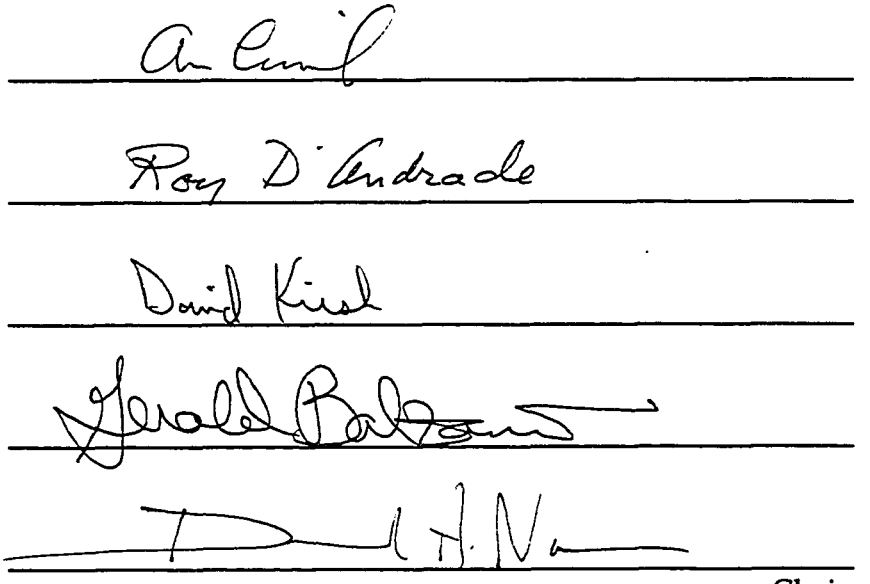

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To Elana, Dahlia, and Rinatte.

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ABSTRACT OF THE DISSERTATION

The Role of External Resources in the Management of Multiple Activities

by

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This dissertation describes observational studies of how people manage multiple activities and handle interruptions in everyday office settings. A number of methodologies were used, including interviews, office tours, videotaped observation of subjects as they worked, and retrospective protocols as taped episodes were reviewed with the subjects. The studies shed light on the structure and dynamics of everyday activities, the way people manage multiple activities and handle interruptions, and the role of external structures in that management. They also reveal inadequacies in the approach of traditional activity theory to delineating behavior. Together, the studies suggest that the management of everyday activities is a distributed

process which relies heavily on the placement and manipulation of pre-existing, meaningful physical items.

Traditional planning is often not possible due to the complex and situated nature of everyday activities. Instead, a distributed form of planning occurs in which spatial configurations come to represent the order in which activities should be performed. This planning relies on routines which configure the environment, and routines which insure that external structures will be encountered at appropriate times and the desired activities cued.

Because of its reliance on external structures, activity management is susceptible to disorder due to conflicts between informational concerns and the physical constraints and affordances presented by a situation. The role of physical constraints and affordances in determining behavior increases during interruptions and when multiple activities are performed together. Cleanup and stabilization routines are employed to correct the problems this can cause. In addition, people develop routines to minimize the detrimental effects of interruptions they anticipate. The dissertation ends with a discussion of the implications of my research on the design of systems used in complex real-world settings.

Chapter 1

Introduction and Overview

Introduction

This dissertation studies how people manage the multiple activities of life. My thesis is that the management of activities is both a situated and distributed cognitive process which relies on the opportunistic use of the external environment. This process is characterized more by the application of routines and heuristics as situations are encountered than by extensive pre-planning.

People do not develop complex algorithms for determining the scheduling and interleaving of activities. Instead, they evolve routines which make use of the spatial arrangement of artifacts that already have task relevant meaning. Physical space is used to represent many aspects of the task domain. Routines which prepare, organize and stabilize this space evolve alongside routines which make use of the space. Elements of planning can be seen to occur through these routines and through manipulation of the artifacts used in the work. Planning is often

distributed over time and space as people's workspaces and environments evolve. Over time, the placement of task relevant items can come to represent the existence, status and relative priorities of goals.

Multiple Activities in Everyday Life

The many activities that people engage in during the course of a day are rarely delineated clearly by time and place. More often than not, activities overlap and intertwine, and the line between where one ends and another begins can be hard to draw.

The interleaving of activities can have many forms. An activity may be interrupted by a visitor, a phone call, or an email message. An activity may be suspended temporarily while waiting for additional information or for a document to print. Activities of long duration are routinely interrupted by human demands such as the need to eat and sleep. And people often do several things at once, sorting mail while talking on the phone, or planning their day as they walk to their offices. An opportunity to further an activity may lead to an interruption of a current activity.

Consider this example based on the videotaped observation of a subject in one of my studies:

A schoolteacher enters her home office to write a letter on her computer. She also wants to install some software on her computer. She turns on the computer and while waiting for it to boot up,

repositions her chair, clears off an area at the front her desk, sits down, and adjusts her chair once more.

The teacher then starts the word-processing program and types the letter. When finished, she stands, walks over to the printer to confirm that it is on and the paper properly positioned, and then returns to the computer where she executes the commands to send the letter to the printer. After a brief pause during which a dialog box appears on the screen, the printer starts. The teacher leans over to verify that the paper is feeding properly and that the text lined up.

While the letter is printing, the computer is devoted to the printing task, and cannot be used for other activities. During this time, she reaches for the disks and instructions she will use to install the new software release. She places the disks in front of her on the desk and pages through the instructions. While she is reading the instructions, the printer finishes printing; the printing sounds stop, the dialog box disappears from the screen, and the computer is again available for use.

The teacher continues reading through the instructions for several minutes after the printing stops. She then looks at her screen, exits the word-processing program and begins the installation process by inserting the first diskette into her computer and starting the install program.

The installation process requires that nine diskettes be inserted into the computer. Each diskette remains in the computer for a varying amount of time–up to several minutes–and is then automatically

ejected. A dialog box on the screen indicates progress and instructs the user which diskette to insert when.

The teacher inserts the diskettes as prompted by the dialog box on the screen. During the delays as the diskettes are in the computer, she reads the documentation. From time to time, she glances at a clock on the wall.

While the seventh diskette is in the computer, she glances at the clock and then prepares several items to take with her for lunch. She stands up and goes to the printer, tears off the letter she had written earlier, tears the perforations from the sides and returns with it to her desk. She folds the letter, addresses an envelope, inserts the letter, and places a stamp on the envelope. She glances at the computer screen again and leaves the room with the letter and the other items she had prepared.

While she is absent from the room, the diskette is ejected and a screen-saver fills the screen, covering up the dialog box displayed by the installation program. When the teacher returns to her desk an hour after leaving, she sees the screen-saver and the diskette protruding from the computer. She reinserts the diskette, which also clears the screen-saver from the screen. The diskette is ejected again, and instructions appear in a dialog box on the screen. The teacher follows the instructions on the screen to complete the installation process.

This episode shows the teacher engaging in two primary activities: writing a letter and installing computer software, and one major interruption as she leaves her office for lunch. The activities overlap in several places; neither is performed without interruption. The letter writing activity consists of typing the letter, printing it, removing it from the printer and tearing off the perforated edges, inserting it into an envelope, addressing and stamping the envelope, and then taking the letter out of the office (presumably to mail it in a mailbox or post-office). But instead of this activity being performed continuously from start to finish, actions that are part of the unrelated software installation activity are interspersed within.

Issues and Questions

An interesting paradox describes much traditional psychological research. The traditional experiment shields the subject from distractions and interruptions that might intrude on the performance of the task being studied. Even in many observational studies, the unit of analysis is a specific task or isolated activity, and interruptions are dismissed as noise and not indicative of the participant's performance. Yet observation of workers in naturalistic settings shows that interruptions are the norm, not the exception. A major goal of my study is to account for the mechanisms by which people manage interruptions in normal, inherently noisy environments. The fact that activities interleave and intertwine presents challenges for the design of systems and tools aimed at supporting those activities. It is not enough for a tool

to support a single activity. It must support interruptions and transitions between the activity and others. A secondary goal of my study is to suggest guidelines for developing tools that support activities by drawing from the mechanisms people use to handle interruptions and activity transitions in their lives.

Several questions prompted my investigation into how people managed multiple activities in everyday life. These questions can be grouped in terms of the larger issues they address:

1. How are activities structured?
2. How do people handle interruptions?
3. What are the informational demands of activity management?
4. How do people remember the activities they have to perform?
5. Do people plan their activities in advance, and if so, how?
6. What role do external artifacts play?

The Structure of Activities

An account of activities must begin with an inquiry into their nature and structure. How clearly are they delineated by time and space? What factors determine when one activity will be suspended and another begun? What factors lead to the resumption of suspended activities?

Interruptions

Interruptions are an important aspect of the interleaving of activities. How are interruptions handled? How do people decide what to do when an interruption occurs? What steps do people take to preserve the context of the interrupted activity, and how is it resumed later?

Information Demands of Activity Management

What informational demands arise when several activities are interleaved? What information is required for the task of managing activities? How is this information represented? How do these representations arise, and how are they transformed over time?

Memory and Reminding

What demands do multiple activities places on memory resources? How do people keep track of the many tasks they need to accomplish? How do they maintain awareness of their different activities? How do they keep track of the states of suspended activities, and how do they know when to resume them?

Planning

We can conceive of solutions to the managing of multiple activities that involve extensive preplanning. To what extent do people engage in

advance planning of the interleaving of activities? When is this planning done, and how are the results represented?

External Artifacts

My research draws from the tradition of distributed cognition, in which resources and structures in the external environment play an integral role. Cognition is seen to occur not simply within the head of an individual but in the interaction with other actors and the external environment. External artifacts play an important role in the management of routine activities. How do people make use of artifacts? What aspects of the goals and tasks are conveyed by these artifacts, and how do people extract or reconstruct the necessary meanings from them?

Studies and Findings

My research involves observational studies of people, primarily in office settings. The studies include interviews, tours by the subjects of the items and areas in their workspaces, videotaped observation of subjects at work, and retrospective protocols as subjects described their activities as they watched them on videotape.

Two studies form the bulk of my research. The first is an analysis of a set of videotapes taken by Apple Computer to understand how people learned and used a new release of their system software. This study yielded fifteen six-hour videotapes of three people working in their office or home workplaces, each studied for a one-week period.

The second study consists of videotaped interviews, office and computer tours, observations, and follow-up sessions with six subjects in their respective workplaces. I designed this study to insure that the contexts in which their activities were performed would be available to me for analysis.

A question can be asked about the use of office settings as the focus of my study. How representative are findings from such domains of how people manage their activities in other, less structured areas of their life? Although this question that can only be answered empirically, I believe that my research illustrates general cognitive processes and phenomena which apply broadly to human behavior. The settings and tasks I studied span a range of levels of structure and predictability. In addition, activities involving the subjects' lives outside their offices were discussed during my interviews, and these confirmed the impression that my observations could be generalized to other domains.

Several themes influenced my research. These will appear throughout the chapters that follow. One is the distributed view of cognition, which expands the unit of analysis for cognition to include external artifacts, representations, and other actors. Another is the view of cognition as a situated phenomenon characterized more by ongoing interaction with the environment than extensive pre-planning. A theme which emerged repeatedly throughout my study was the importance of physical items and spatial relationships to represent task relevant information.

Overview of the Chapters

Chapter 1, this chapter, sets the stage by introducing the issues under investigation. It describes the studies and my major conclusions, and outlines the overall structure of the dissertation.

Chapter 2 presents a theoretical analysis of activity management and interruptions, with an overview of prior research. It positions my research in terms of the different schools of thought.

Chapter 3 describes the first study: an analysis of videotapes taken by Apple Computer. I discuss the goals and design of the original study, the format of the videotapes that resulted, the methodology I used to analyze the tapes, and the results and conclusions of that analysis. I also discuss limitations with the tapes that constrained the extent to which I could draw theoretical conclusions from them. These limitations influenced the design of my office activity study.

Chapter 4 describes the office activity study, in which a combination of methodologies were used to understand how six subjects manage their everyday work activities. I describe the subjects and their work settings in detail, and detail the procedures. I present conclusions based on these studies about different strategies and techniques people use to manage their activities.

In Chapter 5, I present a detailed analysis of a single 18-minute segment observed at one of the sites during the office activity study. By

focusing on one episode in depth, this chapter illustrates how the phenomena identified in the Chapter 4 interact to support multiple activities in a dynamic, interrupt laden environment.

Chapter 6 summarizes the studies I conducted, and answers the theoretical questions posed in this chapter. I conclude with recommendations on how my findings could be applied to the design of tools and systems that support the handling of multiple activities in everyday work settings.

Chapter 2

Theoretical Background and Prior Research

In this chapter, I discuss the theoretical issues that arise in understanding how people manage multiple activities. I also review past research on the topic.

The first issue that arises is the definition of an activity. One approach is to define activities in terms of the goals that prompt them. Other approaches include defining activities in terms of the procedures they involve, the tools they use, the places in which they occur, or the times at which they take place.

A second issue is a formal analysis of the problem faced by an agent trying to perform multiple activities. What constraints and tradeoffs are faced by the agent, and what heuristics and algorithms can be used to solve the problem? What are the informational demands of this problem solving, and how might different ways of representing this information affect the agent's performance? What role does planning play in this process?

A third issue is the role of external resources in the management of multiple activities. What resources are used, how are those resources created and modified, and how do these resources influence performance?

In discussing these questions, I draw from prior research on activity theory and problem solving. I discuss what has been learned in prior experimental and observational studies on multiple task performance and the effects of interruptions on performance. I also discuss prior studies on how people organize their desks and offices, how they use reminders, and the role of paper and other external artifacts in busy office settings.

Delineating Activities

In the first chapter I presented an example of a teacher engaging in two relatively straightforward activities. Even this simple example presents challenges for formal analysis. How can we divide the episode that was reported into its component actions and activities? How can we map the specific actions undertaken by the subject to the goals that motivated them? Before we can talk intelligently about the problems raised by the coordination of multiple activities, we must define what we mean by an activity. We also need to define the components of which activities are comprised.

Activity Theory

There have been several attempts to create hierarchies of actions and activities. One prominent approach is based on traditional activity theory (Leontyev, 1978,1981; Vygotsky, 1978; Kuutti, 1991), which defines and delineates activities in terms of the goals or motives that prompt them. Activity theory views *activities* as the "basic units of development and human life." (Kuutti, 1991) As summarized by Kuutti, traditional activity theory sees activity as a historically developing, collective phenomenon that exist in a material environment and which transforms that environment. All activities are seen as having:

> an *object*, or *motive*, which is the reason the activity exists. This can be thought of as the goal or motivating force behind the activity;
>
> a *subject*, meaning a participant who understands the activity's object or motivating goal.

Activities are said to consist of *actions* or sequences of actions. Actions can be broken down further into their constituent *operations*. While activities are motivated by a higher level need or goal of direct importance to the person engaged in them, actions are motivated indirectly by the need to satisfy subgoals which arise in the course of the larger activity. Operations are seen as well-defined, practiced routines performed by the subject in response to conditions that arise as the actions that make up the activity are performed. Operations are believed

to occur on an unconscious level, although if problems arise they can unfold to the level of conscious action.

The borders between the different levels of the activity-action-operation hierarchy are blurred and constantly subject to change. Kuutti gives the example of building a house, which might be considered an activity for an individual builder yet seen as just one action in the overall activity in which a large scale building contractor is engaged. In practice, it is often hard to determine objectively how such hierarchies should be mapped to observed behaviors. Should writing a letter to a family member be seen as an activity and obtaining a stamp to mail it an action, or should the entire letter-sending operation be seen as an action in a larger activity of maintaining contact with significant people?

Leontyev (1981, p.400) states that we may not always be able to determine immediately whether an example of observed behavior should be characterized as an activity or an action, but suggests that the correct characterization may become clear as events progress. He gives the example of a student who is observed reading a book in preparation for an exam. It is unclear at this point whether the book-reading should be characterized as an activity or an action, because there may be several objects, or motives, behind it. Now assume that the student is informed that the book will not help with the exam. If the student lays the book aside, we can safely say that the book-reading was simply an action, motivated by the desire to perform well on the exam. But if the student continues reading the book, Leontyev maintains, the content of the book

itself satisfied some need of the student and was sufficient to motivate the book-reading. The book-reading, having its own motive, would then be considered an activity.

Leontyev suggests that actions can be elevated to the level of activities when a subject begins to obtain direct satisfaction from them. The action, which was initially motivated indirectly, now can be seen as an activity in its own right. In the example of the student, Leontyev suggests "the need to know, to understand, to master" as the objects of the book-reading activity in the case in which the book-reading is not simply motivated by the desire to do well on the exam. As attention is paid to a problem, solving the problem may become its own goal. The issue is a cloudy one, complicated by the fact that the need to solve a problem, to figure out what went wrong, to get something to work, or to understand an unexpected event. The test Leontyev suggests is a negative one; absent all other known goal-driven activities that may be motivating the behavior, if the behavior continues, we can assume that it must somehow have its own motivation.

Inadequacies of Traditional Activity Theory

The criteria suggested by activity theory for delineating activities are inadequate for delineating observed real-world activities for three reasons:

1. It is often hard to identify the goal that motivates an episode of behavior. This is true even for the subject engaged in the episode, to say nothing of an outside observer.

2. There is often no one-to one mapping between activities and goals. One activity may satisfy a number of different goals, and, in turn, a number of different activities may further a single goal.

3. No indications are made of how broadly or narrowly goals should be construed.

Traditional activity theory maps activities to the goals that motivate them, and requires that the subject performing the activity be conscious of those goals. Yet many activities may be conducted for a number of vague and unstated reasons. The relationship between an activity and the goals that prompted it may be historical; while the agent may have been initially aware of the reasons for engaging in an activity, it may now be habitual, performed without a continued conscious understanding of why it was first undertaken. Identifying the specific goals may be difficult or impossible even for the person engaged in the activity. An approach which requires that such goals be identified by an outside observer is therefore inadequate.

The goals that influence behavior range along a continuum from clearly defined, discrete objects to those which satisfy more nebulous desires. Occasionally, activities can be mapped neatly to distinct external products and deliverables. Many activities involve long term or abstract

goals such as the maintenance of social relationships or providing the impression of overall competence. Other actions are primarily important not because they accomplish any direct goal, but because they maintain an environment in which other actions can be efficiently performed. Such actions have been termed *stabilization* routines (Hammond, Converse and Grass, 1995), and include such actions as insuring that an adequate supply of general resources is maintained or that tools are returned to their expected places.

Activity theory provides no guidelines on how narrowly or broadly the goals of an agent should be construed. Should writing a letter be seen as an activity in itself, with the goal "produce and send a letter" or should it be seen as one task in the larger activity of "keeping in contact with acquaintances?" Should "keeping in contact with acquaintances" be seen as an activity in its own right, or a task in the broader activity of "maintaining a supportive social environment." Because activity theory requires that an activity be defined in terms of its goals, but provides little guidance on how those goals should be delineated, it cannot be used to delineate the activities that form complex everyday behavior.

Even if goals could be adequately delineated, there is often no one-to-one mapping between activities and goals. A single activity may contribute to the accomplishment of a number of goals, and a single goal may be contributed to by a number of different activities. For example, hosting a dinner party for one's boss may further the direct goal of getting a raise, satisfy the broader desire of improving social relationships with

other guests, and provide an opportunity to try a recipe seen earlier. The goals of getting a raise and improving social relationships would in turn be served by a number of different activities in addition to hosting the dinner party.

Alternative Schemes for Classifying Activities

While traditional activity theory defines activities in terms of their goals or objectives, other approaches are possible. One alternative is a process oriented approach, in which activities are characterized in terms of the procedures, tools and resources they involve. Another approach is to define activities in terms of the places in which they occur or the times they are performed. For example, going to the mall could be seen as an activity even though that might include shopping for clothes, finalizing travel plans, and making a deposit at a bank. What one does upon returning from a trip could be considered one activity, even though this may entail unpacking suitcases, picking up the mail from neighbors, checking local news, and telephoning the alarm company.

One advantage to these approaches is that they suggest the use of directly observed phenomena to delineate activities. Unfortunately, many of the same limitations faced by traditional activity theory apply to these approaches as well. How strictly should tools, procedures and resources be tied to specific activities? Should preparing a meal in a microwave oven be seen as a different activity than preparing the same foods on a stovetop? Should using a telephone to talk to a friend be seen as the same activity as using the telephone to dial in to an automated

banking system? Should we differentiate between using the mouthpiece and ear piece of a phone, as during a spoken conversation, and using the keypad and ear piece of the phone, as when contacting an automated phone system?

It became clear during the interviews I conducted that subjects had trouble categorizing their own behaviors. Their responses suggest an additional factor that should be taken into account in delineating activities, namely the extent to which a set of actions or tasks has been conceptualized as a discrete focus of attention.

Imagine a businessman who travels for his job. For each trip, he must prepare a report itemizing the expenses incurred for travel, lodging, meals and the like. There are several ways the businessman could create this report. He could spend several minutes each day adding the expenses from that day to an accumulating report. He could wait until the end of the trip to enter all the expenses from that trip. He could wait until he has accumulated a stack of receipts from several trips, and then sit down to prepare all the expense reports at one time. He could also use various combinations of these techniques, for example tallying restaurant receipts at the end of each day, adding hotel receipts at the end of each trip, but waiting until reports from several trips have accumulated before preparing the official reports for submission.

Which method the businessman uses will influence the extent to which he sees the preparation of the expense report as its own activity.

In the first case, preparing the expense report might seem like one task in the larger activity of traveling, attending a conference, recruiting new clients, or whatever the activity within which the trip was conducted. In the case in which expense reports for several trips are batched and prepared together, preparation of the reports might be a considered a distinct activity. Note that in all cases, the goal of preparing the expense report is the same. In fact, the ultimate goal of preparing the report–maintaining financial fitness–is likely a primary goal of all of his professional activities.

The approach I take for discussing activities combines elements of traditional activity theory with the process-oriented approaches described above. I discuss an activity as an identifiable chunk of motivated behavior involving a characteristic set of goals, procedures, tools, resources and/or times. The combination of factors that defines an activity can vary from activity to activity. If we imagine a network of interacting goals, tools, procedures and resources, an activity would be represented as a coordinated pattern of activation across that network. A critical element in defining an activity is the extent to which the agent conceptualizes it as a discrete chunk of behavior, regardless of the factors that lead the activity to be so conceptualized. This view of activities parallels the way subjects speak of their own behaviors. It therefore allows the subjects' verbal reports to provide guidance in delineating their activities. In addition, the view of activities as having a characteristic, or expected, set of goals, procedures, tools, resources and/or

times sets the stage for the discussion of interruptions I will present below.

The Nature of Multiple Activities

People engage in many different activities in the course of everyday life. Much of the traditional research into problem solving has focused on solving individual, relatively circumscribed problems. Yet in everyday life, selecting which activities to undertake when can be as important as selecting the specific actions needed to solve individual problems. An overall goal of actors in complex environments is to develop a strategy for managing their activities that is sufficiently robust and efficient.

Activities can interact in several ways. Formally, we can say that two activities will be orthogonal, or strictly independent, if there are no interactions between any of the intermediate states obtained during performance of the activities. This implies that the resources used by the different activities are independent; neither activity alters the state of resources used by the other task. Furthermore, there is no temporal relationship between the two activities such that performance of one activity has an impact on the agent's ability to perform the other. If two activities are strictly independent, the decision on when to perform one of the activities has no impact on the decision of when to perform the other. There are no grounds for preferring one scheduling of the two activities over another.

Two activities can be considered partially independent if there are interactions between the two activities such that one combination of the activities would be more efficient than another. While several combinations of the activities would realize the desired goals, there are grounds for preferring one scheduling to another.

Two activities can be considered dependent if the intermediate states of the two activities interact such that only certain schedulings will lead to the desired goals. One activity may exhaust or modify resources required for another activity, or may lead to a state that makes performance of the other activity impossible.

Interruptions

An *interruption* can be defined as a break in the uniformity or continuity of a process or sequence of events. An interruption causes a deviation from an expected progression, sequence or timing of events. This definition does not necessarily imply the existence of a plan or an explicit representation of how events typically unfold. Instead, the expected progression, sequence or timing of events can exist in the form of associations and primings learned implicitly through prior experience.

Interruptions can be characterized by how the factors that cause them are related to the current activity. An interruption can be characterized as *internal* if its cause results from actions performed during the activity itself, and requires that additional actions be performed to complete the activity. Errors and slips can cause internal

interruptions, as can failures in the tools used in the course of an activity. Internal interruptions spawn subgoals that must be satisfied before the activity can be completed. They are seen as interruptions because they lead to deviations from the expected progression of the activity. An interruption can be characterized as *external* if its cause results from factors unrelated to the current activity, and requires that actions be performed that do not further it. Internal interruptions lead to a shift in the actions and operations performed in the course of an activity; external interruptions lead to a shift in activity.

Interruptions can be further broken down in terms of the level of activity at which they occur. In terms of the hierarchy proposed in traditional activity theory, an interruption can lead to the performance of a different operation within an action sequence, a different action within the current activity, or a different activity altogether. In Chapter 3 I present examples of interruptions occurring at each level of an activity involving updating computer spreadsheets. The factors that interrupt the expected flow of that activity include action slips that are noticed immediately and corrected right away, error messages that spawn new tasks in an effort to understand and resolve them, and phone calls regarding entirely unrelated matters.

A *physical interruption* occurs when the normal or anticipated sequence of events is altered because of physical factors in the environment which directly affect the performance of physical actions that are part of the activity. An activity involving mailing a letter would

be interrupted if the mailbox door were jammed and could not be opened or if the roads leading to the mailbox were obstructed. An activity involving printing a document would be interrupted if no paper were available or if a power outage occurred. An *information driven* interruption occurs when the agent modifies the course of the current activity because of information that leads the agent to select a different course of action. There may be both physical and informational elements to an interruption, and the line between the two is not always clear. A tree fallen across a road may create an obstruction and therefore a physical interruption to an activity involving driving over the road, yet knowledge of the fallen tree would be enough to lead the agent to select a different course of action.

Managing Multiple Activities

We can approach the management of multiple activities as a problem that must be solved by an agent engaged in the unpredictable complexity of everyday life. The first stage of understanding this process by which this problem is solved is to define the problem and the situations in which it arises. We can then ask about the nature of the problem solving that takes place to solve the problem. What solutions are arrived at by the agent? What information is needed to solve the problem, and how is this information obtained and represented? Does planning take place to precompute solutions to the organization of activities, and how are such precomputed solutions represented?

The problem of managing multiple activities results from the existence of multiple goals and resource limitations and other constraints that limit the actions that can be performed at one time. The problem is complicated because of interactions between activities. In some situations, performing one activity may move the agent closer to the realization of several different goals. In other situations, an activity that moves the agent closer to realizing one goal may move the agent further from accomplishing others.

Managing activities involves both *ordering* and *scheduling* individual actions. Ordering actions involves determining the sequence within which those actions should be performed relative to each other. Scheduling actions involves determining when actions should be performed relative to some external event or time sequence. Actions can be scheduled relative to an absolute time, such as "at 9:00 in the morning", or relative to some other event, such as "when I leave the house". Actions can be scheduled to coincide with an external event or in terms of a temporal position relative to an external event or set of events (e.g. "before I go to sleep", "after the mail arrives", "between 5:00 and 11:00 PM", "when I get the list of updates"). While ordering a set of actions depends on the constraints and interactions internal to that set of actions, scheduling depends on coordination of a set of actions with events and situations in the external world. Ordering can therefore be seen as primarily describing the sequence of actions within an activity, and scheduling as involving the coordination of multiple activities.

There may be a number of possible orderings of tasks or actions within an activity that can adequately satisfy the intended goals. Still, there are often reasons for preferring one ordering over another. We can say that one ordering is better than another if:

1. The **cognitive costs** of performing tasks in that order is lower. For example, if two orderings are otherwise identical, but one requires that a long number be stored in memory, the ordering requiring the added memory is worse.

2. Fewer **external resources** are required to perform the tasks in that order. For example, if two orderings are otherwise identical, but one requires that a telephone line be engaged for a longer period of time, that ordering is worse.

3. The **benefits** accrued by performing the tasks in that order are greater. For example, if two orderings are otherwise identical, but one allows the use of a printer that yields higher quality output, that ordering is better.

4. Performing tasks in that order is **more reliable** or robust to interruptions.

When dealing with multiple activities, it is not enough to determine the optimal ordering of tasks for each activity alone. Interactions between the various activities must be taken into account to determine how the activities should be scheduled with respect to each

other. So while one ordering of actions might be optimal for performing a single activity alone, a different ordering might allow the activity to be performed together with others and therefore yield a more efficient overall solution.

Returning to the example of the businessman preparing expense reports, we can ask why he would prefer one strategy for preparing the reports over the other possible ones. It is conceivable that the businessman would not uniformly adhere to one strategy, but instead would switch from strategy to strategy depending on the other activities he must perform and additional situational factors. We would then like to know what triggers the different strategies, and when is the choice of strategy made.

The classical problem solving approach reflected in the work of Newell and Simon (1972), among others, sees problem solving as a series of state transitions from an initial state to a desired goal state. Agents can move from state to state by use of operations available to them. The entire set of states and their possible interconnections is referred to as the problem space. At each stage in solving a problem, several states may be possible "next states", i.e. states the agent can move to by use of the available operations. The agent must determine which operations to perform, and therefore which state to move to from among the possible states.

The informational demands faced by the problem-solving agent can be itemized as follows:

1. The agent must know what the current state is.

2. The agent must know what the goal state is.

3. The agent must know what the possible next states are and how to reach them. Stated in terms of the operations from which the agent must choose, the agent must know what operations are possible in the current state, and what are the consequences, or resulting states, of each.

4. The agent must know the difficulty of reaching each of the possible next states, and how much closer each will bring the agent to the goal state.

The specific memory and processing demands of solving a problem can vary based on the strategy used. Simon (1975) presents, for example, an analysis of the varying demands on short term memory (STM) and perceptual pattern recognition of different strategies for solving the classic Tower of Hanoi problem. Zhang and Norman (1994; see also Zhang, 1990; 1992; Norman, 1993)) have shown that the way task relevant information is encoded in external representations significantly affects performance. The role of external resources with respect to multiple tasks will be discussed below.

Strategies for Managing Multiple Activities

We can imagine several strategies that, in principle, could be used to manage multiple activities and determine how those activities should be interleaved. Such algorithms are somewhat analogous to the algorithms that are used to schedule processes in multitasking computer systems. The strategies differ primarily in how they select an activity to be performed, and in how interruptions are handled. They also differ in their cognitive resources they require, and their informational demands.

The cost of switching between activities must be taken into account in selecting a strategy that is optimal overall. This cost results from the need to establish an internal and external context to support each activity, and to achieve coordination between the internal and external contexts. Establishing the internal context required for an activity can involve retrieving items into working memory, perceiving and interpreting items from the external environment, and performing computational work to construct the required internal representations. Establishing the external context required for an activity can involve such things as retrieving physical documents, placing papers so relevant information is readily perceivable, positioning items to reflect relationships between them, collecting required tools so they will be close at hand, and clearing space that will be needed in the course of the activity.

When an activity is suspended, efforts may be required to insure that progress that has been made is not lost. When an activity is suspended with the expectation that it will be resumed later, attempts can be made to reduce the effort that will be required to reestablish the context of the activity when it is resumed. This can involve transferring to external media representations that had been held internally, preserving the spatial organization of external artifacts, and the use of mechanisms such as bookmarks to make perceiving and restoring the current state of physical items easier. These efforts to preserve the context of an activity carry a cost as well, and may require time or the use of cognitive resources that are not available if the transition to the new activity must be made quickly. In practice, interruptions must often be dealt with immediately, and people do not have the opportunity to perform extra work to insure that their activities are left in a state from which they can be easily resumed.

The following are some of the possible task-management strategies by which people could select activities to pursue and handle interruptions:

1. Select an activity at random and work on it until it is completed. Do not work on any other activities until the activity is completed. (This simplistic strategy requires minimal information or processing but is clearly problematic in real world situations.)

2. Select an activity at random, and begin work on it. Work on that activity until forced to stop, either because the current activity ends, because the activity must be suspended due to an internal interruption, or because of an external interruption. Then switch to the interrupting activity, if there is one, or to the next activity that is encountered, picking randomly from the outstanding activities, selecting the next from stack of activities, or selecting the next activity due.

3. Work a set amount of time on each activity, then switch to the next activity in line, working a bit on each activity before returning to an earlier one (time slicing). A problem with this strategy is that the total cost of switching activities, comprised of the cost of establishing and saving state each time activities are switched, can be great.

4. Assign priorities to the activities in a principled way, based on the expected returns of performing each activity and the cost of performing each at that time. Work on the activity with highest priority until forced to stop, or until another activity attains a higher priority. Always switch to the activity with highest priority from among those that can be performed.

5. Allocate resources among several activities Select the activity of highest priority, work on it until an interruption, then evaluate the interruption, and allocate resources

6. Preplan the interleaving of activities in detail to minimize the cost of task switching, maximize the use of resources (minimizing cleanup time), and minimize the disruptive effects of anticipated interruptions. This implies substantial prior knowledge regarding the activities and their costs, and of the environment in which they are to be performed.

Informational Requirements

The information requirements of each of the above strategies for managing multiple activities varies. Depending on the strategy employed, the agent must know:

1. The list of activities that must be performed;
2. The current state of each activity;
3. The relative priority of each activity;
4. Temporal constraints on the performance of each activity, such as deadlines or times when certain resources will be available;
5. The resources required to perform each activity;
6. The effect of performing each activity on the resources required for performing the other activities.

The cost of performing the actions in an activity should be measured both absolutely, and relative to their cost if performed at a

different time. The opportunity to perform a required activity at a lower than expected cost could justify performing that activity, even if it otherwise would be assigned a lower priority than other activities.

In a complex and dynamic environment, the agent must also be aware of changes to the environment. These changes include:

1. Changes to the set of activities that must be performed, and to their costs and expected returns;

2. Changes to the state or availability of resources required for each activity;

3. Changes to the probability of success of the algorithms the agent uses.

Maintaining awareness of relevant changes to the environment may necessitate additional activities whose primary purpose is to monitor the environment for changes that affect current activities or require that additional activities be performed. While such activities cannot be mapped directly to a specific goal or subgoal, they are required to maintain an overall level of competence.

Dealing with Interruptions

There are a number of ways in which an interruption can be handled when it occurs. On one extreme, it may be possible to ignore the interruption completely. On the other extreme, the current activity may be suspended entirely and attention and resources shifted fully to handle

the interruption. Between these extremes, other solutions which involve a sharing of resources between the current activity and the interruption are often possible.

Determining how to handle an interruption may require a process of evaluation during which the costs and benefits of each way of dealing with the interruption are weighed against the costs of removing resources from the current activity. When an interruption initially occurs, the necessary information to determine how to handle the interruption may not be known. The process of evaluation that occurs can require seeking additional information about the interruption. It is desirable to minimize the extent to which this evaluation process requires the removal of resources from the current activity. Otherwise, resources might be removed from the current activity only to reach the determination that the resources did not have to be removed.

Planning

One suggested strategy for managing multiple activities involves planning through which the optimal interleaving of activities is specified in detail. Traditional planning is based on the notion of a distinct process in which the individual actions required to reach a goal are determined and ordered. In its purest, most idealized form, planning requires that:

1. A distinct planning process occurs, during which a sequence of actions is determined;

2. A representation of the sequence of actions is stored;

3. This representation is consulted or read (the plan is executed) and the agent performs the specified actions in the indicated sequence.

We can ask several questions about the role of planning in the management of multiple activities. Does planning occur, and if so, when does it take place? What representations are involved in the planning process, and how is the plan itself represented? How and when is the represented plan used, and how closely is the plan followed? We can also ask how explicitly the plan is represented. The constant time criterion for determining explicitness is particularly appropriate in the context of planning, as the purpose of planning is to off load a portion of the processing required for a task and precompute solutions that can be read off at the time the activity is performed. If interpreting the plan requires significant amounts of processing, then clearly much of the value of pre-planning is lost.

We can also inquire about the extent to which the interleaving of activities is even amenable to extensive, detailed pre-planning. There are several reasons why such pre-planning may not be practical or even possible:

1. The up front cost of planning in great enough detail, even assuming all information were known, might be substantially higher than the gains realized by such preplanning.

2. Because of the situated nature of activities, the information required for planning may not be available until the agent is in the situation. Furthermore, the agent may not be consciously aware of all the factors that will affect its behavior, and that it should take into account when scheduling its activities.

3. The real world involves a large amount of uncertainty. Even those things which can be anticipated may not be precisely predictable in terms of their timing and content. So we may know that we will have a number of phone calls in the morning, but exactly when they will come and how long they will take may be hard to predict. We may know that the mail will arrive sometime in the morning, but not exactly what it will include. We might know that a specific parcel will come in the mail, but not the day that it will arrive. It would be impractical to plan for all the different permutations of contingencies that we could anticipate.

In the studies I conducted, I looked for examples in which planning was performed as a discrete, explicit process. I also looked for examples in which elements of planning occurred implicitly in distributed way, through the application of routines and procedures which structured the environment so that it would serve much of the function of a traditional plan.

Theoretical Influences

My research was influenced by two major theoretical ideas. One is the view of *situated cognition,* in which the specific shape of purposeful activity results through an ongoing interaction with the environment and not through extensive preplanning (Lave, 1988; Suchman, 1987). During this interaction, characteristics of the environment and the subject's cognitive state affect each other and are constantly subject to change. Within the situated cognition approach, plans are not seen as strict prescriptions of actions to be followed but rather as often post-hoc descriptions of activity that has unfolded naturally. I looked for evidence that similar phenomena shape not only the performance of individual tasks, but also the management and interaction of multiple tasks and activities.

The second theoretical idea behind my research is the *distributed cognition* approach of Hutchins (1990, 1995), Norman (1990, 1993) and others. This approach sees cognition as distributed among individual agents and external representations. The distributed cognition approach is typified by an expansion of the unit of analysis of cognitive science beyond the head of a single agent and sees groups of actors working together and the artifacts they use as together forming a cognitive system. Cognition is seen as resulting from the transformation of representations across different media. The external environment is seen as playing an integral role in cognition, and not just as defining the playing field on which an individual's cognitive work takes place. A practical

consequence of this approach is that many of the representations that are studied are directly visible to the researcher. The approach therefore opens up cognition to empirical investigation in a way that traditional approaches cannot. Much of my research was aimed at understanding the role external artifacts play in the cognitive work necessary for managing multiple activities.

External Representations

There has been considerable past work on the role of external representations in supporting behavior. Norman (1990) and Zhang (1990, 1992) demonstrate how external resources are used in problem solving tasks, not only as a memory aid, but also as mechanisms by which the nature of the task itself is changed. Norman and Zhang show that the specific way in which information is represented is a critical factor in how that information will be used in a task. In earlier work, I showed how the specific design of a graphical representation influences the cognitive tasks in which it is used (Gruen, 1992). Strub (1992) shows how people customize the external environment to support the cognitive work involved in their tasks.

Lewis (1990) cites the familiar findings that internal representations are often neither complete nor particularly detailed, implying that they are not sufficient for guiding behavior but depend on the ongoing availability of external information. Simon (1975) describes a "sophisticated perceptual" strategy by which certain classes of problems can be solved, in which the directly perceived state of a problem directly

cues the operations that must be performed. Larkin (1989) provides a formal model of how external information can continuously guide behavior, using the examples of making coffee with an electric coffee maker, solving algebraic linear equations, and solving the Tower of Hanoi puzzle. Among other advantages of display-based problem solving, Larkin suggests that it minimizes the cognitive effort required to solve problems, allowing for additional activities to be performed at the same time. Furthermore, she states that it is robust to interruptions. Larkin claims that display based problem solving allows the steps in a procedure to be performed in a variety of orders. This ability to modify the order in which steps are performed increases the flexibility with which interruptions can be handled and multiple activities performed.

Explicitness of Representations

We can ask about the extent to which information contained in the external environment is represented explicitly. Kirsh (1990) proposes the definition that a representation is explicit if it can be applied to the task domain in constant time.

The explicitness of a representation cannot be judged in a vacuum. Rather, it must be measured relative to the actor, the task, and the situation in which the representation is to be used. So, for example, an instruction written in French accompanied by a French-English dictionary could be considered an explicit instruction for one who speaks French, but not for one who does not. Explicitness of representation is a matter of degree, not an all-or-nothing affair. Using Kirsh's constant

time criterion, we can say that the more processing required to transform a representation to a form that can be applied to the task domain, the less explicit the representation is.

An example will illustrate some of the ways that task relevant information can be represented in external structures. This example is a rather antiseptic one, stripped of the social and cultural factors that influence the performance of even simple tasks like the one presented here. Yet the example is still beneficial in clarifying the different ways a piece of task relevant information can be represented. Imagine the task of having to install a software package from a set of 5 diskettes. To perform the task, the diskettes must be inserted into the computer in a fixed order. An agent performing the task must know that the task has to be done, the general procedure for performing the task (i.e. insert a diskette, wait for a while until it is ejected, then insert the next diskette if there are any or stop), how to do the necessary operations (e.g. how to physically insert a diskette into the drive), and the order in which the diskettes must be inserted.

This last piece of information – the ordering of the diskettes – can be represented in various ways. Assuming the diskettes can be differentiated in some way such as by color or a labeled designation, the diskettes might be listed in order explicitly on an external list. The diskettes might have numbers written on them corresponding to the order in which they should be used. Alternatively, a human expert could stand on the side and hold out each diskette when it is needed. Or

the diskettes might be stacked or placed in such a way that the physical arrangements of the diskettes corresponded to the order in which the diskettes should be used.

This last case can be further broken down. The diskettes might be stacked in a pile with the first diskette on top, the second below it, and so on down through the stack. The diskettes might be laid out across the desktop in order. We should note that the agent doing the task must know that the physical arrangement of the diskettes contains a representation of the order in which the diskettes should be used, and how to decode that representation. The agent must also know the rules by which the spatial arrangement of physical items is mapped to the ordering of operations with those items in the task.

Absent specific information, the person may rely on general assumptions and cultural norms to recognize situations in which a spatial arrangement encodes information, and how to extract that information. For example, the agent might assume that diskettes laid out in a line are to be used from left to right, or that diskettes stacked in a pile are to be used from top to bottom. Using diskettes from the top down has the added benefit that the physical operations the agent must undertake are reduced. The next diskette to use is always on top and accessible without moving the other diskettes. At each stage of the process, the arrangement directly affords grasping the correct diskette. The next diskette to use is also more visible than the others below it, which may also have benefits for the task at hand. Because of such

benefits, this arrangement is often a sensible one. This may heighten the agent's assumption that it is present in a specific case.

Other clues may help the agent determine the appropriate mappings. Imagine if the stack of diskettes were rubber-banded to hold the diskettes together and then placed on a desk. The agent might still assume that the ordering of the diskettes reliably preserves information on the order they should be used. But because a rubber-banded stack of diskettes can be tossed around as a single unit and left right-side-up or upside-down without destroying the internal ordering, the agent may be less sure of whether the diskettes should be used from top of the stack or from the bottom.

Affordances

One way that an agent's behavior is guided by the environment is through perception of the affordances the environment presents. The term affordance was coined by Gibson (1977,1979) to describe the fit between an animal's capabilities and the characteristics of the environment that provide functionality to the animal. Gibson proposes that recognizing the affordances presented by a situation is a major goal of perception.

Affordances can be thought of as bits of potential functionality that exist in the environment, specified by the interaction required between the actor and the environment and the outcome of that interaction. As such they can be seen as predictions of what will occur when the animal

interacts with the environment in a specific way. An affordance depends on objective features of the environment and the animal, and exists whether or not it is perceived or utilized. Perceiving an affordance requires that a given interaction is seen as being possible, and that the results of that interaction are understood.

Affordances play an important role in the ongoing interaction between an actor and the environment described by the situated cognition view. This interaction is shaped as characteristics of the environment suggest actions that the actor can take, and the actions the actor takes modify the environment. Both aspects of this relationship are contained within the concept of affordances. The environment influences behavior through the affordances it is seen to provide. And because the affordances that are available are described in terms of the results of functions the actor can perform, they specify the modifications to the environment that the actor can make.

Past research into the perception of affordances has tended to focus on rather low-level, physical affordances (e.g., the affordance of "climability") in which the parameters for the existence of a good fit between actor and environment can be measured and stated in terms of physical properties and relationships (Warren, 1984). Similarly, much of the effort by interface designers to make the affordances of designed tools visible has focused on rather low-level, direct aspects of the users' interaction with a tool. Efforts are made to ensure that selectable areas on a computer screen will look like they can be chosen, that editable

fields will look like they can be changed, and so on. The use of metaphor to depict certain tools in a way that indicates function by evoking a real world counterpart (e.g. tools which remove text or graphics are made to look like erasers, and those that remove files to look like trash cans) does not change the fact that the functions that are depicted are rather immediate and direct. It should also be noted that much of the past research into the perception of affordances, at least with adults, has involved verbal judgments by subjects of whether a given affordance exists in a specific situation. The affordance in question is generally supplied explicitly by the experimenter. Subjects are asked, for example, if a given staircase could be climbed, or if a given archway could be walked through (Warren, 1987). This is somewhat different than the more naturalistic situation in which many potential affordances exist but only some attract attention and influence behavior. While it is relevant to know, for example, that a subject will judge a given arrangement of blocks capable of affording climbing when explicitly asked, a more essential question for understanding how actions are triggered by the environment is whether, when presented with the arrangement of blocks, the affordance of climbing will be noticed in the first place.

A major aspect of affordances is the belief that they are directly perceived; they therefore require little additional cognitive effort to be interpreted before they can influence behavior. This suggests that especially at times of interruptions and multitasking when cognitive resources are heavily taxed, low level affordances can play a significant

role in influencing behavior. My research supported this notion, and showed how this can have both good and bad implications for the agent. On the positive side, the affordances of a properly structured environment can guide an agent along the proper course of action at times when cognitive resources are strained. On the negative side, subjects can be led by low level affordances to place items in locations which violate spatial schemes that have evolved or been established to carry task relevant information. Reliance on low level affordances rather than on the higher order meanings assigned to spatial locations and relationships can lead to a sloppiness in which information is lost or obscured. Such sloppiness is especially likely during interruptions and at other times when resources are strained.

Multiple Task Performance

A number of experimental studies have been conducted on how people perform multiple tasks. These studies have largely involved relatively simple experimental tasks such as spelling and simple arithmetic (Hirst and Kalmar, 1987), combining manual tracking tasks with tasks requiring verbal or keyed responses (Vidulich, 1988; Wickens and Liu, 1988), and dual-axis tracking tasks (Fracker and Wickens, 1989). In general, the design of these studies has been based on the view of human information processing as involving limited resources that must be divided among tasks that are performed concurrently. Broadbent's early theoretical view (1958) assumed a single processing channel, requiring that processing for secondary tasks be delayed until the channel

was free. Other views (Kahneman (1973), Norman and Bobrow (1975), Gopher (1986), many others) suggest that processing resources can be divided continuously among different tasks, and allocated to the tasks in varying amounts.

Norman and Bobrow (1975) discussed the relationship between task difficulty, resources, and performance in terms of the task's "performance-resource function" (PRF). As more resources are allocated to a task, performance on the task increases. Different tasks have different PRF's depending on the difficulty of task. This arises from the assumption that fewer resources are needed to reach maximum performance on an easy task than on a hard one. In studies in which subjects were asked to divide their effort in different proportions between two tasks, the general finding was that performance on the tasks traded off reciprocally. This supports the view of limited resources that can be shared between tasks in varying amounts, allowing for gradual transitions from activity to activity. This tradeoff can be depicted graphically as the "performance operating characteristic" of the two tasks, created by plotting the PRFs of the tasks against each other. (Norman and Bobrow, 1975). It leaves open the question of how people determine the best division of their resources, and the mechanisms by which they adjust the allocation of resources to each task.

Wickens (1991) discusses three factors that influence the performance of multiple tasks. These include *confusion* between elements of the different tasks, *cooperation* between processes that can

result when elements of the tasks can be integrated, and *competition* for the resources required for the individual tasks. He further suggests that the extent to which different tasks can be performed together depends in part on the codes they employ at different stages of processing, as shown in the matrix in Table 1.

Table 1. Different tasks characterized by the codes employed at each stage of processing. (From Wickens, 1991, p. 18)

	Stage of Processing	
Code	**Perceptual/Cognitive**	**Response**
Verbal	Print reading Voice understanding Rehearsal Mental arithmetic Logical reasoning	Speech
Spatial	Velocity flow fields Spatial relations Mental rotation Image transformations	Manual control Keyboard presses

Lintern and Wickens (1991) show that experts can achieve efficient timesharing between activities, not only because of their efficiency in performing individual tasks, but also because they develop skill at timesharing. Experts develop strategies for allocating their resources between the different tasks they face. It is not clear, however, to what extent experts develop a general timesharing skill that can be applied to other tasks and situations. The authors suggest that most timesharing skills are specific to a given task combination, developed through experience in a specific domain.

Schneider and Fisk (1984) demonstrate that performance on a practiced task can drop to near-novice levels when that task must be performed together with an additional task. This suggests that the way the initial task is performed may have to be altered to account for the devotion of resources to the new task. Detweiller and Schneider (1991) propose several strategies to compensate for the need to perform tasks together. These include:

1. Shedding, delaying, and pre-loading tasks;
2. Dropping sub-optimal, high-workload strategies;
3. Utilizing non-competing structures and processes;
4. Employing chunks or more compact codes for task-relevant information.

The Structure of Activities

Cypher (1986) conducted a study into the way certain computer based activities are interleaved, using programs modified to record a history of the keystrokes and commands entered by a user. The programs also gave users the ability to annotate the record with comments describing their current activities.

Cypher discovered numerous cases of interleaved activities, though he does not report statistics on their frequency or duration. He characterizes the activities that are interleaved as being either unrelated, as in the case of scanning email messages while conducting a separate

conversation, or related, as in the case of checking a calendar program to find a date to include in the text of an email message. The most common source of related activities, Cypher suggests, are subactivities performed to help carry out the higher level activity. Related activities are those in which specifics of one activity may have bearing on the execution of the other.

Cypher also introduces the concept of "While-I'm-At-It" activities. Such activities occur when, during the execution of one activity, you notice something that causes you to switch to another activity. He gives the example of looking at a listing of files and happening to notice an outdated one, leading to the beginning of a "delete file" activity. Similarly, one can imagine searching for a letter in a pile of mail and happening upon an overdue bill, triggering a new "pay bill" activity. Cypher presents several examples of interruptions and activity switching, and discusses the difference between externally and internally generated interruptions. He suggests that externally generated interruptions may be especially disruptive because they can occur at times that are not natural transition points for the user.

Cypher discusses ways in which mismatches can occur between computer programs and human activities, and ways that computer programs could better support multiple activities. These primarily involve mechanisms aimed at preserving the context and state of the current programs when the user switches to perform a different activity, and mechanisms to help the user restore context and orientation when

the suspended activity is resumed. He also describes a process which he describes in terms of the classical Artificial Intelligence notion of *linearization,* in which several activities that compete for the same resources are arranged to be handled sequentially.

The picture Cypher paints is one in which an agent works on one activity at a time. Switches between activities occur, but periods of multitasking in which an agent performs more than one activity at a given time are rare. This view may have been encouraged by the methodology he used, which relied on capturing actions the agent was performing on their computer terminals. The computer terminals served as a single resource bottleneck on which only one activity could be performed at a time; other activities performed simultaneously using other resources were not tracked. In contrast, my research found many examples in which people were effectively working on more than one activity at a time. Subjects frequently engaged in verbal conversations regarding one matter while performing unrelated work using their computers. Furthermore, while Cypher describes complete shifts from activity to activity, my research showed evidence of gradual transitions between activities in which the amount of resources devoted to each activity changed over time.

Miyata and Norman (1986) present an analysis of the psychological issues involved in supporting multiple activities. They include a discussion of the differences between long- and short-term memory, conscious and subconscious control systems, and task-driven versus

interrupt-driven processing. The different types of control and processing systems are related by the authors to differences between the demands of current, backgrounded and suspended activities. Miyata and Norman also discuss issues of planning, interruptions, and the role of reminders as both *signals* that something is to be remembered, and *descriptions* to aid in the retrieval of what was to be remembered.

The authors state that systems designed for multiple activities should support the suspension of activities in several ways:

1. Suspending an activity should be easy and require little additional activity, to insure that the process of suspending the activity does not interfere with the working memory demands of the current activity or the internal processing related to the interrupting task;

2. When a task is suspended, sufficient information should be preserved by the system to enable the user to resume the task where it was left off;

3. The system should remind the user of the existence of the suspended task.

While Miyata and Norman's comments were geared to the design of computer-based systems, my research showed the influence of these ideas in the way people made use of their real physical environments in the management of multiple tasks. In the chapters that follow, I will show how the routines employed by subjects and the physical artifacts in

their environment have evolved together to form distributed cognitive systems which support the suspension of activities in the ways Miyata and Norman propose. This can be seen most clearly in the ways subjects prepare their environments for anticipated interruptions. I will provide evidence of preparation both for specific known interruptions, such as a break for lunch or for an absence of several days, and to support a general environment in which interruptions are anticipated but the timing and specifics of the interruptions are largely unpredictable.

Past Research on Interruptions

There has been a sizable amount of research into the way interruptions affect performance on different tasks, though this has largely been done in artificial experimental settings. A standard paradigm used in experiments on memory is to have subjects wait a period of time between their initial exposure to a set of stimuli and subsequent testing for retrieval and recall. Subjects are given a distracter task in which to engage during this period, to insure that they do not rehearse the stimuli to be remembered. These distracter tasks can be seen as interruptions to the optimal remembering activity in which the agent would otherwise engage.

An early finding, known as the Zeigarnik effect (Zeigarnik, 1927; cited in Schiffman and Greist-Bousquet, 1992), is that tasks that are not completed are recalled better than tasks that have been completed. More recent research suggests that tasks which are interrupted are perceived to be of longer duration than tasks which are allowed to progress to

completion (Schiffman and Greist-Bousquet, 1992). Such findings have been used to support the Gestalt notion of "closure" which posits a goal-oriented need to complete a task once begun. Unfinished tasks do not offer this closure, and are therefore maintained in memory in a way that prompts continued cognitive effort.

A study by Gillie and Broadbent (1989) investigated the factors that make some interruptions more disruptive than others. In a series of four experiments, subjects were given the task of collecting a set of items by moving through locations in a computer adventure game. The locations in the task corresponded to the different items; for example, a subject could expect to find "stamps" at the location marked "post office." At the start of each trial, subjects were given a list of three or five items to collect. Subjects could ask to be reminded of the items on the list, and could also request an inventory of the items they had collected so far.

In each experiment, selected trials were interrupted midway by an additional task, after which the subjects resumed the item collection task. The researchers experimented with a variety of interrupting tasks, including having subjects perform two digit addition or subtraction problems, performing a free recall task with verbal rehearsal, and performing a mental arithmetic task on numbers whose digits had been encoded into letters by a simple scheme. The researchers also varied the length of the interruptions, though in a limited way. In one of the experiments (the free recall task) subjects had to begin working on the

interruptions immediately, while in the others subjects could pause to begin work on the interruption when they were ready.

The conclusions of the study the researchers report are that:

1. Memory load at the time of an interruption is not a crucial factor in determining whether or not an interruption will be disruptive;

2. The temporal length of an interruption does not determine how disruptive it will be; rather

3. Interruptions that are similar to the main task, and which demand immediate attention, can be particularly disruptive; and

4. The complexity of an interruption, in terms of the memory and processing resources required, is a factor in determining how disruptive it will be.

Several serious limitations affect the applicability of findings from this study to situations encountered in everyday life. Firstly, the study investigated the effect of interruptions on memory for specific details within a task, but not on remembering what the interrupted task was in the first place. Yet in many real world situations, remembering what was being worked on before the interruption is a significant issue. It can be assumed that the entire experimental setting reinforced subjects' memory for the fact that they had been working on the item collection task. Given the nature of most traditional experiments, one can even

imagine that had the subject neglected to resume work on the primary task, the experimenter would have prompted them.[1]

Secondly, the experiments investigated the effect of interruptions on a task involving a specific type of memory, involving recall for a relatively short list of items. The underlying task did not involve the potentially sub-symbolic structures that may play a role in more complex problem solving. It also did not involve extensive use of external artifacts and representations, and therefore the need to recognize their significance and remember their placement.

Finally, where no effect of an interruption on the task was seen, it is possible that either the task or interruption were of insufficient complexity or length to show disruptions. So the finding that the length of interruption does not determine how disruptive it will be may not hold true with different types of tasks or for interruptions of longer duration than those tested here.

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[1]Note that this problem is similar to one Leontyev presents in his discussion of the role of goals in activities, and the failure of many experiments to sufficiently address the issue of how goals are formulated. "Under laboratory conditions or in pedagogical experiments we always place before the subject a, so to speak, "ready" goal; for this reason the process of goal formation itself usually escapes investigation." (Leontyev, 1978, p.64)

The result that interruptions that demand immediate attention are especially disruptive suggests the existence of coping strategies that people could have used, if given time, to handle interruptions. The researchers point out that such strategies do not invariably insure that the interruptions will not be disruptive. Allowing subjects to pause as long as they wanted before working on an interruption, presumably using the intervening time to review the list of items, did not prevent the complex task from having disruptive effects. But the finding that coping strategies do not work in every case does not negate the fact that they may work in others. Assuming that coping strategies were in fact employed by the subjects, it is quite possible that they were the wrong strategies, and that given time, subjects would come to develop better ones.

O'Conaill and Frohlich (1995) conducted an observational study on the nature of interruptions in the workspace. In their study, two subjects were followed and videotaped for a full working week. Both subjects were described by the researchers as "mobile professionals for whom communication formed a central part of their job."(p.262) 125 naturally occurring interruptions were identified in the 29 hours of video data the researchers studied in depth. The criteria used by the researchers to define an interruption were that it be: 1. a synchronous interaction not initiated by the subjects; 2. unscheduled; and 3. result in the subject discontinuing their prior activity, at least for the duration of the interruption. Interruptions were analyzed in terms of frequency of

occurrence, benefit accrued to one of the parties, and broad effect of the interruption on the course of the activity that had been in progress.

The researchers found that the subjects were interrupted, on average, about 4 times an hour, with the average length of interruption being 2 minutes 11 seconds. 43.2% of the interruptions were deemed as having a result beneficial to both the initiator and recipient of the interruption, while 32.8% were deemed to be beneficial to only the initiator. Interestingly, 20.8% of the interruptions were found to be beneficial to the recipient, but not the initiator, of the interruption. It should be noted that benefit was determined in terms of the content of the conversations, and did not reflect the possibly detrimental effects the interruptions had on ongoing activity.

In 55.2% of the cases, subjects resumed their original activities after the interruptions. In 15.2% of the cases they proceeded to work on the interrupting activity, while in 10.4% of the cases they proceeded to work on a task other than the original or interrupting one. Unfortunately, the researchers did not explore the factors that led to the subjects resuming the interrupted task in some cases while ignoring it for a different task in others.

In 14.4% of the cases studied, the subjects were interrupted again while in the course of handling an earlier interruption. Such nested interruptions are not uncommon, and will tend to increase as the

number of interruptions and the length of each interruption increases. (Dan Russell, informal presentation, Apple Computer, 5/3/95.)

In this limited study, only two attempts by the subjects to avoid interruptions were observed. One involved requesting that a secretary hold incoming calls, the other involved an attempt, delivered jokingly, to limit the length of the interruption. Aside from these two cases, the researchers do not report in any detail on the different strategies subjects may have employed to handle interruptions.

The researchers suggest the value of mechanisms to filter interruptions, and point out that in many organizations receptionists or secretaries perform such functions. Because many interruptions are very brief, it is important that the filtering mechanisms demand minimal additional effort lest they become as intrusive as the interruptions they are meant to control. Although the researchers present no specific data in this paper to suggest that forgetting the interrupted task is a major reason interrupted tasks are not resumed, the researchers also suggest the value of using video diary technology to refresh the context of the interrupted task. Similarly, such technology could be used to remind people of the topic of the interruption in cases in which work on the interruption was deferred.

Reminders

Much of the structure that guides human behavior is naturally occurring or incidental; people learn to opportunistically exploit the

structures they encounter as they go through their activities. Often, however, people add structure to the environment specifically with the goal of guiding their later behavior. A reminder is a piece of structure that one places in the environment with the hope of prompting a change in the person's behavior when the reminder is encountered at a later point in time. Such reminders can be thought of as bridging the gap between two points in space time: the point at which the reminder is first created and the later point at which it should trigger a specific activity. Harris (1978, 1980) has suggested several of the factors that make an effective reminder. According to Harris, a reminder must catch the attention of the person to be reminded at an appropriate time, and be meaningful so the person understands what was to be remembered. These requirements parallel Miyata and Norman's view of the dual purpose of reminders as both signals and descriptions (Miyata and Norman, 1986). The timing of a reminder is a critical factor. If the reminder comes too late it is obviously ineffective. If it comes too early, the information conveyed by the reminder must be stored in memory until it is time to act on the reminder, and the information is then susceptible to many of the problems the reminder was meant to avoid.

The design of a reminder is influenced by several factors. The tools required to leave the reminder must be physically available at the first point in time and space when the reminder is being left, and the reminder (or its physical effects) must be present at the later point in time and space when it is to "remind" the person of something. Because

an effective reminder must catch the person's attention at the required time in a way that significantly conveys that which is to be remembered, the design of the reminder is influenced by a prediction at the first point in time and space as to what will be attention grabbing and significant at the later point. The kinds of reminders people leave for themselves therefore provide insights on what they believe now to be their mental situation and state at some later point in time. Similarly, notices left for others reflect beliefs of what will be meaningful and attention grabbing to the people for whom the notices are left.

The creation of a reminder reflects the belief that a reminder will be necessary, and thus can provide insights into people's beliefs about their own memory processes. These beliefs are often based on past experience. People learn over time the items they are likely to remember unaided, and develop strategies for remembering items they would otherwise forget. But reminders do not always imply a conscious realization that a necessary item might be forgotten. Leaving a reminder may become a habitual part of a procedure that is applied automatically in certain situations without conscious recall of the factors that contributed to the evolution of the procedure.

In my research, I looked for examples in which subjects added structure to their environment to remind them of things they had to do. Past studies on the creation and use of reminders have largely been based on retrospective interview studies (Harris, 1978; Harris, 1980; various studies cited in Cohen, 1989) or artificial exercises in which subjects were

asked to suggest the methods by which they would remember information in different situations (Intons-Peterson & Fournier, 1986; Cohen, 1989). While such studies undoubtedly provide important insights on the use of external memory aid, they can only uncover instances of explicit reminders that subjects were conscious of and could recall. It is therefore possible that these past studies do not capture entire classes of reminders, and incorrectly report the frequency of use of others.

Reminders may not require conscious recall to be effective aids in guiding behavior. Lewis's (1990) theory of attunements and direct perception can be combined with Chapman's notion of cognitive cliché's as "patterns commonly found in representations which can be exploited when recognized." (Chapman, 1986). This can yield a sort of "cognitive affordance" representing a structure in the environment which offers itself to specific kinds of mental manipulation, even absent the retrieval of specific task-relevant information. Along with the more traditional physical affordances, cognitive affordances undoubtedly play a role in guiding everyday behavior (Gaver, 1988).

The Role of Paper Documents

Harper and Sellen (1995a, 1995b) have studied the role of paper documents in a variety of activities and specifically with regard to collaborative work. One aspect of paper documents they point out is the ease with which interacting with them can be interwoven with other activities. Because marking paper documents is easy and direct compared to creating annotations using some of the computerized

systems they observed, such marking can often be done while someone is engaged in other activities. The authors point out that this "ability to do concurrent activities is especially important at times of high workload." (Harper & Sellen, 1995a, p.5) Paper is also light, transportable, and easily positionable, allowing its flexible use in the creation of spatial arrangements.

Lansdale (1991) conducted a series of experiments on the extent to which people remembered characteristics of the documents they encountered, specifically their appearance, format and location. Although he found no significant evidence for the automatic encoding of the appearance or location of documents, he did find that the extent to which the location and appearance of documents were remembered depended on the extent to which attention was paid to those characteristics when the documents were initially handled. Recall of appearance and location was lowest in the experiments in which such characteristics were arbitrary and incidental to the tasks in which the subjects were engaged. Lansdale points out that in most real office settings, meaningful spatial systems are employed. Recall of the location of a document is therefore based on a consideration of the nature of the document with regard to the preexisting spatial system, not simply on retrieving an arbitrary association between document and location. These findings were supported by the studies I conducted. They also help to explain the observation that items whose placement was influenced by low level physical affordances more than by the meanings

associated with different locations in the office were especially susceptible to being lost or forgotten. As suggested above, this can occur during interruptions and at other times when resources are taxed.

It is important to note that the majority of Lansdale's experiments involved recall of the location and physical features of a document, not recognition of the document after it has been encountered. So while the results may influence a persons ability to find a document, they do not address the use of the document as an effective reminder if placed in a location where it will be noticed.

The Use of Space to Support of Multiple Activities

Early in my observations, it became clear that the placement and arrangement of the physical items involved in the subjects' work played a significant role in their behavior. Space was used to track the existence and state of activities, represent the priorities of different tasks, categorize items, mark items that required certain treatment, represent temporal relationships between activities, and remind subjects of tasks they had to perform or of outstanding issues that required monitoring.

Kirsh (1995) has commented extensively on the intelligent use of space to enhance performance in a wide variety of domains. He maintains that the way people manage the space around them "is an integral part of the way we think, plan and behave." (Kirsh, 1995, p.1)

Kirsh illustrates how space can be used to encode the temporal order of actions and encode the desired placement of items. Spatial

arrangements can also simplify perception, such as by clustering items to reflect relevant categorizations or by using the placement of an object to mark it as distinctive in some way. Spatial arrangements can also reduce the need for internal computation by using the manipulation of items in the physical world to create task relevant representations that would be more difficult to create internally.

Kirsh suggests that experts "jig" their environments, structuring and preparing them to reduce the perceived degrees of freedom and thereby making the optimal course of action more salient and noticeable. Jigging involves structuring the environment to constrain the set of possible choices and to cue the user to the desired actions.

Kirsh and Maglio (1994) have discussed the distinction between pragmatic actions which bring an agent closer to a physical goal, and epistemic actions whose role is to improve the ease, speed, or reliability of mental computation. Their work arose from the observation that agents sometimes engage in actions that seem unnecessary or which appear to move them further from a physical goal. Epistemic actions are performed to make explicit information that would otherwise be hidden or difficult to compute. Many of the actions subjects performed with the documents and other items in their offices had a similar quality; they were not necessary for the physical accomplishment of the tasks at hand, but had value in their ability to remind, inform, or represent information that was needed by the subjects.

In an often cited study, Malone (1983) conducted interviews with ten people to understand how they organized information in their desks and offices. The stated goal of Malone's study was to draw implications for the design of computer systems. Malone claims that a principal function of desk organizations is to remind the user of things to do, and not simply to aid in the finding of specific items and information.

Malone differentiates between *files*, in which the individual elements are explicitly titled and systematically arranged, and *piles*, in which the ordering of elements is less systematic and the individual elements are often not titled. Although he points out that the dynamics of pile creation often lead to an inverse chronological ordering of the elements in a pile, this ordering is usually not intentional or systematic. While files often have explicit names, piles generally do not. A pile's spatial location is therefore particularly important in locating the pile. Malone points out that while the organization of items on peoples desks often involves unnamed piles, most computer systems required that the user provide names for new documents and collections of items.

Malone suggests that one reason for the extensive use of piles is the cognitive difficulty of classifying information. Other reasons for the prevalence of piles include the mechanical difficulty of creating labeled collections, the desire to have frequently accessed information readily at hand, and the way people use the items around them as reminders of things to be done.

Kidd (1994) studied twelve "knowledge workers" whose primary function was to use their expertise to understand a body of knowledge and generate new information based on that understanding. Kidd noticed that knowledge workers rarely consulted information filed in their offices and rarely carried externally represented information with them when they traveled. Kidd suggests that knowledge workers are changed in the course of processing information. The primary purpose of consulting external sources of information is the process of being informed and the resulting changes to the knowledge workers' internal mental structures. Until they have processed an item of information, they cannot categorize and file it because they have not yet determined the role the information will have in their activities. And once they have been informed by an external source of information (e.g. a printed document), they no longer have a need to retain a physical copy of the information source.

A major finding of Kidd's study was the importance of spatial layouts for the workers she studied. Although many of the workers she studied had cluttered desks and floors, changes to the placement of items in this clutter was seriously disruptive to their ongoing work. Kidd suggests that knowledge workers use the spatial layout of materials:

1. as a holding pattern for inputs and ideas they cannot yet fully categorize;

2. as a primitive language allowing flexible and generative structures with which to construct and explore models of the world;

3. to provide contextual cues reminding them of complex threads of ideas they are in the process of creating; and

4. as a visible, tangible record of their progress on different projects.

Kidd distinguishes knowledge workers from two other categories of office workers. These are communication workers who collect, distill and distribute information to change the understanding of other people in their organization, and clerical workers who apply extrinsic information such as procedures and policies to maintain the smooth and efficient operation of their organization. Kidd acknowledges that no worker's work fits totally in one category, but maintains that categorizing the worker rather than their activities can be helpful in understanding the different ways people handle similar situations. In contrast, I found it helpful to understand the purpose and use of individual items of information the subjects in my study encountered in an effort to understand why the same subject dealt differently with similar informational items. On a large scale it was possible to characterize the subjects in terms of the extent to which their work belonged to each of Kidd's categories, and this could explain gross level aspects of their office's organization. Understanding the specific actions I observed, however, required an understanding of the significance of each informational item in terms of the subjects' individual activities.

Rouncefield, Hughes, Rodden and Viller (1994) studied cooperative work in a setting that included frequent interruptions. Among their other observations, the researchers found that the spatial organization of the paperwork in the office constituted a working map which enabled much of the work to get done. This enabled experts who understood the work and the setting to see "at a glance" where in the course of their work activities someone was. It also made returning to an activity after an interruption easier. The physical state of documents and piles often made it "obvious" where the work had been left off and how it should be resumed.

The common use of spatial relationships to represent task relevant information can be understood in view of theories on the importance of spatial reasoning to cognition in general. Lakoff and Johnson (1980) suggest the centrality of spatial metaphors to much of cognition, with space commonly used to express concepts like time. Langacker's Cognitive Grammar (Langacker, 1987) finds roots in spatial schemas for many linguistic terms. Mandler (1992) posits a central role of spatial reasoning in early development, and suggests that spatial reasoning influences the formation of concepts. The spatial arrangement of physical items can be used to represent categorizations, dependencies, and other logical relationships between the concepts the items can come to represent. Using the spatial arrangement of meaningful items can therefore serve as an efficient means of representing and recovering the state of activities, especially at times of multitasking, during

interruptions, and when linguistic facilities are otherwise occupied. It also allows the application of pre-linguistic reasoning mechanisms that may underlie much of cognition.

Stabilization Routines

Hammond, Converse and Grass (1995) have suggested that artificial agents should be designed with the capability of adapting their environments to suit themselves. They contrast this approach with what they see as the two prevalent approaches in artificial intelligence research for assuring a match between an agent and the environment: designing an agent to suit a specific environment or designing an agent with the tools necessary for it to adapt itself to suit an environment in which it is placed.

The authors call the act of modifying the environment to suit the agent *stabilization*, and suggest that humans engage in such behavior in their everyday life. They give the example of a person in a kitchen with a fixed number of drinking glasses in a particular cabinet. From time to time, the person takes a glass from the cabinet, drinks from it, and then puts the glass in the sink to be washed. The continued success of this process requires that a supply of clean glasses be maintained in the cabinet, so every once in a while the person washes the glasses in the sink, dries them, and returns them to their place. The glass washing is a stabilization to the environment in that it maintains the resources in the environment in such a way that they will be accessible and ready for use when required for some later activity.

The authors suggest that "the question of how the glass-washing behavior is organized and cued is by far the most interesting one here, and, in the case of a human being, is a question for psychologists and anthropologists..." (p.310) They suggest several mechanisms by which a supply of clean glasses could be maintained by a person or an automated agent designed for that task. The person could wash each glass immediately after it is used, or wait until a certain number of dirty glasses accumulated in the sink. The person could wash all the glasses at a fixed time or interval. The sink could be scanned from time to time, and the glasses washed whenever a dirty glass was noticed. Or the glass washing could be triggered by the failure that occurs when the person goes to get a drink and finds that no clean glasses remain.

The authors suggest several types of stability that stabilization activities maintain. These include:

1. *Stability of location,* insuring that desired resources are available in their expected locations;

2. *Stability of schedule,* insuring that expected events occur at their expected times and allowing for coordination with other events and activities;

3. *Stability of resource availability,* insuring that a supply of required resources is maintained;

4. *Stability of satisfaction*, insuring that goals which can be optimally satisfied by activities performed together are properly clustered;

5. *Stability of plan use*, insuring that familiar plans can be used without the need for modification, thus eliminating the need for additional planning effort; and

6. *Stability of cues*, insuring that the cues and reminders on which an agent depends to cue its behavior are maintained in such a way that they will be noticed and meaningful at the appropriate times.

The authors suggest that clean-up plans play an important role in the stabilization of environments. Clean-up plans exist separately from other activities, and exist to restore the environment to a stable environment after violations caused during the performance of other activities. Because clean-up plans are generally disassociated from the plans that make them necessary, they must be triggered in other ways. For this reason, clean-up plans are often incorporated into regularly occurring routines. So, for example, a person might perform a set of standard actions to restore their office to a stable state before leaving for home each night.

Stabilization routines are important to the management of multiple activities in two ways. Firstly, stabilization routines minimize the effort required for individual activities, freeing resources for use in others. Secondly, stabilization routines can minimize the effort required to start an activity or to save the state of an activity when it is suspended, thereby

reducing the cost of switching from activity to activity. I looked for examples of actions the subjects undertook to maintain the stability of their environments in the ways Hammond, Converse and Grass suggest. I also tried to understand the factors that triggered these stabilization routines.

This chapter introduced the theoretical issues that arise in a study of the way people manage their multiple real world activities, and reviewed past research that sheds light on the subject. In the chapters ahead I will describe the studies I conducted, present their major results, and discuss my theoretical conclusions from them.

Chapter 3

The First Study: Three Weeks, Three Settings

In this chapter, I describe my initial study into the way multiple activities are managed in everyday life. This study was of value in helping me identify factors that influence the interleaving of multiple tasks. It also raised questions for future investigation. The study made use of videotapes created by researchers at the Apple Computer Corporation during an earlier study they had conducted for other purposes. In the original Apple study, three subjects were videotaped using their computers in their workplaces during a one week period. I describe the original study, the videotapes that resulted, and the factors that led me to use the tapes as a source of data. I discuss the analysis I conducted of these tapes and outline my findings. Finally, I discuss problems with the tapes that limited the extent to which I could draw theoretical conclusions from them, and which influenced the design of the study I conducted myself.

The Original Study

In mid-1994, the Apple Computer Corporation (henceforth to be referred to as Apple Computer, or simply Apple) conducted a study to understand how people would learn and use its latest release of operating system software, System 7.5. The study was conducted by David Schroit, a senior human interface designer at Apple's Human Interface Design Center, and Mimi Ito, a PhD Candidate from Stanford University working as a summer intern with Schroit.

Subjects

Apple recruited three subjects who were willing to be videotaped for a week as they worked with their computers. An attempt was made to recruit subjects representing a range of computer experience, usage styles, and settings. Two of the subjects were recruited by San Jose Focus, a commercial market-research firm; the third worked for a company which had done work in the past for Apple and was recruited directly through personal contacts. To be included, subjects had to have two to five years of experience using Macintosh computers, spend between ten and twenty hours a week using the computer, and not yet be using the new system software. Subjects had to use a word processing, spreadsheet, graphics, or database program on a regular basis.

The two subjects who were recruited by the market-research firm were paid $500 for their participation in the study. The subject recruited

directly by Apple was given System 7.5 upgrade software for each of the eleven computers in the office in which she worked. Subjects signed consent forms indicating their willingness to be videotaped and agreeing to have those tapes reviewed by researchers performing work with or for Apple.

The three subjects, described here based on their initial interviews with the Apple researchers, were:

1. A primary school teacher, working in her home office. This subject used her computer for work related activities, including the preparation of lesson plans, grading sheets, and class records. She also used her computer for personal activities, such as writing a letters to family members. She used a small number of programs on a regular basis, primarily Inspiration, a program for organizing and presenting ideas, and Microsoft Word, a popular word processing program. The subject taught third grade in a local public school, and had several computers in her classroom. In the initial interview she reported having used Macintosh computers for approximately three years and other computers (Apple IIs) before that. She stated that she was not "into knowing a lot about the insides of the computer" but was more interested in using computers "as a tool to accomplish things." (JM Interview Transcript, p. 2) At the time the Apple study was conducted, this subject was preparing notes and handouts for a teachers' conference on problem based learning.

2. A graphic artist, in a medium-sized graphic arts firm. This subject had worked as a graphic artist for approximately 8 years, and had used computers throughout that time. She has a background in graphics art and design, and has done both production and illustration work. Her position at the time of the study involved art direction and design. She used illustration, design, page layout, and photo-manipulation software programs on a daily basis, and is quite experienced in their use. Owing to the demands of the graphics work she does, this subject's computer was more powerful than those belonging to the other subjects; it had a faster processor, significantly more memory, and more capacious storage devices. At the time of the study, this subject had worked in her present company for about one year. Her work during the period under observation involved the preparation or modification of advertisements, brochures, and other documents for client companies.

3. A construction and real estate contractor working from a home office. This subject had used a Macintosh computer for approximately three years, and had owned an Apple II and IBM PC before that. He used the computer primarily for financial and word processing work, with such software packages as Microsoft Excel (a spreadsheet program) and Quicken (a personal financial accounting program). He also dialed in to computer networks on a regular basis for entertainment and personal communication,

and occasionally to access real estate data related to his work. His wife also used the computer on a regular basis, often for work she brings home from her job working for the local school district's administrative offices.

In addition to the main subjects, each of the sites under observation involved other people who interacted with the primary subjects or shared their computers. The first subject's computer was used by her husband and by a neighbor who came by to experiment with the new system software and play games. The second subject worked in an open cubicle, in an area shared by other artists and designers. Coworkers frequently stopped by, and their conversations can often be heard in the background on the videotape. And, as mentioned above, the third subject's computer was used extensively by his wife. These secondary subjects were informed of the study, and gave their consent to be videotaped.

Procedure

An interview was conducted at the start of the study during which subjects were asked about their experience using computers, what they used computers for, what specific software packages and programs they used, and how they learned to use new programs and to accomplish novel tasks with their computers. Subjects were then given a copy of System 7.5 and asked to install it sometime during the first day of the taping. Subjects were told that the software included several new

features and capabilities, and that they should feel free to explore it as they wished during the week. Other than those general instructions, subjects were told to do the work they normally would do and to use their computers as they normally would throughout the week. The researchers phoned the subjects periodically during the study to informally inquire about how things were going and to resolve any problems that had arisen.

On the first day of the study, the researchers installed video equipment in the areas in which the computers would be used. This included a video camera placed behind and above the subjects to capture the setting, a videotape recording deck, and additional equipment to capture onto videotape the contents of the subjects' computer monitors. In two of the settings a video signal splitter was used to feed the monitor image directly to the recording equipment. The larger computer monitor used by the graphic artist prevented the use of a direct feed, so a second video camera pointed at the computer screen was placed at her site.

Subjects were instructed in the use of the video equipment, and were responsible for starting the taping at the beginning of each session. Subjects were told to leave the tape running continuously throughout the day even during extended absences from the room. The tapes were standard VHS-120 tapes, set to record at the slow SL speed. While reducing the quality of the tapes, this allowed for six hours of interrupted taping on a single videotape cassette.

The final videotapes resulting from the study contained a view of the computer monitor filling most of the screen, with a smaller image of the general setting visible in one of the lower corners of the frame. Figure 1 shows an image from one of these tapes.

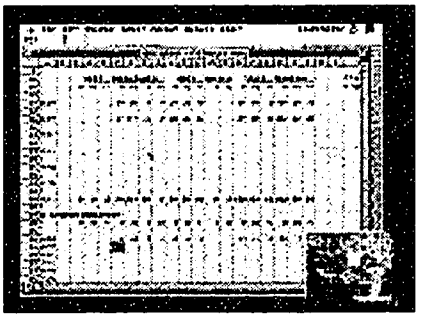


Figure 1. A sample image from one of the videotapes shot during the initial Apple study. The computer screen fills most of the frame, while a view of the workspace shot from behind the subject can be seen in the bottom right corner. (Apple Computer System 7.5 Study, tape 3.2)

Original Analysis

The original analysis of the tapes by the Apple researchers focused on identifying episodes in the tapes in which elements of the new system software were used. The tapes were viewed and transcribed in broad terms, with a sentence or two describing the actions the subjects were doing with their computers. Subjects' dialog was not transcribed in any detail, nor were details of non-computer activities. Similarly, details about interruptions that occurred were not transcribed except for occasional notations identifying segments of the tape in which, due to an interruption, the subject did not use the computer. The CVideo computer transcription tool was used, enabling the researchers to

automatically synchronize the printed transcript with the corresponding segment of videotape. This process yielded approximately 10 pages of transcription for each tape. A sample of the transcripts that were produced is presented in Table 2.

Episodes in which the subjects used features of the new operating system in ways that were of interest to the researchers were identified. A follow-up session was held with the subjects in which these sections were reviewed and discussed. These discussions focused on the subjects' models of the computer system and the software they used, and on their interpretation of specific interface elements. Subjects were asked to describe what they were trying to accomplish in selected portions of the tapes.

Table 2. A sample of the original transcript made by Apple.

5:23:08 returns works on Quark file 5:28:49 launches e-world - Welcome e-World window displayed 5:44:45 C leaves area and tape stops shortly after that

The researchers created extract tapes showing examples of problems and successes subjects had with the system software, and conducted a series of meetings and presentations with relevant software designers and engineers. The study was viewed as a success by Apple, responsible for insights into how interface features were understood and used. It was

also seen as valuable in demonstrating the benefits of observational studies of users in their natural settings, and in prompting discussions between different teams of researchers and system designers.

The Apple Tapes as a Source of Data on Real-World Activities

At first glance, the tapes from the System 7.5 study appeared to be a rich source of data for my inquiry into how people perform activities over time. Essentially, the tapes offered an opportunity to observe a week in the life of three different work settings. The tapes were an already existing source of data available immediately to me for analysis. After verifying that the terms of the consent forms signed by the subjects allowed for the tapes to be given to me, I obtained the original tapes and copies of the transcripts prepared by the Apple researchers

Procedure

Because of the vast amount of videotaped data, I sampled the tapes to locate episodes of interest to me. Yet I had to ensure that I did not simply select instances that would support my developing theories while ignoring examples that would tend to contradict them.

Throughout my work with the tapes, I was interested in segments that involved:

- *interruptions*, in which an operation, task or activity engaged in by the subject was interrupted by some external event;

- *multitasking,* in which a subject engaged in two or more activities at the same time;
- *interleaving,* in which subjects switched between two or more activities before completing them; and
- examples in which the resources required for an activity accumulated over time before the main activity was triggered or begun. I was interested in understanding how the resources necessary for an activity were stored and organized in preparation for the activity.

I began my analysis of the Apple tapes by viewing the first tape from each site in its entirety to familiarize myself with the subjects and the kinds of activities they performed. I did not take detailed notes at this point. I noted sections of the tapes that I wished to return to later for more detailed analysis. These were transcribed later in detail.

I then selected one tape from each of the sites, using the Apple transcripts as a guide, and transcribed that tape in detail.

I also used the Apple transcript to help me identify segments of the other videotapes on which to focus. Often, segments of the videotape that were of least interest to the Apple researchers were of greatest interest to me. These segments were described only rudimentarily in the Apple transcripts. For example, the transcripts would indicate that the subject was engaged in a phone call or was talking with someone who had stopped by their desk, but would contain few details on the topic of the conversations or the specifics of how the subject handled the

interruption. Descriptions of interruptions and other non-computer activities were given primarily to explain why fewer computer activities were done. I transcribed such episodes in detail.

In several instances, I scanned other tapes from a site to locate places in which an activity of interest was being performed. During this scanning, I viewed the tapes at two-times or eight-times normal speed, slowing to normal speed periodically to trace what was going on. These enabled me to more quickly locate interruptions and places in which it appeared that a transition from one activity to another was taking place. I slowed the tape to view such episodes of interest in detail, and transcribed portions of these in depth.

The transcripts I produced from the videotapes were formatted in three columns. The first column contained the tape's counter number at the start of the segment. The second column contained my descriptions of actions I observed, as well as transcriptions of dialog spoken by the participants. I attempted to make these transcriptions as objective and theory-free as possible, describing the actions of the subjects but not the overall significance I attributed to them. The third column contained my own remarks. I used this column to note theoretical issues, connections between segments, and questions I wished to answer through other portions of the tapes. The following extract represents a portion of the episode covered in Table 2, and shows the format of the transcripts I made.

5:28:25	C resizes QuarkXPress window to make it smaller, then opens several folders on the computer desktop, then double clicks on eWorld application.	Minimizing distraction from one activity (page layout task with Quark XPress) on the activity she is about to start.
5:30:22	eWorld application starts dialup procedure, message "call cannot be completed as dialed" is heard over modem speaker. C changes an option, moves arrow to "connect" button and clicks on it, gets same audible message. C displays options screen again, moves arrow to "connect" button, pauses, then moves cursor from the button and closes the window. C slowly moves cursor over the other icons in the eWorld folder and opens one which displays a file entitled READ ME FIRST. She starts scrolling through the file.	INTERNAL INTERRUPTION as C is using eWorld due to problem. Dealing with interruption (eWorld problem preventing dialing in) Initially considers trying connect again, but then decides to investigate other options instead. She seems to be looking at the icons as she moves the cursor over them, determining other actions she can take. (Mouse pointer appears to indicate her focus of attention.)
5:32:40	G comes by C's office, brings some papers which she presents to C saying "job numbers!", makes comments about the recording equipment ("does this pick up sound?") C: "I guess I wasn't doing that [...] number thing" G: "The way that reads, I can't even guess at it, so just guess at it, that will be good enough." G leaves.	EXTERNAL INTERRUPTION Mention of videotaping In earlier activities, it appears that C had not specified job number everywhere... The issue of assigning those job numbers later comes up. Part of earlier activity that was not important to C before is now reinstated as an issue she must deal with.
5:33:09	C now looking at papers with job numbers, while the eWord read me first file is still open full screen on her computer.	
5:33:35	C reaches over to right side of terminal, picks up a pen, and starts marking the sheets.	No competition between the two activities for information, screen space, tools. (Though there is competition for C's attention and cognitive resources; she can't do both at the same time. visual/lexical code)

5:37:10	C finishes marking the papers, places them on surface at right. C goes back to looking at the screen.	Returning papers to G is now an open task. Use of surface on right to store tasks in queue? RESUMING SUSPENDED ACTIVITY

Findings

As I reviewed the tapes and transcripts, I noticed commonalities in the subjects' behavior and in the way their activities progressed over time. I will now present the results of my analysis, with examples from the tapes to illustrate major points.

Multitasking

At all three of the sites, there were clear instances in which people appeared to engage in more than one activity at a given point in time. In the following extract, L is beginning an activity in which she will update a number of spreadsheets by entering values that she will draw from a set of printed documents she has before her. She is attempting to locate the files on her computer that correspond to the printed documents, which involves opening and closing computer files, paging through the documents in her hands, and comparing information she sees in each. At the same time, she is concluding a conversation with P, her husband, regarding the taping that is being done for the study.

0:06:22	L and P discuss some matter (hard to hear) as MS Works loads and the document opens up. L then scrolls through file, mumbles "oh dear" and closes it, then starts looking through a stapled document she has in her hands. P: "OK, so I think they just want to keep this running all the time, so even if you quit, [MS-Works dialog box listing documents to open appears] or...y'know, for a short while..." L: [leafing through paper document] "yeah" P: "Y'know, just keep it going" L keeps leafing " Well, are you going to, can you, can you, [folds page of the paper document over] what happens if you turn on the TV here?" P: "I'm going to go..." L "I thought that you'd stay up here with me, you don't" [double clicks on a different file name than had been selected before] "need to?" P: "No, everything's the same, they just have more functions" L: [looks at the document on the screen, then closes it] " But there's nothing I'm going to need?" [dialog box reappears] P: "Not that you have to" [L selects a different file from the dialog box, then clicks on the open button] "if you want to look around..." L: [as file opens] "This is a Microsoft spreadsheet, I wish it was Excel" [closes this file too] P: says something (inaudible) L: "I'll call you"	L and P continue discussion during loading of MS-Works. P is extricating himself from working with L, discusses issue related to Apple taping while L is working on her task. P and L continue discussion on P leaving (which developed out of his mentioning taping) while L continues to try to find the file she needs. L sometimes double-clicks, sometimes uses button to open file from MS-Works Dialog box. Verbal channel now used for comment related to the spreadsheet activity

The activities truly overlap; many of the actions L performs on the computer occur concurrently with her verbal productions in her conversation with P. As in this example, activities that were performed simultaneously largely made use of different sets of resources. Here, L uses her manual motor and visual channels for the work with the

spreadsheet updating activity, while using her auditory and verbal-production channels in her conversation with her husband. In each of the sites, there were examples in which subjects engaged in verbal conversations related to one activity, while performing manual actions on a computer related to another. Computer work performed concurrently with conversation involved mouse movements and button presses but not the typing of large blocks of textual information. This accords with Wickens' (1991) matrix, presented in chapter two, illustrating the effect of processing code on the ability to perform activities together.

The ability to monitor and participate in verbal communications while doing other work allows for people to engage in the activity of maintaining social work relationships concurrently with many of their more official work activities. The following example is typical of many observed at the graphic arts company, in which employees worked in cubicles in a shared open-plan space.

3:59:01	C looks back to screen with open font windows. Moves cursor up, then down in window, then scrolls window. (off screen) "...this funky 60's jive music" C: "no, this is the 80's" [C turns around] "this is the 80's. this is the 80's" [C turns back to screen] "this is John Lennon... you were in high school" [said while C moves cursor and scrolls window. C hums along with music as she selects more fonts and copies them.]	C attempts to locate the fonts she needs to copy. C hears conversation others are having about music playing in background C participates in social conversation while performing visual/manual activities on computer

Maintaining relationships with coworkers was an ongoing activity in which the subject could participate as opportunities arose and as her involvement in other activities allowed. As in the above example, the music that played in the background was often the topic of such shared discussions.

Before the start of the following episode, D had answered a phone call to the office. After hanging up, she calls out to C (or to the room in general) a piece of social information involving one of her colleagues:

11:54:20	D had answered phone call [11:52:00] off screen. After saying goodbye and hanging up, says out loud: D:"A *woman* just called up asking to speak to N, like [imitating sing-song voice] *'Hi, is N there."* C: "Oh" [mumbled] C continues the folder moves she's working on, without looking up	Maintenance of social relationships constantly a factor, here going on in background. C acknowledges conversation while limiting the extent to which it interrupts her work

C acknowledges this with a quick "Oh" without turning from her work, limiting the extent to which this exchange intrudes on her current activity. The amount of disruption that would be involved if this exchange had to take place over the phone, or via email, almost insures that the exchange would not have taken place.

People can monitor verbal conversations while performing other activities. This can lead to the assumption that people will be aware of discussions that occur near them. Prior to the next extract, a

conversation had taken place between two of C's coworkers about changes to one of her old projects.

3:37:13	Photoshop is calculating changes to picture to redisplay (progress bar on screen). C is staring at the screen. A comes to C's desk and stands behind C. A:"Did you hear your name mentioned" <pause> C?" C:"Yeah" A:"I guess now you're deep in concentration?"	INTERRUPTION of one task by someone walking in, to discuss follow-up work on a project that had been done much earlier. A asks about C's level of concentration (A evaluating extent to which she can interrupt C, provides C with an opening to have the interruption put off?)

When A comes to C's desk, C is staring at the monitor waiting for a photograph she has modified to be redisplayed. A asks if she heard her name being mentioned. When she gets no answer, she asks:

A: " I guess now you're deep in concentration?"

It may have seemed that this was an acceptable time for A to interrupt C. It appeared that C waiting for the computer to finish its processing and was not performing any actions herself. But when C does not respond, A inquires about C's internal state and her openness to interruption.

Gradual Transitions Between Activities

As the episode continues, C asks why her name was mentioned. A tells her about the revisions that have to be made, and gives her a set of

documents the client sent describing the changes. C pages through the documents.

3:37:30	C:"Why did you mention my name?" A:"we're redoing the [names project] and N just said that W got revisions in from X, and she said that it would be a good thing for you to artwork" C:"Oh, OK" A:"So, do you want me to just give you this? <showing some documents> C:"Sure, I guess so. I mean, well, what is this exactly?" A:"It's the original <gives C the document> that you probably did last time copied and then changed" <C pages through document> C:"OK. .."[inaudible] .remember what this is...a while ago" A:"OK?" C:"OK"	INITIATION OF NEW ACTIVITY (Related to an activity C had done on some prior date.) C attempts to restore some of the internal context related to the old project, and to determine what new work is needed.

A does not leave immediately after discussing the project with C, instead, she notices an unfamiliar item and inquires about it. (The item appears to be a piece of cable left by the Apple researchers.) This leads to a discussion of the videotaping.

3:38:10	A notices an item lying on the desk on the side, picks it up "Does this look important to you?" <photo finishes redrawing> C glances to the item A is holding, then to her screen. C: "looks like a piece of [inaudible], probably from the video stuff..." A goes to look through the video camera viewfinder, then talks about what can be seen in the screen. C : "hmm" <meanwhile, C pages through the printed sheets. A leaves. After looking through the papers for a few more seconds, she places them on a stack on the counter to her right. She returns to work on the photo in Photoshop, moving the cursor on the screen.	Further interruption triggered by noticing something anomalous. Appears to be a piece of cable. C RESUMES INTERRUPTED ACTIVITY, looking at screen AWARENESS OF VIDEOTAPING C's attention is focused primarily on the Photoshop activity, yet she acknowledge the other party, while not detracting too much from her attended activity ATTENDS TO THE NEW ACTIVITY(now glancing over the change document) RESUMES INTERRUPTED ACTIVITY (Counter on right appears to be a surface on which items for pending activities are stacked.)

This example shows how noticing an anomaly in the external environment can prompt a new course of action. As in this example, the presence of the recording equipment used for the study prompted comments that would not have otherwise occurred.

While A looks through the camera and discusses the videotaping, the computer finishes redrawing the picture on screen. C looks at the screen for several seconds, and then down at the papers A gave her. She answers "hmm" to A's comments; it appears that C is concentrating primarily on the papers. After looking through the papers, she places them on a stack of items on a counter to her right. She looks back at the

monitor, and move the cursor on the screen as she begins to work on the picture. But then she picks up the new papers from the stack on her right and pages through them again.

3:38:45	C picks up the document she had just been given again, pages through it, and then puts it back down. Then returns to work on the photo again.	Appears that C is still thinking about the topic of the interruption, evaluating or planning work she will do.

After several seconds, she returns the papers to the stack on the right and resumes work on the photograph.

This episode illustrates how activities can overlap, allowing for gradual transitions between activities. Actions related to C's prior activity (work with the picture on screen) are interleaved with actions related to the interrupting activity (revisions to the old project). In addition, discussion of the videotaping occurs while C attends in varying amounts to the other activities. Nothing external prompts C's returning to look at the papers after she had placed them on the side. It appears that she continued to think about the new assignment even as she resumed work on the picture. Based on her actions before and after, it seems likely that C was evaluating or planning the work she would have to do, refreshing her memory on the old project and determining the extent of work that will be needed. The episode also illustrates how new activities can involve elements of old ones, requiring that some of the context of the earlier activity be restored.

Unfolding of Activities Over Time

In many settings the materials or information required for an activity accumulate over time, and may depend on activities performed by other people. The activity will therefore depend on events that the person may not be able to control or predict. In addition to limiting the extent that advance planning is possible, this can lead to interruptions. Activities must be suspended or modified until information is available. Activities are also interrupted as information arrives and must be handled.

In the next episode, C is preparing to work on the revisions to the old project. This involves locating relevant document, graphic and font files, and looking through the printed sheets to determine the changes that should be made. As the extract begins, C is finishing a discussion with A on whether new graphics will be needed in addition to the two already in the document. A said she will contact the client to find out.

3:49:20	C: "Y'know, if there are two illustrations, or if there will be a bunch more?" A: "OK" <Dialog boxes appear as QuarkXPress opens.> C looks through files on computer desktop. Then opens system folder. In the background, a call to the client requesting info on the number of graphics changes can be heard.	A attempts to obtain information as C looks for the computer files (physical resources) that she will use for the project.

3:51:36	A: "She's not there" "C: OK" A: "and her cover sheet says she'll send another illustration tomorrow, I just don't know when she's sending it, because she's having a really hard time getting it from the people at [client name]"	Unclear when additional information will arrive.
	C: "Well, I'll give it to, leave that there, to B to play with it, so she can get familiar with it, and then as decisions get made we can adjust it, and see what we're going to do..."	C delegates work to B. Not all information available yet - B will be able to prepare for activity ("get familiar with it") but course of activity will depend on info ("as decisions get made")
	A: "Do you want to show her this as a sample, of what you did? C: "Sure"	

C decides to delegate some of the work on the project to B. But because information needed for the activity is not yet available, B will be limited in how much she can do. C decides that B should start the project anyway and "play with it so she can get familiar with it", letting her prepare for the work she will do. Any specification of the activity C makes now will have to be adjusted "as decisions get made" and they "see what we're going to do." C does not know when the needed information will be available ("I just don't know when she's sending it"), limiting her ability to plan the activity.

Several minutes later, C requests the job number that will be used to track and bill work on the project. The job number is not readily available, but A promises to get it.

4:05:00	<as soon as copy is over, C turns around, calls out:> C: "A, did you have another job number for this, or anything?" A: <inaudible> C: "No?" A: <inaudible> C: "But you will?" OS: "Yeah." C: "OK."	Computer action ends. (C could have asked this during the copy.) REQUEST for job number from A. Job number is required at some point for this activity. When does A give C the job number? What does C do with it? (PENDING GOAL for A - get job number)

C is away from her desk when A arrives with the job number. The job number is written on a post-it note, and A affixes it to C's monitor where it is likely to catch her attention. A walks away, but then turns back and verbally provides the job number to B. (B's work area is in front of, and facing, the back of C's cubicle. A person standing at C's desk can look over and see B.)

4:12:36	A places a post-it note on C's monitor, with the project number written on it.. A then walks away, but a moment later walks back, saying (and apparently looking at the post-it note?) A: "B, that project she just gave you for the [client name] white paper is job number 1730." B:"one - seven - three - oh "	JOB NUMBER REQUESTED EARLIER IS DELIVERED A also notifies B of job number. (C had assigned some of the work on the project to B.) B's "read back" acknowledges that she heard the info and verifies the information.

A knows from an earlier conversation that B will be performing work on the project. But she does not immediately tell B the number when she delivers the post-it. A remembers that B will need the job number only later, as she walks away. (Another possibility is that she recognizes the opportunity to provide the information to B.)

The job-number was already written on the post-it note when A came to C's desk. Although it is possible that A anticipated C's absence and knew she would need to leave a note, it is likely that she had written the number on the note so she would not have to remember it. When she tells the number to B, it appears that she looks at the post-it and reads the number.

Shortly thereafter, A tells C that she left the job number at her desk. C returns to her desk for the post-it note and walks away again.

4:13:46	Off screen, A says: A: "I put a sticky note on your thing and you can see it on the <inaudible>" C returns, takes post-it note, walks away...	A verbally notifies C of job number even though C will see it on her monitor.

C would have discovered the note when she returned to her computer; it was not necessary for A to inform her that the note had been left. But because she is told about the note, C can make use of the information immediately. C does not perform any other actions when she returns to her desk. It appears that she returns solely to get the job-number.

There were many other instances in which the flow of activities was altered because information from external sources was needed. In the following extract, the cost of making revisions to a document are being discussed after a "blueline", or approval copy, has been sent by the printer. The printer is awaiting word from the graphic arts company

before proceeding with the printing. The graphic arts company must contact the client to determine how to proceed.

1:38:20	While C is standing up: Offscreen (OS): "C" C: "yeah" OS: "if D doesn't want to do that change now that it's so expensive..." <discussion of "blue line" and cost of revision> OS: "so, if you can call E and tell him that that's the scoop"	A "blueline" (according to Artmania, a San Diego graphic arts firm) is sent by the printer for approval before the final print run is started. PENDING ACTION: Call E regarding changes to the blueline to see if changes should still be done

Tracking her work with job-numbers is not an integral part of the graphics activities C performs. It arises from her company's accounting procedures and is part of the overhead C must do with each project. It does not influence the design of the end products or the techniques C uses. Because C can complete her specific projects without consistently recording their job-numbers, failure to record them has consequences that are peripheral to her immediate activities. This may explain why C occasionally fails to record the job-numbers when she does work on a project, as evidenced by the next extract.

5:32:40	G comes by C's office, brings some papers which she presents to C saying "job numbers!", makes comments about the recording equipment ("does this pick up sound?") C: "I guess I wasn't doing that [...] number thing" G: "The way that reads, I can't even guess at it, so just guess at it, that will be good enough." G leaves.	EXTERNAL INTERRUPTION Mention of videotaping In earlier activities, it appears that C had not specified job number everywhere... The issue of assigning those job numbers later comes up. Part of earlier activity that was not important to C before is now reinstated as an issue she must deal with.
5:33:09	C now looking at papers with job numbers, while the eWord read me first file is still open full screen on her computer.	
5:33:35	C reaches over to right side of terminal, picks up a pen, and starts marking the sheets.	No competition between the two activities for information, screen space, tools. (Though there is competition for C's attention and cognitive resources; she can't do both at the same time. visual/lexical code)
5:37:10	C finishes marking the papers, places them on surface at right. C goes back to looking at the screen.	Returning papers to G is now an open task. Use of surface on right to store tasks in queue? RESUMING SUSPENDED ACTIVITY

C's current activity, setting up an account on an electronic communications service, is interrupted when the absence of job-numbers is noticed. The absence is noticed during an external activity performed by someone else. The time course of this activity is not related to the activity C is currently performing.

The interrupting activity (adding the job-numbers) and C's current activity (setting up the account) both involve visual and lexical codes and require the use of her hands. They cannot be done at the same time. C suspends her current activity to work on the interruption. When

finished, she places the documents on the surface to her right and returns to the suspended activity.

Levels of Interruptions

There was evidence from the Apple tapes of the many levels on which interruptions can occur. As defined in Chapter 2, an interruption is a deviation from the expected or usual unfolding of events. Interruptions can have many causes, external or internal to the main activity at hand.

Examples from the third site illustrate this point. The wife of the main subject of study is entering data from printed documents into a computer spreadsheet. This activity involves selecting a document and the corresponding computer file, opening the file, finding a value in the printed document that must be entered, locating the corresponding spreadsheet cell, and entering the value.

Several events interrupt the orderly progression of the activity:

1. The subject overshoots a cell when tabbing to it. She tabs back to the desired cell and enters a value;

2. The subject enters the values for a row in the spreadsheet but comes up short–the row has one more cell that should have a value. She sees that she entered two values into the same cell, and corrects the problem;

3. The subject notices that a total at the end of a row does not match a value in her printed document. She checks the values she has entered and corrects one;

4. Asterisks fill a cell after the subject enters a value. She makes several attempts to correct this problem;

5. The subject notices problems with the monitor's color and attempts to improve it;

6. The subject's husband enters the room;

7. Phone calls arrive regarding unrelated matters.

The first four events occur within the spreadsheet activity. They show how feedback resulting from the subject's actions leads to deviations from a strict, error-free performance of the activity. These within-activity interruptions occur at different levels of the task/action/operation hierarchy proposed by activity theory.

The first interruption occurs at the operational level. The subject presses a key one more time than she should when moving the cursor to a cell. The feedback is simple–the cursor is to the right of the one that was intended. The problem is noticed, understood, and corrected immediately.

Events two, three and four involve more complex feedback, and require more effort to correct. They occur on the action level after the

subject enters a value or series of values, and lead to additional actions. The second interruption is triggered when the subject finishes entering data for a row and notices that the row is one too short. It has one fewer filled cells than the rows above it. The feedback is directly perceived; the subject can tell at a glance that something is wrong. Correcting the problem takes longer. The subject scans the row to determine the cause of the problem, and then reenters data from the point at which the two numbers were entered in the cell.

The third event occurs when the subject compares the total calculated by the spreadsheet to one printed on the document. This is something the subject does routinely after entering data for each row. (The checking was directly observable because the subject had to scroll the spreadsheet to display the total.) The subject notices a discrepancy; the number on the document does not match the one she has just read from the screen. Correcting the problem requires that she check each of the values she entered, find the one that does not match the document, and reenter the value.

The fourth event requires the most effort to correct. This interruption begins with feedback from the subjects actions internal to the activity. Correcting it, however, requires that she understand functions of the computer tool that she does not normally encounter. The subject enters "100.2" into a cell and presses a key to move to the next cell. Immediately, asterisks fill the cell she has just entered. This occurs when a value is too wide to fit into a cell. The subject seems to

understand the cause of the problem and attempts to resolve it. She selects a large range of cell including the one with the asterisks, and then a menu option "column width." A dialog box appears with the words: "Column width: 4". She changes the "4" to "4.5" and presses return. The message "Invalid number: 4.5'" appears on the screen. (The program requires integers for column widths.)

The subject then selects only the column containing the problem cell. She places the cursor on the left border of the column header and drags it to the left. This has the effect of shrinking the column to the left of the one with the asterisks but does not change the width of the problem column. (She would have to move the right border to do that.) Ultimately, she clicks on the cell and replaces the value "100.2" with "100" so it fits.

The subject uses different mechanisms to move the cursor back to a previous spreadsheet cell depending on the reason for moving the cursor. She consistently uses the keyboard to move along a row to a cell before entering a value. She does this both when moving forward to a cell and when moving back to a skipped cell. She does this even when some time had passed since she last moved the cursor with the keyboard. But she consistently uses the mouse to move the cursor to a cell when going back to correct a value. She does this even when the cursor is immediately to the right of the problem cell. This suggests some effect of the action on the choice of low level operations.

The fifth interruption also involves the tool the subject is using for the activity. During earlier dialog with her husband, she had complained about the color tint of the monitor. Attempts to improve the color did not work. After she opens one spreadsheet file and selects the first cell in which to enter data, she again tries to improve the color. This takes close to three minutes, during which she encounters problems which lead her deeper into options and sub-windows. When finished, she closes the control panel.

0:08:08	L moves mouse to Apple menu, holds mouse on Control panels, initially opens up "Window Shade" closes it, then "Color " control panel. Chooses "highlight" pop down menu, then "other", then "more choices" button . (confusion due to color wheel being black)	Trying to find tool to modify screen appearance. "Garden path" trying to adjust screen background: she's in the wrong tool, and goes deeper and deeper into it.
0:10:58	Closes Color control panel. See's Finder, with the folder window containing the MS-Works documents open on top. She moves mouse to one file, then towards close box, then back again, then double-clicks on the file. Disk whirs, watch appears, MS-Works is brought to front with her file's window from before open and labeled, though without the contents repainted (window is empty except for a black rectangle where a cell had been selected). There is a beep, and a dialog box appears with text: "File is already open." L clicks OK, the dialog box disappears and the window contents are filled in. L then moves mouse to the selected cell, then away from it.	She had originally selected the control panels (first WindowShade, then Color) while within the MS-works window with the document she wanted to work with prominently visible. But opening a control panel made the finder the frontmost application, so when she finished her task of adjusting screen settings, she exited to a screen on which the document she wanted to work with was hidden. Mouse move to file, then to close box, then to file: is she uncertain how to proceed? Selected cell draws her attention.

0:11:25	L moves cursor over to highlighted cell, then away from it, then starts typing a data value to fill the empty cell.	Moves to select the cell even though that does not have to be done.

Her efforts to improve the color have side effects which lead to confusion afterwards. She had opened the control panel while she was in the spreadsheet program, with the opened file filling the screen. This moved her to the "finder", or operating system level of the computer. When she exits the control panel the spreadsheet file is no longer visible on screen. Instead, she sees the desktop-level folder showing the files on the disk. She moves the mouse to one file, then to the window's close box, then back to the file. She double-clicks on the file to open it. This moves her back into the spreadsheet application, but displays a box with the message "file already open." She dismisses the box by clicking "OK." The cell she had selected is still hilighted, but she moves the mouse to the selected cell anyway, then away from it. She then enters a value into the cell.

Adjusting the screen color is not necessary for the spreadsheet activity. It is an attempt modify the environment in which the activity is performed to make it more pleasant or efficient. The subject performs these actions almost immediately after she opens a spreadsheet file, not while in the midst of entering data for the sheet. She does hilight the first entry cell before attempting to adjust the color, but this appears to be part of the routine she follows when she opens a spreadsheet. Selecting the cell does not require consulting the sheets in front of her; it is clear from the file itself where the next entries should be made. When

updating the other sheets the subject opens the file, clicks on the first ell for entry, and then looks down to locate the relevant values in the papers before her. While the actions to improve the screen color are inserted into the task of updating the single spreadsheet, they come at a time when she is between two stages of the task (opening a sheet and entering data).

The other interruptions result from events external to the subject's current activity. I will discuss the ways she handles phone calls below.

Evaluating Interruptions

At each of the sites, there was evidence for an evaluation process that takes place when an interruption occurs. A person faced with an interruption can proceed in several ways. The options available to the person range from ignoring the interruption completely and continuing and continuing to perform the current task to suspending the current task immediately to handle the interruption. The interruption can be deferred to a later time. The person can attempt to multitask, continuing to perform the old activity while handling the interruption. The person can slowly disengage from the old activity while beginning the new one. The person may also perform additional actions to preserve the context of the existing activity before suspending it to handle the interruption.

Examples from the third site illustrate a variety of responses to the same interrupting stimulus. Several phone calls arrive during the time the subject is entering spreadsheet data. The subject answers one of them

immediately, waits for three rings to answer a second, and ignores a third call completely. These different responses imply a process of evaluation in which the subject determined what to do.

In the first case, the telephone call arrived at a time when the subject had just completed work on one spreadsheet file, and had closed the file. The dialog box requesting a new file to open was on the screen. Following the procedure the subject had used repeatedly before, the subject should now select the next paper document, locate the corresponding file, and open it. Assuming the subject continued with her standard procedure, the information on how to proceed was represented in the external environment by the next paper document in the stack. Furthermore, the subject's hand was free to pick up the receiver. The subject could answer the phone immediately without upsetting an action in progress, and without losing track of where she was in the spreadsheet activity.

The second phone call arrives when the subject is in the midst of entering values into a spreadsheet document, copying the numbers off the printed document before her. It is clear that the cells in the spreadsheet do not follow the organization of the document. The subject looks down at the next number indexed by her finger, and then searches for the corresponding cell in the spreadsheet, moving the mouse from cell to cell as she looks. The phone call arrives during one of these searches. The subject does not immediately answer the phone, but instead continues to search for the desired cell as the phone rings two

more times. She finds the cell she needs and clicks on the cell to hilight it. Only then does she answer the telephone.

This action has the effect of maintaining her place in the data-updating procedure on which she is working. Knowing what cell she is up to serves as an index into the document from which she is copying the numbers. Even if she does not remember if she has already entered the new number, a quick comparison of values can yield that information.

When the third phone call arrives, the subject is also in the midst of entering spreadsheet data. She knew based on earlier conversation that her husband was in the house. When the phone rings she does nothing herself. Her husband answers the phone after four rings.

The examples suggest the kinds of information people take into account when they determine how to handle interruptions. These include a consideration of the effect of the interruption on the current activity and actions that can minimize that effect. People also consider the consequences of not handling the interruption. For example, the knowledge that someone else is around to answer the phone eliminates the need for the subject to do so. There is often little time to consider these factors; many interruptions must be handled within a limited amount of time. Phone calls must be answered before the caller hangs up. In the case in which the subject continues to search for the spreadsheet cell and clicks on it before answering the phone, she

performs an action which can be done quickly and which adequately saves her place in the activity.

Negotiation of Interruptions

People often evaluate the extent to which others are open to interruption. This was illustrated in an extract discussed above, where C's openness to interruption was not visible. A inquired about the extent to which C's internal state allowed her to deal with an external matter, asking: "I guess now you're deep in concentration?" In other episodes, subjects informed visitors that they were "on hold", and therefore open to interruption, despite their holding a telephone handset to their ear.

When an interruption involves other people, the handling of an interruption may be negotiated between the parties involved. Such negotiation is seen in the following excerpt.

11:50:06	(Offscreen: B: "Bye, see you all in about an hour"), B stops by C's desk, asks: "Did you have a question for me?" C asks about printer problem: "Friday, I guess I was playing around with the modem and stuff...and I think I um unhooked the uh...and now I can't print. I put it all back, but it doesn't come up, so I thought you might know" "I can't deal with it right now" "Yeah, I know, but like I thought I'd tell you this in case you knew right away, you could fix it. otherwise I could call CSI(?)... "Well, you should check your, all your connections, make sure you're hooked into the thing where it has the icon of a printer in the back of the cpu, instead of like like the arrow things...." "Yeah, I may have moved that one." "Yeah" " OK, I'll play with it" "Yeah, make sure it's got the printer icon or it WILL NOT show up." "OK" "Yeah, that's probably your problem" "OK, I got so confused after moving, running around last week"	Woman about to leave for lunch interruption of activities of both C and the other woman C taking advantage of opportunity to resolve problem (not part of the immediate sequence of actions she is working on now) negotiation of how much time other woman can devote to problem; initially, I can't deal with it now. ultimately, woman gives her initial solutions, first stage of actions C can take. PENDING TASK: check printer cable connections

In the above example, B's walking by C's desk as she leaves for lunch leads to an interruption of both of their immediate activities. It also affords them the opportunity to communicate and possibly resolve the issue. B asks "Did you have a question for me?," acknowledging that there is a pending issue she for which she may be responsible, and also implicitly requests information on the specifics of the matter. C responds by providing information on the printer problem she has been having. B makes an initial evaluation of the effort required to resolve the

problem, and decides to defer work on the interruption to a later time. She states, "I can't deal with it right now."

C's response, "Yeah, I know, but like I thought I'd tell you this in case you knew right away," is an acknowledgment that if resolving the problem would require a substantial amount of B's time and effort, it could be deferred to a later time. It also implies that she had not known herself how much effort the interruption would require, and needed B to provide that information.

It is possible that C's next statement, "otherwise, I could call CSI," is an attempt to raise the cost of deferring the interruption to a later time. CSI appears to be an outside computer support group, and C may know that contacting CSI would imply that a problem had been encountered that B could not handle herself. B may see this as a challenge to her overall competence.

Ultimately, B suggests a solution to the problem:

B: "Well, you should check your, all your connections, make sure you're hooked into the thing where it has the icon of a printer in the back of the cpu, instead of like like the arrow things...."

B does not stay to insure that the solution she suggested is effective. She leaves, but the issue is still open, and may require her further attention. For the moment, however, responsibility for this issue has been passed to C.

C does not act on the new information she received from B immediately. C has several opportunities after this conversation to check the printer connections, including times before and after she leaves for lunch herself during which she is not engrossed in other activities. It is only two and a half hours later, when she prepares to print a document, that she makes use of the information to resolve the printer problem. This is shown in the following extract.

The extract starts with C opening the Macintosh "chooser" dialog box, which should display a list of available printers and allow her to select one. No printers are displayed, indicating that her printing problem is still unresolved. It is unclear if C forgot about the printing problem until she went to print the document, or if she remembered the problem and was checking to see if it had resolved itself.

2:23:00	Opens chooser, selects print driver which should display available printers, none shown, closes chooser. Does something under desk (playing w/ cables?) Restarts computer opens chooser again, still no printers, switches appletalk off, selects printer icon again, gets dialog box asking to turn appletalk on, clicks to do this, clicks printer icon again (repeatedly), clicks on other printer icon and then back on the one she wanted, closes chooser window, now goes back under desk, seems to be dealing with cables, then with other things (papers?) on her desk, then goes to chooser again and selects a printer.	WORK ON PENDING TASK: check printer cable connections Effect of information discovered earlier (re: getting printer to work) was not seen right away; she did not fix the cable connections when she had earlier opportunities to do so. In fact, she goes to select a printer again (and seems to try other things) before implementing the cable fix that had been suggested to her above.

Note that the goal of fixing the printer connections is a general one; it does not arise from any one specific activity, but is required for many of the activities in which C engages. C does not perform it until it is triggered by one of the other activities she performs.

Periods of Openness to Interruptions

There were times when people seemed especially open to interruptions. These included times when people had completed one activity and were preparing to begin another. These periods arose regularly as people were arriving to or leaving from their workplace. these were all times at which people had extricated themselves from deep involvement in one activity. They were also times when people were moving around the workplace and were more likely to encounter each other by chance. The start and end of the day and lunch time were occasions when people were likely to handle issues that were peripheral to their main activities. This led to interruptions of others who had to be consulted regarding the peripheral activity, as when B stopped by C's desk on the way to lunch to help with the printer problem.

Additional interruptions often occurred after an activity had been interrupted. Several explanations can be proposed for this "bundling" of interruptions. For the interrupter, it is more efficient to handle as many issues as possible at one time. This saves additional trips and eliminates the danger that the other person will not be available later on. For the person being interrupted, once an interruption has occurred the cost of

disrupting the previous activity has been incurred. The cost of a second interruption at this time is therefore less than it would be if it came separately at a later point. People may have felt pressure to minimize the disruptive effects of their interruptions on others, and therefore tried to handle as many issues as possible at one time. Finally, it appeared that once a person's attention had been drawn from their primary activity, they were more likely to notice items in their environment that prompted additional actions.

Use of Space

There was an impression as I viewed the tapes of the importance of space in the management of activities. Several extracts showed the graphic artist placing items related to pending and completed projects on the surface to her right. The subject updating the spreadsheets seemed to use the placement of the printed documents to keep track of those that still had to be entered. The teacher at the first site grouped items that she would take from her office together. Unfortunately, for reasons that will be discussed below, it was hard to determine conclusively how subjects used space as a resource.

Limitations of the Tapes

Several factors seriously limited the extent to which I could analyze the videotapes and make theoretical conclusions based on them. The most serious limitations involved the extent to which I had knowledge

of the context in which the activities were taking place. I had only limited information about the subjects and their activities, based primarily on the short interviews conducted with the subjects on the first day of observation. These interviews touched only briefly on the tasks the subjects did, and did not address the specific activities or goals the subjects intended to work on during the week of the study. Unfortunately, I had only limited access to the subjects after the fact, hampering my ability to obtain answers to questions that arose as I analyzed the videotapes.

I had little knowledge of the physical setting in which the subjects worked, and was therefore limited in the extent to which I could draw conclusions about the physical items the subjects used and where they were placed. I similarly had no information regarding the other people with whom the subjects interacted. Although I could often draw inferences on such matters as I repeatedly watched the tapes and observed events unfold over time, I could not be sure of the accuracy of these inferences. And because I could not interview the subjects after reviewing the tapes, I could not elicit their own introspections on the significance of different areas in their workspace.

The focus of the original study by Apple had been on the computer tools used by the subjects, and not on the activities they performed or the other physical artifacts and tools they used. This was reflected in the videotapes themselves, in which the contents of the computer screens were generally legible but the image of the physical setting was small,

often poorly lit or obstructed, and only partially in view. My inability to accurately track the physical location of items and my limited knowledge of the layout emphasized to me the importance of such information for a complete account of how the subjects managed their activities.

Finally, the audio quality of the tapes varied, and was especially poor at the site in which the graphic designer worked. This made accurate transcription of the dialog a tedious process, despite the use of a graphic equalizer to enhance voices and attenuate background noises.

Summary of Major Findings

In summary, my analysis of the Apple tapes revealed the following phenomena related to the structure and management of multiple activities and interruptions:

1. Multitasking;
2. Gradual transitions between activities;
3. Interruptions at every level of activities;
4. Evaluation and negotiation of interruptions;
5. Periods of openness to interruptions;
6. Use of external structures to preserve activity state during interruptions;

7. Use of space to manage resources used in activities (suggested, but not conclusively shown).

These phenomena will be explored in the following chapters.

Chapter 4

The Office Activity Study

I now discuss my study of how people manage multiple activities in everyday work settings. A major goal of this study was to understand how activities are managed within their physical, task, social and organizational contexts. I wanted to understand the subjects' roles in their organizations, their responsibilities and goals, the layout of their offices, and the procedures they used. I also wished to have ongoing access to the subjects and the settings to answer questions that arose during my analysis.

This study utilized a number of techniques including interviews, mapping the location of external objects in the workplace, examining the organization of computer files, videotaping subjects as they worked, and retrospective protocols as subjects watched portions of their videotapes. The study involved six subjects, observed intermittently over periods of time ranging from several days to several months. The design of this study arose in part from a desire to obtain information I lacked during

my analysis of the Apple System 7.5 Study videotapes, as discussed in Chapter Three.

Procedure

I designed the study in hopes that a convergence of evidence from a variety of techniques would help me accurately understand the subjects' behaviors and the contexts in which they took place.

The study consisted of:

1. An interview with the subject in which I asked about their job functions and responsibilities, their daily routines, projects and activities in which they were currently engaged, and other issues that helped me understand the context in which they worked;

2. A detailed tour of the subject's office or workplace;

3. A review of the subjects computer and the organization of computer file directories and on-screen icons and windows;

4. A period of videotaped observation during which the subjects engaged in their regular activities;

5. Transcription of the videotapes;

6. Review of selected portions of the videotapes from certain subjects with the subjects, during which they described their activities and identified items that appeared on the tapes;

7. Analysis during which results from the different sites were compared in an effort to extract general principles.

Interview

The questionnaire I used to guide my initial interview with each subject was developed in cooperation with Tom Erickson and Dan Russell of Apple Computer, who conducted similar interviews with other subjects. I modified the questionnaires slightly over time to clarify wording and to insure that issues that arose in earlier interviews were explicitly addressed to me in later ones. For example, after the first interview was conducted, I added the question: "Do you have, or give yourself, periods of time that are relatively quiet and free from interruptions, and what kinds of things do you do in them?" I attempted to keep the conversation natural and freely flowing, in an effort to obtain as much information as possible on how the subjects perceived of their jobs and routines. The structure of the printed questionnaire was generally adhered to, although the precise wording of the questions was not always followed exactly. Deviations in the structure of the interview occurred if a subject's responses led to a discussion of issues I had planned to address later. A copy of the final questionnaire is attached as Appendix A. All interviews were videotaped.

The interview began with a request for the subjects' name and age, their job title, and the length of time that they had been working at their current position. A series of "work practice" questions followed, aimed at understanding the subjects' responsibilities and work patterns. I asked

subjects to describe their overall responsibilities, and if their work had a natural rhythm to it or was governed primarily by individual, non-recurring projects. I also asked about the extent to which their work involved other people.

I then asked the subjects to describe a typical day, starting from when they first woke up. I asked what they did when they first arrived at work, before, during and after lunch, and what they did before they left. Other questions dealt with the extent to which subjects planned their days in advance. I asked if they generally knew what they would be working on when they came in on a given day, and when they figured that out. I asked how frequent departures from their plans occurred, and what caused those departures. I asked if they had, or gave themselves, periods of time that were relatively quiet and free from interruptions, and what kinds of activities they did during those periods.

The next set of questions focused on the specific day of the interview. This had several purposes. One was to obtain information that would help me contextualize the events I recorded during the period of videotaped observation that took place during the day of the interview. It also set the stage for the subjects' description of items in their workplace encountered during the office and computer tour. Questions about the day of the interview also served as a starting point for obtaining information on the subjects work routines in general.

I asked what goals, if any, the subjects had for that day, and what specific tasks they planned to perform. I asked if that number of tasks was a typical number for them to work on in a day, and how many tasks the subjects had all together. I asked about the number of scheduled meetings the subjects would go to that day, the number of informal meetings they would expect to have, and about the number of times they got interrupted during a typical day. I also asked subjects to estimate the number of phone calls, email messages, letters, faxes, and informal conversations they expected to get or have that day. Although these questions concentrated on the specific day of the interview the subjects answers often dealt with larger periods of time, for example describing the number of faxes they received in a week, or the number of regularly scheduled meetings they had in a month.

I asked the subjects how they remembered to do the things they had to do, and to describe any reminders they used. I asked them how they organized their physical files, how often they had to search for things, and how long it usually took to find them. I asked what items the subjects used to manage their time and activities. These questions were accompanied by a detailed tour of the subjects' office or workplaces that will be describe in more detail below.

Office Tour

During the interview, I asked the subjects to give me a tour of their office or workspace. I asked subjects to point out the general functional areas of their offices, and then go in order through their offices describing

each item as it was encountered. If the subjected passed by an item that I thought was potentially important, I prompted for information asking non-leading questions such as "what's that?" or "what are those things over there?" Encountering an item often led to further discussion of the subjects' tasks and routines, and revealed details that had been left out during the interview. Detailed maps were made of the subjects' workplaces. The maps from the study appear in Appendix B.

Computer Tour

The final set of questions focused on the subjects' use of computers. I asked subjects to characterize their computer expertise, and to describe their past experience using computers. I recorded details about the hardware they used. I asked how the subjects used their computer in their work. I asked what applications they used and if they ever wrote programs, scripts or macros. I asked subjects if they used email, and if so, how often they checked for new mail and how they organized the messages they sent and received. I asked them how they organized their computer files, windows, and on screen icons. I asked about problems they encountered organizing work on the computer. I asked how often they searched for files or information, how many applications they had running at once, and to estimate the amount of time they spent preparing to work on the computer.

Observation of Ongoing Activity

Subjects were videotaped engaging in their normal activities for periods ranging from two to six hours. Subjects were instructed to ignore the presence of the camera as much as possible and to do what they normally would. They were told to leave the camera running if they left the room. Subjects were shown how to turn off the camera and were told to do so if they were uncomfortable with the taping or needed to maintain the confidentiality of issues being discussed. (None of the subjects did this.) At the end of the videotaped session I asked the subjects if anything unusual had occurred, or if the period was relatively normal.

The interview, the office and computer tours, and the activity period were recorded using a professional quality Hi-8 camcorder. Because of the tight confines of the settings being studied, the camcorder was equipped with a wide-angle attachment to increase the field of view. The camera was positioned high in the room facing downwards toward the subject's main work area. The camera was mounted on a tripod or on a bracket I constructed which could be placed on bookcases or file cabinets or clamped to doors and other vertical surfaces. During the office tour, I removed the videotape camera from its mounting and carried it in hand. This let me focus on items the subjects discussed and capture them in detail.

Transcription

All videotapes were viewed in their entirety. Portions containing the interviews were used to augment the notes I had taken. Sections in which the subjects discussed issues of particular interest were transcribed verbatim. Videotape of the office tours was used to enhance the detailed maps of the subjects' workspaces. Screen shots were captured of important items and added to the maps. These maps and screen shots were annotated with relevant dialog from the office tours.

The period during which the subjects conducted their normal activities was viewed to track the overall activities and locate episodes of interest. These portions were transcribed in detail, capturing each of the subjects' actions and utterances and tracking the use and placement of external artifacts.

Transcription was performed using an AV equipped Macintosh computer running the CVideo software program. This let me control the video deck from the computer and automatically insert timecodes into the transcript. It also let me capture video extracts and screen-shots which I annotated using traditional drawing programs.

Retrospective Protocols

I selected portions of the videotapes that I transcribed in detail and reviewed these with the subjects to obtain their retrospective protocols as they watched the tapes. I asked the subjects to describe what they were doing in the tapes and to identify each of the items they used. I was

careful to prompt for details in none-leading ways, as I had been during the initial office tours. Only after the subjects had described the episodes in their own terms did I ask questions that had arisen during my viewing of the tapes. These sessions proved helpful in helping me understand the episodes in detail and frequently led to discussion of the subjects' more general procedures.

Subjects

I recruited six subjects through personal contacts within and outside the university.

The six subjects were:

1. The financial services officer in an academic department in a large university;
2. The personnel officer working in the same department;
3. A student services representative in the same department;
4. A real estate developer;
5. An architect/developer;
6. A medical school assistant dean.

I will now describe each subject in turn, drawing from the information they provided at the start of the study.

Subject 1, KF

KF was an Administrative Analyst responsible for general accounting for her department. Her responsibilities included grants management, and overseeing financial issues related to purchasing, staff and personnel. She had worked at the university for thirteen years. She had held her current position for six years; prior to that she had done technical report editing, typesetting, and general secretarial work. KF stated that she served as a general resource on many matters owing to the amount of time she had worked at the university and the variety of positions she had held. KF is 34 years old. She no longer works in the department.

Subject 2, MS

MS is responsible for academic, staff and graduate student personnel matters for her department. Much of her work involves processing forms and paperwork for payroll actions and keeping university appointments current. MS stated that a major goal of her work is insuring that people get paid on time. She is also involved in recruiting new faculty members to the department. MS has worked in the department for approximately five years. MS is 39 years old.

Subject 3, AD

AD is a Student Services Coordinator and Program Representative for undergraduate and graduate programs. The overall goal of her work is "to make sure the programs keeps going." Her responsibilities include

scheduling courses with faculty members, answering students' questions, moving students through the proper channels to make changes to their programs, and maintaining coordination with the office responsible for graduate student research. She has held this position for eight months. AD was 26.

Subject 4, JC

JC is responsible for real estate development and project management for a New York and London based firm. He is responsible for finding properties for his company and then developing or redeveloping them, making a profit by adding value. Much of his work involves other people including consultants, contractors, architects, attorneys and investors. JC stated that his work depends on knowing people in the marketplace and maintaining good relationships with civic leaders and local politicians. He has headed his company's office in San Diego for four years, assisted by a part-time administrative worker. JC is in his mid 30's.

Subject 5, RW

RW is an architect who also engages in real estate development. He runs his own business which performs architectural work including renovations. He has a limited partnership of investors for whom he locates, purchases, develops, and sells properties. His work often involves outside consultants. RW has worked in his current position

for two and a half years. His wife is an accountant who works with him part-time, preparing the books for the business. RW is 42 years old.

Subject 6, NL

NL is an Assistant Dean for Curriculum and Student Affairs of a prominent medical school. She is the director of the school's tutorial program which provides academic support to the school's students. NL designs handouts and other instructional materials and conducts group reviews and private tutorials. She has a staff of three full time academic colleagues and an administrative assistant. NL is also a lecturer in the fields of physiology and pharmacology. She contributes sections on these topics and edits several medical textbooks. She is also a mother who is active in the daily care of her children. At the time of the study she worked half-days in her office and spent the rest of the time with her family or working at home. NL is 48 years old and has been with the medical school for twenty-three years.

Subjects were informed of their rights under the human subject guidelines of the University of California, and signed consent forms indicating their willingness to be interviewed and videotaped. They were told of their right to terminate the study at any point. Subjects were not paid for their participation in the study, though in some cases favors were provided informally after their participation. For example, I assisted one subject with a networking issue involving his desktop and laptop computers. I helped another subject use a database program to track information cards filled out by potential customers. These services

were performed after my observations were complete so as not to influence the behaviors I observed.

Three subjects, KF, MS and AD, all worked for the same university department. The fact that this was also my home department raised several concerns. I felt a heightened need to preserve the confidentiality of matters that might concern people I knew. I was afraid that the subjects might feel a compelled to participate in the study because they were obligated to assist me with other matters arising from my status as a student in the department. I emphasized repeatedly that the study was voluntary and tried to be especially sensitive to signs of discomfort. (I had considered another individual as a subject but quickly dismissed her when she seemed uncomfortable about being taped.)

Despite these concerns, studying three subjects from my own department yielded substantial benefits. The nearly five years of experience I had in the domain helped me attribute meanings to the items and behaviors I observed. I was in the department daily, making it easier for me to contact the subjects when I needed clarification of some point. It also led to informal opportunities for me to observe the subjects and their environment. I noticed things as I walked by the subjects' offices which confirmed or contradicted impressions I was forming. This often led to additional discussions with the subjects that enhanced my understanding of their activities.

The two subjects involved with real-estate development, JC and RW, shared one project in common. This project involved the renovation of a commercial space into residential lofts. In addition to the other observations made for this study, I was able to observe them individually and together working on this project. I attended meetings they conducted with outside contractors and accompanied them to the project site on several occasions. This helped me understand their work in its larger context, and gave me an opportunity to observe them working away from their offices where they said much of their work was done.

Methodological Issues

Before I present my findings, I will briefly address two methodological concerns. These deal with the effects of videotaping and the reliability of interview data.

Effects of Videotaping

A concern in all observational studies surrounds the effects of the study on the phenomena being observed. Were the observations I made representative of what the subjects would have done had they not been under observation? Did the presence of the videotape camera alter the subjects behavior in a way that invalidates the theoretical conclusions I drew?

It is clear that the videotaping did affect elements of the subjects behavior. As in the Apple study, there was evidence that subjects were

aware of the videotaping. It was mentioned occasionally by the subjects and was the source of interruptions. Yet I believe that the videotaping did not alter the subjects' behavior in a way that seriously affected the issues under investigation. The subjects continued to perform their activities competently despite the study, even when things got busy. Cicourel suggests that this would have been difficult or impossible had they deviated substantially from their habitual behavior. Furthermore, I had opportunities to observe the subjects informally when they were not being videotaped. The behaviors I observed were very similar to those captured on the tapes.

Accuracy of Interview Data

Well known concerns exist regarding the accuracy of interview data. (See Ericsson and Simon, 1984, for a discussion.) Valid reasons exist to question the extent to subjects' self reports can be used as a source of data in understanding their own activities. Subjects may not be aware of factors that influence their behavior, or may not have access to report them verbally. Self reports are subject to distortions resulting from characteristics of human memory, and biases introduced by the way questions are phrased. For these reasons I did not rely on the subjects' self reports alone, but depended on a convergence of data from several sources. Items noticed during the office tour and videotaped observation session helped me verify the accuracy of the subjects' reports.

The interviews were valuable in helping me understand the context in which the subjects worked, from the subjects' perspective. The

interviews also gave me insights into the subjects' internal verbally accessible representations of the routines they followed. I will present evidence to show that these routines were not, in fact, always followed. I will also present evidence to show that these introspections played a role in shaping the subjects' behavior. Subjects relied on these internal representations and the belief that they were followed in structuring their environment to support their activities.

Observations

Difficulties Delineating Activities

It became clear during the interviews that subjects had trouble categorizing their own behaviors. When asked about the number of tasks they performed or had outstanding, subjects asked for clarification of what was meant by a "task" and showed confusion on how to circumscribe their activities. When asked to estimate the number of tasks she performed in a given day, KF replied: "It depends on what level you're looking at it too. I mean for me, sometimes, making a call to ask someone where some package is and why we haven't gotten it is a task, although, and, though it's just this five minute thing, and also a task is preparing a grant proposal which is typically four to eight hours of work."

MS replied to the same question: "Do you mean each time I do an email message, that's a task, or [makes circular motion in air with right hand] the whole thing of doing email?" When asked if that felt like a

task, she answered: "Oh definitely yes, cause a lot of times I have to think about how to word a message, sometimes I think that I probably spend too much time on email."

NL asked: "Do you define writing exam questions different from writing lecture notes?" When asked if she would consider that as a different task she said: "In a way it is; it's an entirely different thing, but it's all part of the same...[gestures towards open space]. I don't know how to count... Separate out what a task is. I don't know what it means."

Daily Routines

There were similarities in the daily routines the subjects reported. One of the first things every subject did was to check for email or voice mail messages. When subjects were asked to describe what they did when they first arrived at their offices, they responded:

AD: "Check email and respond to anything urgent. Then it depends on what's going on. Right now, I'm involved with admissions. I prioritize the day; if there's anything that has to be done regarding admissions, do that first. Then I see if there are any other deadlines to meet, work on those."

KF: "I typically I try to at least glance at my email, the headings of my email, I don't always answer it right away depending on what I have to do, but I'll at least see if there's anything urgent. I try to check my voice mail to see if there's anything urgent there"

MS: "What I'll do tomorrow morning is try and get maybe one or two things done out of the short term pile, just to get rolling, to get something off of this pile, but the very first thing I do is answer email messages, read and answer email messages. Then I try to get something done from this pile [pointing to her "short term pile"] if there is something here."

NL: "Check the computer, see if there are any messages on my voice mail; if there are, I'll take care of that, but I don't usually get that many calls, so that's not usually it. I'll check my e-mail...I tend to leave the computer on, because the main thing I really do is word-processing; I'll need to do it for writing handouts, notes, exam questions, memos, anything. The first thing I would do is check my mail."

RW: "Check phone messages and faxes."

JC: "I always use the car phone on the way in to try and..., since I feel terrible that it's already five to nine or some time like that." "I listen to all my voice mail messages in the car, discard the ones I don't need, hear if there are any emergencies, and save all the ones I can't deal with cause I can't remember the phone number and I don't want to crash, etcetera."

Many of the subjects' activities involved other people or arose from situations in their organizations. Checking for phone calls and email messages let the subjects obtain information that could affect they way they pursued their existing activities. It also let them know of new issues

which would prompt additional activities. One reason subjects checked their messages when they first arrived was in case any of these were "urgent" or "emergency" issues that had to be handled immediately.

Subjects also discussed their end of day activities. These fell into three major categories:

1. Cleaning the office from items that had accumulated during the day's activities to leave a clear work area for the next day and restore tools to their places;

2. Externalizing information so it would not be forgotten during the absence from the office;

3. Prioritizing and planning activities for the next day, and creating reminders to cue those activities.

I will cover these in more detail below.

Interruption-Free Periods

I asked subjects about interruption free periods they had during the day, and what kinds of things they did in them. Quiet times tended to be at the very start or end of the day, when the people who are the source of many interruptions are not around. MS uses quiet times when in the shower or walking to work to plan and prioritize her day. JC uses the first hour after he wakes up to read the three newspapers he gets at home, as it important that he keeps abreast of economic and political developments.

KF said that the first hour after she arrives at work is relatively free from interruptions. "Typically between 8 and 9 it's a little bit quiet people aren't in yet so there are typically fewer interruptions and so I, it's often a time for me to wrap up something, get something mailed, or finish it off and make printouts and distribute them or something like that, or get some order placed if I have to do that right away."

NL said that interruption free periods arise at different times, depending on the time of year. She uses these periods to prepare and plan her teaching. "That would be my studying, writing exam questions, preparing for lectures, going over my lectures...I really invest a lot in my teaching. I think that teaching takes a lot of planning and preparation. I really try to get things just right to the point where I know which blackboards I'm going to use for which--I tend to write a lot on the blackboard--you get this great lecture hall with six feet blackboards going across the front. And I'll know that I'm going to start on this end, I'm going to go like this [makes writing motion in the air] and when I hit this topic, I'm going to go and erase this one. I actually have it all planned out. So I'll do that kind of careful work to make sure it's just right."

Predictability of Activities

The extent to which subjects reported contemplating and planning their activities in advance varied. All subjects, however, reported frequent departures from any plans they did make.

AD reported: "I try to set some kind of a schedule, but a lot of times, I don't even touch the project that I was planning to finish that day." This was because "something else comes up, N [her direct boss] may have another project for me to work on, or the faculty does. Or what I thought would be a small project may take the whole day instead."

MS said that "when I get up I usually, I get in the shower right away and already I'm I'm trying to plan my day, prioritize the tasks that I would like to get done in that day. Since I park on Gilman drive I also use that walking time that it takes to get from Gilman drive up here to continue to think about my tasks for the day and how I would like to accomplish them." She stated that departures from her plan occured "All the time. " When asked what causes these departures, she said "Interruptions, just from people coming and asking for things. Interruptions from the telephone. Sometimes my supervisor will have emergency projects that require priority."

When asked if he generally knows what he will work on when he comes in, JC said: "I usually have a few things that I know I need to do. I have three or four main things, and the night before I leave I'll make a list that these are the things - I take home a lot of things in the hope that I'll really do them at night.... But I almost never look at the things that I take home with me.." "But generally I have some idea of the two or three things and then usually if I get one or two of them done it's impressive because I tend to take the things that come in, I'm just one of those people that tends to field everything as it comes in - I'm easily

distracted - so I don't stick with, I don't triage effectively." Because of this, he says he departs from his plans "constantly, constantly."

RW said his work has all the natural rhythm of "an earthquake or a volcano." While he follows similar steps in the early stages of each project, each has its own idiosyncrasies. Later on, and especially when a project is under construction, unexpected matters that have to be dealt with immediately continuously arise . At this stage he says a project is "like a freight train - you do whatever you have to so nothing slows the project down." RW sees responding to situations as they occur as a normal part of his work, limiting the extent to which he can plan each day in advance.

NL said that she generally knows in advance what she will be working on. She says: "It's usually pretty obvious." "I will often have written something I'll need to start with the next day, but usually it's so obvious that I tend not to write what I'll need to do." She explained: "These courses have their rhythm to them, so I know what I'll be doing is physiology. OK, now we're studying cardiovascular, I'll be doing lectures on certain days, I have to be sure my handouts are ready, that the lectures are prepared, and then I know the exam questions that I need to write are due on a certain day, so if those are pertinent I have to get those ready. It's just by the pace of the course that I know what I have to take care of." Although her work is largely scheduled and predictable, departures from occur "pretty often" because of the other non-work activities she performs. "The worst thing is with a sick kid. Then you

know that what you thought was going to happen is not going to happen."

Several subjects revealed their impression that sticking to a plan was important, and that failing to do so reflected negatively on their competence. MS said, "I'm ashamed to say that I cannot accomplish my plan too much of the time." AD estimated that she manages to work on what she had planned to "about half the time," which she said was "not too bad, I guess."

Subjects who identified key projects or responsibilities said they gave priority to activities that involved them. This simplified their choice of what to do. At the time of the study, one of AD's main projects involved new student admissions. AD stated that when she prioritized her day, "if there's anything that has to be done regarding admissions, do that first." Similarly, MS had stated that she saw payroll as her primary responsibility: "Usually then if I have any payroll issues I try to take care of them right away since the payroll is definitely a timely process, things need to keep flying. No reason to hold those kinds of things up, so I usually try to take care of those as soon as I can in the morning." As mentioned before, NL said that she often knows what to work on because much of it depends on the predictable school program.

Reliance on External Artifacts to Prompt Activities

Deciding what to work on resulted from a combination of prior deliberation, responding to new information from mail, email and

phone calls, and following routines which brought the subjects into contact with items in their environment that prompted activities.

All subjects relied on the environment to cue their activities. Although some subjects did use dedicated structures like to-do lists, they mostly relied on physical items that were used in their work to remind them of what they had to do. KF reported that she sometimes has a written outline of things to do "cause then I can check them off." " But mostly I just have an idea of...there's a stack of things I really need to get done today. So like, my stacks today are these [pointing to two stacks of papers on her desk] stacks." "I put all the urgent stuff in one stack." When asked when she does this, she replied: "I guess I do it the previous day... yeah, I guess, I usually sort of during the day I create a little stack of, of work, I don't know, it's not a conscious thing, it's like when I come in, there's the stack."

MS also has a pile of short term work which accumulates as she performs her activities. During the day, this pile moves toward the central area of her desk where she performs the bulk of her work. At the end of the day, MS cleans off her desk. She consolidates the short-term pile, and places it on top of a pile which contains items she needs for ongoing projects but which do not have an immediate deadline. She turns the pile ninety-degrees before putting it down, to keep the two piles distinct (Figure 2).

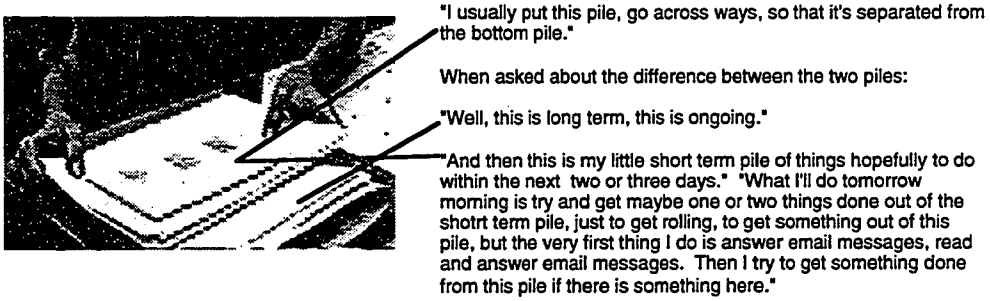


Figure 2. Turning a pile ninety-degrees to keep it distinct from the pile below it, signifying different ways the items should be handled.

In many cases, the presence of an item is sufficient to cue the required activity. In others, subjects add meaning to the items by marking the item or affixing a post-it note to it. This was especially true for MS, and to a lesser extent AD and KF. A large part of their work involves identical forms, and a form can be present for a variety of reasons. An additional notation may be necessary if the item is to be processed in a non-standard way. MS, for example, had a document related to a lecturer's appointment out on her desk. "I have it on top here because I [reading from a post-it note she has written and placed in the top right corner of the document] still need to do his payroll form, so this is on top to jog my memory." She wrote the post-it note "to keep track of that this is not just to be filed but I actually need to do something with this." Figure 3 shows the items in MS's short-term pile, some with additional notes affixed. Adding notes implies the subject's belief that the item alone will not be a clear enough reminder of what has to be done.

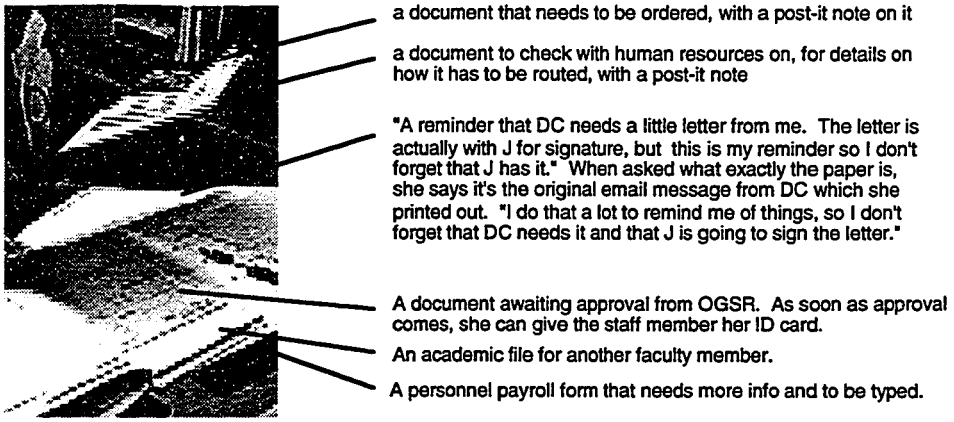


Figure 3. The contents of MS's short term pile, showing items with additional notes affixed.

The Use of Space

People use the spatial organization of the physical items involved in their activities in a variety of task relevant ways. Space can be used to characterize information, to label items with specific meanings, to enable items to serve as reminders, to represent relationships between items, and to minimize interference between activities by keeping their physical resources distinct.

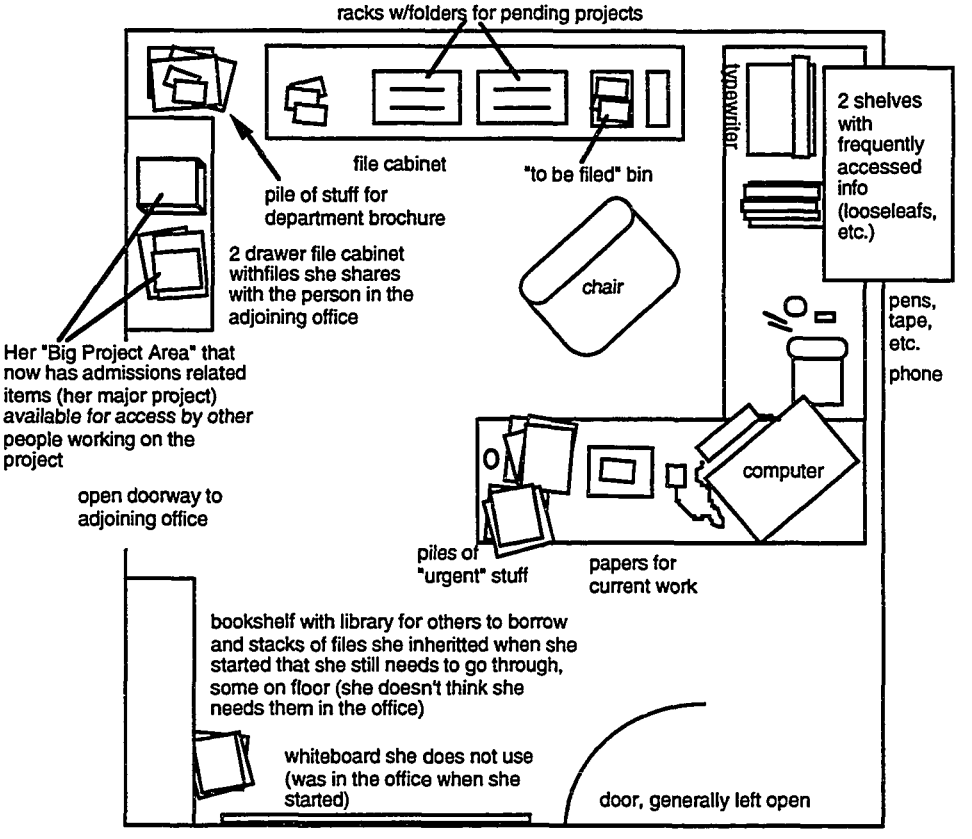
Spatial locations attain meanings in several ways. The central, manually reachable area of a subject's main desk is where current work is usually done. The proximity of items to this central area can represent their urgency or relevance to current work. Locations can attain meanings because of their proximity to tools or other resources. The area near a telephone was often used to place items related to phone calls that

had to be made. Occasionally, meaning is assigned consciously and intentionally, as with a labeled folder or file drawer.

The meaning of a spatial location can evolve over time. Initially, the placement of an item may be incidental, based more on low level features of the situation than on a deliberate decision to establish a meaningful location. For example, the item may be placed in the nearest free space, or in the first noticed location to the side of the central work area. As more items related to the same activity are placed on or near it, the association of the location with the activity is reinforced. The association of activities with locations minimizes the cognitive effort required when searching for or placing items. The subject knows where to look for items related to a given activity, and knows where items related to the activity should be placed.

Examples from my study illustrate the ways space can be used. AD's office (Figure 4) contains racks of folders for pending projects, Above her desk are shelves with frequently accessed information. On the center of her desk are the papers she is currently working on, also on the desk but to the side are two piles of "urgent stuff." She tries to go through this pile when she first comes in each morning, and again at 3:00 or 3:30 to catch items that must be completed that day. She also has a bin with items from completed projects that she needs to file.

Figure 4. The map drawn of AD's office, indicating the different functional areas.



The flat surface above two file cabinets is her "big project area" on which she keeps materials for a project of relatively long duration. This allows her to keep materials related to the project easily accessible with their spatial configuration intact, while freeing her desktop for her immediate tasks. At the time of the study, the "big project area" was currently devoted to the admissions activity. A doorway connects AD's office with that of a co-worker, and the file cabinet nearest the doorway contains files they share.

JC's office includes piles for specific projects or parts of projects (e.g. the marketing, sales and design materials for one project are in a separate pile from the financing and community relations materials for the project), a set of bills to be paid, an in-box with new mail, and a stack of recent business cards on his windowsill. Over the center of his desk is strewn an "inventory of things I have to go through right now that I haven't put in any neat category." JC tends to work on top of these; he places his notebook computer on top of the papers on his desk when he works on it.

KF's office includes several piles representing things to do, divided by urgency. She also has a bin that holds non-critical items she has not yet had a chance to sort through, and piles with items to be filed. Near her phone on a secondary desk are messages related to people she must contact or from who she is awaiting information. Items are left there to remind her of "outstanding issues," even when no specific action on her part is needed.

KF's use of "in-box" and "out-box" piles illustrates how the physical location of items can represent activities, and how the meaning of physical locations can evolve. Initially, the in-box pile was where KF placed items like mail that physically arrived at her office. The out-box pile contained items that were to be physically removed from her office, such as letters to be brought to the mail-room or a paper to be given to a faculty member for signing. The meanings of the piles has grown to reflect the status of items in terms of her current work. KF places items

in the in-box pile that are to be brought into her current work-space, often transferring them from other locations within her office. The in-box thus serves as a queue of items for processing. The out-box pile contains items that are to be removed from her current workspace even though many of these, such as items to file, will remain physically within her office. Items in the out-box pile are further marked by their location within the pile. Items to be removed from the office are placed on the top of the box, on top of a folder containing items to be filed. One of KF's routines is to grab the items from the top of her out-box pile when she leaves her office on an errand that will take her past the mailroom. Keeping the two groups of items distinct helps facilitate this routine.

RW's Desk

Figure 5 shows a view of RW's main office. At the time of the study, he was working on three major projects. On the desk in front of him are three piles corresponding to the three projects. These piles contain documents related to his current work on the projects; they are left out upon his desk so he can access them easily. On the credenza behind him are three vertical bins of folders, again corresponding to the three projects. The order of the bins matches the order of the piles; the bin closest to the wall contains files for the same project as the pile closest to the wall. Piles and folders for the same project thus line up in space.

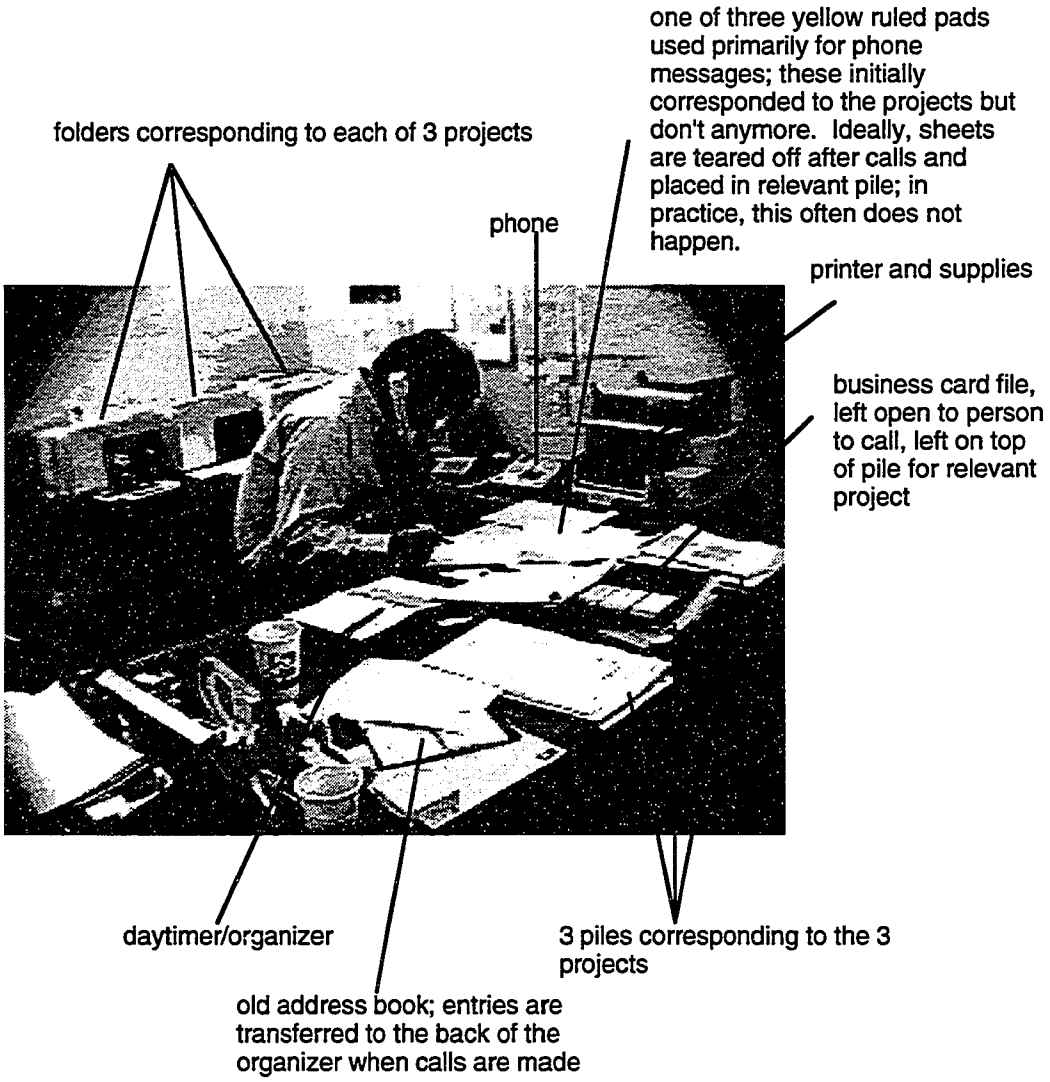


Figure 5. A view of RW's desk, showing the use of spatial locations to represent his three major projects.

The spatial locations marked by the bins and the piles have come to represent the projects. Items left on or near a pile are marked as being relevant to the corresponding project. RW uses this fact to organize his work and to leave reminders of outstanding tasks. In Figure 5, an open

business card album can be seen on top of the middle pile. RW left the album open to page containing the card of a colleague he must contact, and then placed the album on top of the relevant project. By juxtaposing the business card representing the colleague with the pile representing the project, he creates a new structure which represents his ongoing need to contact the colleague about the project.

RW's work involves many outside consultants and contractors, and he receives calls from them throughout the day. These calls are an expected part of his work. When asked during the interview how frequently he was interrupted, RW said "ahh, continuously – y'know, I don't call it interrupted, it's it's that you know it's like being at a party and different people come up to you, it's not interrupted, you know, you interact with many people, in an uncertain fashion, shall we say."

RW has three yellow ruled pads which he uses to take notes during phone calls. At one point, these had also corresponded to the three projects, but they do not anymore. When a phone call arrives, he generally grabs the closest free pad, turns to a fresh page, and jots his notes. In Figure 5, RW is in the midst of a phone call and is taking notes on one of the pads. A second pad is partially resting on the business card album on top of the middle pile. The pad is open to a page containing notes on a matter RW needs to work on that day. The placement of the pad on the center pile connects the information on the pad to the project it concerns. The fact that the pad is not squarely on top of the pile but extends into RW's current working area further marks the pad as related

to a more immediate matter than the other items in the pile. By using a different pad for the current call, he preserves the information represented by the placement of this pad.

MS's Desk

Similar factors influence the organization of MS's desk, shown in Figure 6. At the time the picture was taken MS was insuring that the academic files for the department's faculty were complete. The central area of her desk contains materials used in this activity. MS is sending an email message to one faculty member requesting that he review and sign two documents for his academic file. Piles on the left of her desk contain items for other short-term and ongoing projects. MS places items to be taken from her office on the far edge of her desk, marking the items and making it easy for her to grab them as she leaves her office. The folders overhanging the edge of her desk, conveying a sense that they are in the process of leaving her workspace. One of these folders contains the documents for the faculty member to review; MS will bring it to his mailbox the next time she leaves the office.

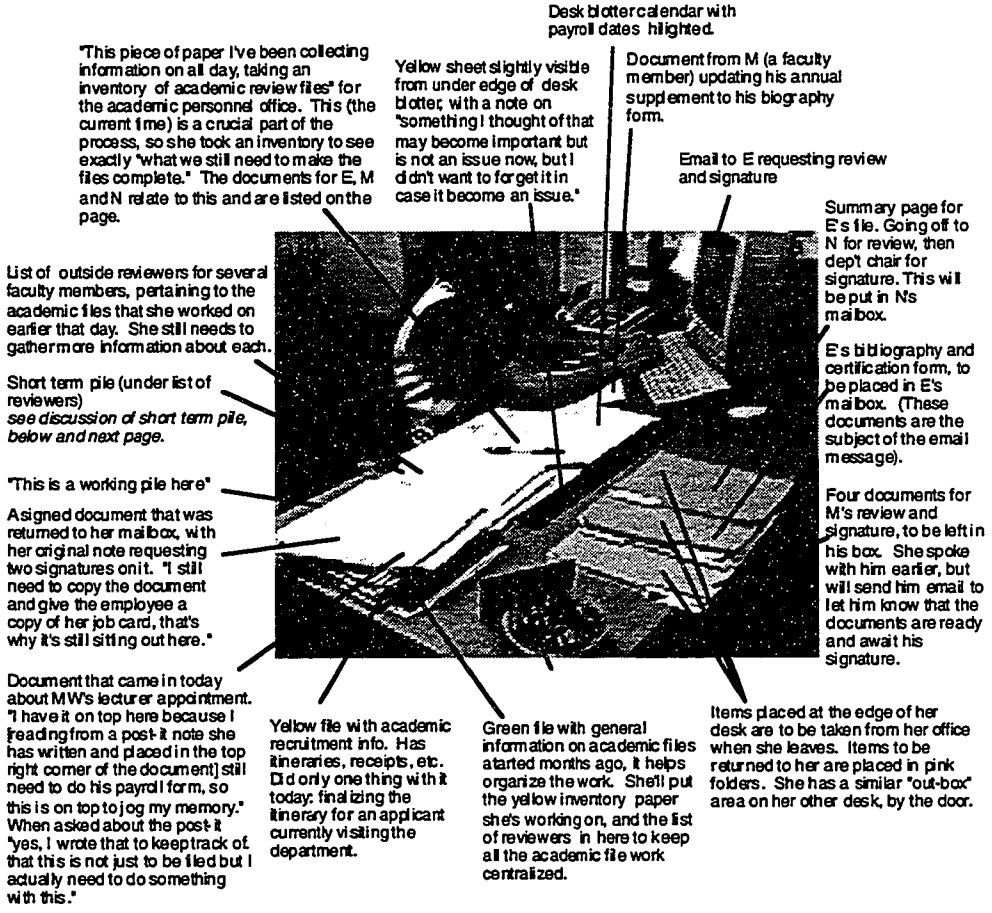


Figure 6. MS's office, showing the use of spatial locations to represent information on current and pending activites.

MS's desk reflects the subtle meanings spatial locations can convey. A blotter-sized desk calendar covers the center of her desk. (MS uses this to keep track of payroll dates, which she has hilighted.) The calendar has a vinyl edge covering its top edge. A yellow slip of paper was barely visible protruding from beneath this edge. MS said that this was "something I thought of that may become important but is not an issue now, but I didn't want to forget it in case it become an issue." The

placement of the note leaves it barely visible, but clearly distinct from MS's existing activities.

Space and Computer Layouts

The importance of spatial layouts is evident in the ways subjects structured their computer screens. Figure 7 shows a view of KF's computer, and Figure 8 is a diagram showing the screen's layout.

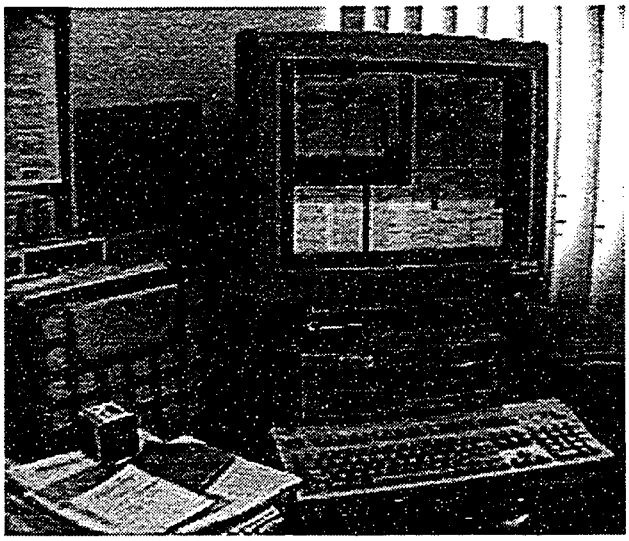
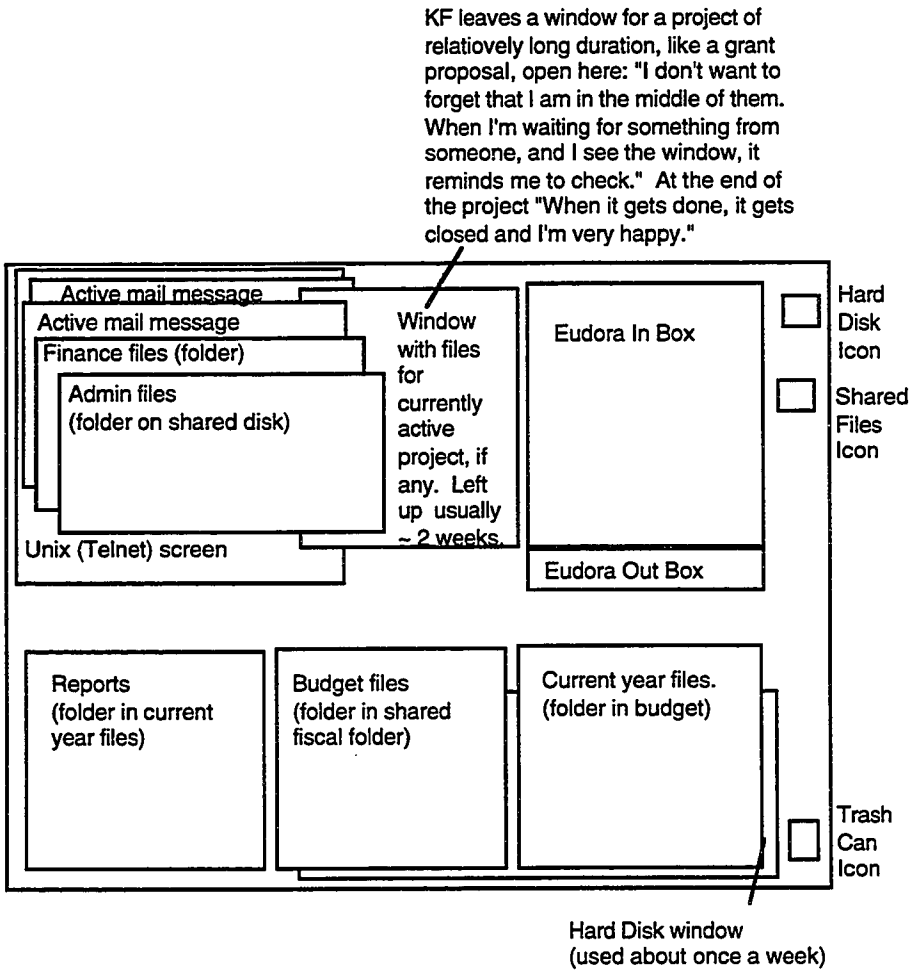


Figure 7. KF's computer screen, showing the use of windows to organize activities in dedicated spatial locations.

The screen's organization reflects two goals: maintaining a visible manifestation of ongoing activities, and insuring that different activities do not intrude on each other. KF has structured her large monitor window so that activities take place in distinct areas of the screen. If KF is working on one activity, she can handle interruptions involving other activities on the computer without disturbing the windows she was

using. Email windows are kept open in the top right corner of the screen.

Figure 8. A map of the areas on KF's screen, showing the use of an open window to keep a visual manifestation of an unfinished activity.



KF says she leaves a window open at the top center of her screen for projects of relatively long duration such as grant proposals (Figure 8). She says "I don't want to forget that I am in the middle of them. When I'm waiting for something from someone, and I see the window, it

reminds me to check." Closing the window is a visible sign that the project is no longer an outstanding goal. "When it gets done it gets closed and I'm very happy."

The organization of MS's computer screen (Figure 9) reflects similar considerations. MS leaves windows open for open projects to help "jog" her memory. These are left on the bottom half of the screen.

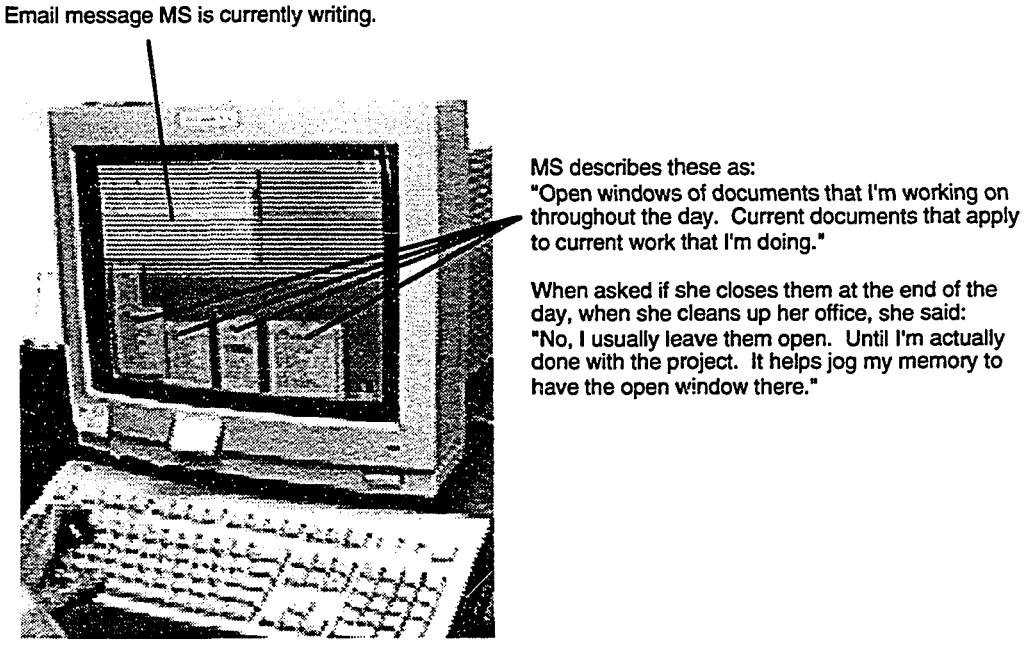


Figure 9. MS's computer monitor, showing windows left open to "jog" her memory and paper reminders affixed to the bezel beneath the screen.

Both KF and MS keep windows for email open in a top corner of their screens. Writing or reading email messages is a component of many of their activities, and this lets them do so while keeping the windows related to those activities visible. It also enables them to check the headers of arriving email messages at a glance, allowing them to

evaluate such interruptions with minimal disruption to their current work.

NL was atypical in her use of diskettes to store her computer document files. She has a set of ten diskettes which she keeps in a drawer under her personal working desk. These diskettes are neatly labeled by subject matter; each diskette contains all the files related to a specific topic or activity. NL said that having a physical item "she can hold in her hands" associated with each activity helps her keep track of which files are where. Shortly after my interview, I asked in an email message whether this use of diskettes might be a vestige from the earlier computer she had used. She responded:

> Yes, I did use the diskette-type system with the original PC I had in my office, which essentially was a clone of the original IBM PC XT. I had a really small hard disk then, so that may have been part of my reason for keeping stuff on diskettes. But I think probably the major reasons were the ones I told you: I find I can keep track of organization better this way and also it is easy to bring home just the files that I am currently using. (NL email message, 3/24/95)

Dedicated External Artifacts

Subjects also used dedicated artifacts whose primary purpose was to help them manage and remember activities. These ranged from formal to-do lists and calendars to hastily scrawled post-it notes. Dedicated

reminders were used for time-critical activities. Subjects desired more explicit reminders than might be provided by existing items, and wanted to leave them where they would be sure to be encountered. Dedicated artifacts were also created when there was no preexisting physical item to use as a reminder. For this reason, dedicated notes were frequently created when information was received by telephone.

For example, AD makes written lists of things to do when things are especially busy, but says she sometimes loses the list. She crosses off items when she completes them, and the list helps her insure that no task is forgotten. It also lets her gauge visually how much work is left. She says: "I feel I need it, like if I have a lot going on and things are... in part to insure that I finish what I have to do." At one point she had "tried putting little stickies everywhere" to use as reminders, "but that didn't work." She would "get piles of little notes everywhere and that was very confusing."

KF occasionally writes lists of things to do. These help her insure that she completes critical projects despite diversions caused by interruptions. She says: "usually, it's just like a list of about five things that I will put down and say 'OK, I really have to get these things done today', cause often I get interrupted or sidetracked and if I have the list it helps, cause I go 'oh, right, I have to finish that' if they're sort've project kinds of things, such as 'make sure I get the signatures and make copies and get it to such and such an office', or 'make sure I finish this particular grant and put it in the professor's box because they need to make some

sort of budget decision.'" KF writes notes on small pieces of paper when she has no existing physical representation of an issue. She places these notes in different areas of her office to mark their relevance to her activities. She describes, for example, the notes she has left in her "in-box" pile: "Those are sorts of things somebody has asked me to do, but I don't have [gesturing to "in-box" pile] pieces of paper to remind me, kind of, they are either things that are gone or that are totally in the computer, and I won't remember otherwise, it's sort of like a memory aid kind of thing."

MS says she writes brief notes on post-it notes and puts them across the bottom bezel of her computer monitor "if I need to jog my memory about something." She generally uses one post-it for each item, but sometimes puts two related items on one sticky with a dotted line between them. She places them on the computer so "they will be the first thing I see, to jog my memory in the morning."

MS also keeps a weekly to-do list on a copy stand mounted on the side of her monitor. She created a form for this list with sections for each of her major areas of responsibility. She explained: "This is a logical sequence for me to break my work up into so I can ... keep it separated into the general areas." She writes items by hand beneath the typed section headings. These are items "that people have asked me to do or that I know I have to do. It's a memory jogger too. A little more long-range memo-jogger; the notes I put up here [she taps her monitor] are more short term." She crosses off items as she does them.

A problem with the formal to-do list arises from the effort needed to add items. "I have found that this [taking formal to do list from the side of her monitor] is somewhat effective but not totally effective, because as the day goes on I get phone calls and people come in I find myself not reaching up to write something on this list. What's proved to be more effective for me is to have little sticky notes." At several points, MS wrote information on post-it notes and then affixed them to the appropriate areas on the to-do list. Later, when she removed the list from its holder to add a new item, she also copied the items from the post-it notes and threw them out.

In general, MS tries to review the list and create a new one each Friday afternoon, before she leaves for the weekend. The list serves as a focus for planning the next week's activities and lets her externally represent information she might forget during her absence from the office. "...I've tried to get into the process of really looking at it on a Friday, before I leave, so I can get things down here that have been on my mind all week long, before I leave for the weekend and I might forget something. And then I can glance up at this Monday morning and say, oh yeah, I needed to do that, or I have to work on that this week." Although she tries to do this weekly, "sometimes the same list stays up for two weeks." Old lists are stored behind the current one, held in place with a paper-clip. This provides MS with a history of her major activities.

The Role of Paper

The use of paper in the workspace points to the value of having physical manifestations of information. This was seen in the way subjects printed out email messages. Subjects often printed email messages to place them in locations where they could serve as reminders. For example, MS had received an email message from a faculty member requesting a brief official letter. With the email message still open on the screen, MS opened her word processing program and typed the letter. She printed both the letter and the original email message. She left the letter for the department chair so he could sign it, and placed the email message on her short-term work pile. She explained afterwards: "I do that a lot to remind me of things, so I don't forget that D needs it and that J is going to sign the letter." While the letter was with the department chair for his signature there was no physical representation of it in MS's office. She printed the email message to use it as a reminder that the task was not complete.

Creating a physical manifestation of computer information allows the information to be inserted into the meaningful spatial scheme that exists in the office. This marks the information in terms of its relevance to the subject, and helps insure that the information will be encountered during activities that need it. NL lectures and edits or writes chapters on several medical topics, and she keeps a folder for each of these topics. When she receives a notice, accesses an abstract, or is sent an article related to one of those topics through her computer, she prints it out and

inserts the printout in the appropriate folder. When the time comes to prepare a lecture or article, she takes out the folder for that topic and goes through it, insuring that she will be reminded of relevant information she received throughout the year.

NL also relies heavily on her traditional calendar/organizer book. "I'm lost without this thing and I have been known to make trips back to school if I've forgotten it, because I have my whole life written in here." She has a calendar program on her computer, but prefers the paper calendar for two main reasons.

One advantage to the paper calendar is its portability. "...I need to have something that I can carry with me. And this way I can put stuff to do with the rest of my life, and always have it with me, so this." "In fact, I keep this when I'm at home just out in the kitchen on the counter...Really orients my schedule so I rely heavily on that." While at work, she leaves the calendar open on the desktop beside her phone. When at home, she leaves it open on the kitchen counter near the phone she tends to use. The calendar provides continuity between her office and home, letting her transfer some of the external structure on which she relies. This is particularly important to NL, who works half-days in her office and frequently handles work-related matters at home.

The second advantage to the paper calendar is the ease with which it can be accessed without disrupting her current activities. "I tend not keep a calendar in the computer, because I did that for a while in the

other office; I would keep a calendar there and to-do list there, but I found that it just seemed a nuisance to have to exit what I was doing just to go look at it. I didn't have Windows so I guess now you could set it up with a window and it might be easier to use, so... I haven't tried that."

Portability is a factor in JC's use of paper notes. JC does much of his work outside of his office–in his car, at sites, or at meetings with associates. JC states that he writes to-do lists on pieces of paper that he can fold and place in his shirt pocket. "I did organize a to do list on this [taps notebook computer] um but the problem is when I'm in the car, I can't access it, and so if I'm if you're trying to make calls from the car, and I don't have the numbers down, so sometimes I'll pull it up [points to the notebook computer] and I'll write down four people that I must call, must talk to, you know on my way home try to get them, or on the way from one place to another."

KF has a printing calculator which she uses extensively during many of her activities. She prefers it to the calculator program on her computer because of the record the paper tape provides. "I hate it [the calculator on her computer], because I can't look back at it anymore. See like with these [motions to the paper tape coming out of the back of the calculator; note that "these" in plural refers to the calculations or sections of the tape] I can, there's a permanent record, so if I add it up and then want to refer to it ten minutes later or even a day later, because I tend to leave the tape on for like a week or two at a time, I can just pull through the tape and find it again very easily."

On a subsequent visit to her office, I noticed a particularly long trail of paper tape coming out back of calculator. The tape was 190 inches long, representing approximately 950 lines of calculations. When I asked how long a period of time the tape represented, she looked at the earliest calculation on the tape, recognized the calculations, and then retrieved the file for which the calculations had been done. She was able to determine quickly from information in the file that the tape represented a one month period. She said that she tears off the tape when she "can't stand the clutter." She rips it off and drops it into the recycling box beneath the table with the calculator, where it often stays for a significant time afterwards. This serves as a form of archival storage; she has sometimes gone to the recycling bin to retrieve a calculation from a tape.

The paper tape also allows KF to share her calculations with others. "When people give me receipts I add up their receipts on the calculator, if there are human subjects receipts, sometimes there are thirty of them , say and it's easier, its easy to punch them in and then I have a tape that I can attach to the receipts when they go to accounting so it saves accounting a little bit of time because they don't actually have to do it, they don't have to keypunch it again." This helps her maintain good relationships with people in other departments, which KF sees as important to her job.

Insuring that External Artifacts will be Encountered

Because subjects depend on physical items to cue their activities, it is important that they encounter these items at appropriate times. Subjects

have developed routines to insure that they come into contact with items they rely on to prompt their activities.

One of JC's general activities involves maintaining relationships with a large number of colleagues and acquaintances, including developers, architects, lawyers, civic leaders and local politicians. It is important that JC keep in touch with many of these people even when no specific goal or deadline requires it. JC gains valuable information about the local business situation from them, and they can play influential roles in helping JC get approval for his projects. JC relies on several external structures to keep track of these people, including a traditional address book, a business card album, and a stack of recently received business cards. JC has developed routines to insure that he will come into contact with these structures, and will thus be reminded to contact the people.

"I've got a little old style phone book and it's fast but I get very frustrated when I'm looking for a phone number and I can't believe that someone I do business with that often isn't here."

"And then another way that I keep track of people [reaches for large business card binder]" "...but this is a card thing which is very helpful to me because it allows me [flips through binder] there are certain people just graphically it stands out [points to a card with a multicolored design] and it's alphabetical and every now and then I'll go through it and I'll say

wow, I haven't called like Jack C for months, call him, or I'll look through my phone book for people I'm just getting out of contact with."

JC keeps the most recently received cards in a separate stack on his windowsill. From time to time, he flips through this stack so that he will be reminded about the people who gave him the cards. He purposely keeps this stack of cards distinct from the rest; they represent people with whom he has current dealings.

"Then I've got over here [picking up stack of cards on windowsill] this is my inventory of business cards which I've gotten recently and I don't file them in there for a little while so that I've got like real current ones out here cause then it reminds me when I look through them just if I had to call them or follow up with them."

Keeping phone numbers in different places helps JC group and characterize them. It helps him insure that recent cards are encountered on a regular basis, though it presents problems when JC needs to find a specific phone number. JC complained about his frustration when a number he needs is not in his address book, and described the problems that arise from having several places for phone numbers: "So I've got like six places to look for phone numbers and this is one of those things I'm trying to get into this mode where I have one place where I know I have things but I haven't figured out how to do it yet. Probably if I had one of those little hand-held things but there's it's sort've like there's just so much business equipment I can deal with." He alludes here to the

overhead required to learn and use new technologies, a problem he had mentioned several times during my interview and observations.

KF has a bin on her desk containing folders labeled with numbers from one to thirty-one, corresponding to the days of the month. She uses them to store meeting announcements and other items that should be dealt with on a specific day. "It's got a number for each day so if there's something urgent I'm supposed to do that day, or some reminder thing I stick it in there." When describing her procedures she said that she adds items to the appropriately dated file throughout the day when she gets them. "Well actually in the beginning of the day I usually take out the folder, pull out the stuff, put it – look through it quickly and put it in my in-box, and then you know put the day's folder back there."

Although checking the dated folders each morning is part of her stated procedure, it became clear that she does not always follow it precisely. When we came to this bin during the office tour, KF realized that she hadn't consulted it for the last two days. She pulled out the folder for the current day and processed the items in it one by one. "Like today [pauses as she removes the folder] I'm supposed to check, oh [looks at the first item in the folder] on some photocopier stuff, [flips to next item] and computer access stuff, [flips to next item] and graphics stuff, and [flips to next item] check to see if I got a credit which I did so I don't need that [places the item related to the credit in her "to be filed" folder] and sometimes [places the folder on her "in-box" pile] I get a day or so behind, [takes out the folder from the previous day] which of course is no

good when I've got a meeting reminder in there, [removes an item from the folder and places it on top of her "in-box" pile] but it usually works." Although KF does not rigorously check the folder each day, the expectation that she will leads her to rely upon it when leaving reminders for herself. She continues to insert time-critical items into the dated folders. Assuming that she follows her stated procedures, this means of organizing items will insure that they are encountered at the appropriate time to trigger the desired activities.

While I'm At It Activities

People engaging in one activity often encounter items related to other activities. This can lead to interruptions or multitasking when an item prompts performance of the activity associated with it. Such "While I'm At It Activities," as Cypher call them, were apparent throughout my study. They were seen clearly during the office tour, while the subjects were describing the items in their offices in detail. Although the subjects' ostensible activity was the tour, they often performed other tasks of short duration as they encountered items in their workspace.

For example, while JC was describing one of the piles on his desk he leafed through the items in the pile and handled each as he came to it. "I'll get something like 'Developing Urban Entertainment Destination Projects' [reading title from a conference brochure he holds], and it's something I should go to but I'm not ready to make a decision because I don't know if I'll be able to go, but I don't want to throw it away so I save

it until the date's past and then I can throw it away because I'm obviously not going [throws the brochure in the trash]." He continues to leaf through the items, and pulls one out. "This is an idea that I saw in New York for um a temporary marketplace called Grand Central Spring Market which I thought was absolutely phenomenal. Oh good, this is where this is, this goes with this" he says, reaching to put the item on top of his "new ideas" pile.

Later in the tour, JC described the contents of a bookcase in his outer office. He noticed a battery on one of the shelves and picked it up. "This is a battery to my dead Compaq computer that I can't use, it's probably even safe to throw that out. Oh what the heck [throws the battery in the trash] I always hate to throw things out."

JC had previously described his style of work as interrupt-driven, saying "I'm just one of those people that tends to field everything as it comes in". It was not surprising that he interrupted the office tour activity to deal with items he came upon. But similar behaviors were seen at every one of the sites. Each of the subjects performed actions not necessary for the tour with items they encountered during the tour. Subjects occasionally moved an item to a more "correct" place. For example, as NL was describing the items on her desk, she came to a stack of opened books. "These are the physiology books that I want to review, because I want to get some ideas about if for this new physiology book that we're editing is going to come out, what sort of things I might keep in mind for improving that." She left those books where they were; they

were needed for a future activity (reviewing the books) and their presence would remind her to do so. Then she came to another book, also open on her desk. "This is the physiology book that I had written before that I don't need to have out now because... I'm going to put that away." She picks up the book and puts it into a bookcase. "I probably had that out because when I was working with students I was looking up stuff in there." The office tour may have encouraged subjects to think deliberately about the location of items in their offices, and provided an opportunity free of other activities in which they could perform such cleanup actions.

Stabilization Routines

Subjects performed actions whose primary purpose was to maintain the efficiency of their work environment. These included returning tools to their places, clearing off the central work area, and filing documents that had accumulated. Hammond et al. have termed such actions *stabilization routines.*

For example, KF periodically files the contents of her "to-be-filed" pile in the topic-specific cabinets in her office. Filing is a stabilization activity; it is not required for any one activity but is necessary for the smooth running of the office and will make future activities more efficient. The filing activity is not triggered as a direct subgoal by her other activities, so it must be cued in other ways. Several events trigger filing:

1. If she notices that the pile is more than a few inches thick;

2. If it takes her more than about ten minutes to locate a document she needs;

3. When she has to reconcile the department's books. Reconciling the books is a periodic, scheduled activity that is much more efficient when all the receipts are in their proper files.

Filing is thus triggered by perceiving a physical attribute of the pile, by failure of an activity that depends on the filing, or through the execution of an activity that directly depends on the filing. These parallel conditions Hammond, et al. discuss as potential cues for stabilization activities. KF could theoretically file items immediately when she is finished with them instead of putting them in the intermediary "to-be-filed" folder. Performing the filing in one batch may be more efficient due to economies of scale. It also isolates the filing actions, minimizing their effect on her other activities.

Preparation for Interruptions

Subjects had several strategies to prepare for interruptions they anticipated. Subjects prepared for two classes of interruptions:

1. Unexpected interruptions from others during the course of their activities. Subjects could not predict exactly when such interruptions would occur, but had learned to expect them in general;

2. Scheduled or self-caused interruptions to their activities.

Unexpected interruptions included visitors and phone calls. Scheduled interruptions included the need to suspend activities to attend a meeting, to go to lunch, or before leaving the office at the end of the day.

Subjects had several strategies to minimize the disruptive effects of unexpected interruptions. Over time, subjects had come to learn the topics that interruptions commonly involved. They left information they would need to handle such interruptions where it could be accessed quickly, without disturbing items they had out on their desk. Such information was often taped to the wall or tacked onto a bulletin board. KF, for example, kept a calendar with paydates taped on her wall. Although this information was not critical to her job, she said that people often came in to ask for it. NL kept a card with photographs of first year students open on her counter where she could glance at it quickly (and surreptitiously) if a student dropped by her office. RW kept a sheet of information related to an insurance claim taped to the wall above his desk where he could refer to it easily when adjusters or attorneys called. Subjects similarly kept the tools they would use to handle interruptions, such as note pads and pens, in expected, easily accessible places. MS also kept a tray with scratch paper and pens on the table by her door. She explained: "People always come in and need to write something down that may be payroll or personnel related and then they have that available to them." Before she left the tray out, she often

had to interrupt her work further to find a piece of paper and a pen for a visitor to use.

The main way subjects prepared for scheduled interruptions is by externally preserving the state of their activities. Subjects frequently left reminders for themselves before they left their office, and often left items they needed to work on in prominent places such as the center of their desks or on their keyboards. JC described how he leaves reminders for himself before he leaves if there is something critical he has to do: "...I'll just take a piece of paper right out of the printer [motions to computer printer behind him] and I'll just write a neat little note over here and leave it on my chair or right on the middle of my desk so it's the first thing I see in the morning before I put something down on top of it."

MS said that at the end of the day, "If I do have a lot of work sitting out, I organize it into the area where I can find it the next morning, and if I have pending things, I will usually make out a little list of what needs to be done the next day just in case I don't remember." MS also creates a formal to-do list on Friday afternoon to protect against forgetting things over the longer interruption imposed by the weekend, as was discussed above.

Multitasking

There was evidence throughout the tapes of subjects performing several activities at essentially the same time. Subjects continued working on their current activity during interruptions, and took

advantage of pauses in one activity to pursue others. This often led to situations in which their processing resources were split between the two activities. Subjects often performed manual actions related to one activity while talking on the phone regarding another. Furthermore, they developed procedures which increased their ability to perform such activities at the same time.

The following extract from JC's office illustrates a technique he used when making phone calls. By leaving the handset in the cradle and dialing with the speakerphone, he kept his hands free to continue working on other activities for as long as possible. He picks up the handset only after he reaches the person he is calling. (When discussing this extract he said that he prefers to talk using the speakerphone because it leaves his hands free but people find it rude and impersonal. He believes this is partly due to their perception that he is not devoting his full attention to the call, but is doing other things at the same time.)

In this extract, JC calls an associate to discuss a property in another city. He also works on his notebook computer to prepare an agenda and press release for a meeting regarding an unrelated project. JC reads the number from a sheet he takes from his pocket, and dials the associate using the speakerphone (Figure 10).

Figure 10. JC dials a call using the speakerphone. His notebook computer is open in the center of the desk.

00:02:33	returns to desk, pulls paper from shirt pocket, looks at number and dials phone (on speakerphone) consulting paper
00:02:46	starts working on powerbook (preparing agenda and press-release text for meeting with public relations firm later that day regarding loft renovation project)
00:02:49	ring heard from phone, JC continues to work on powerbook
00:02:52	phone is answered with name of company. "yes, is K____ there?" "speaking" (J continues working on powerbook, glances down to paper with information related to the work he is doing on the powerbook)

He continues to work on the notebook computer until it is clear that he has reached K. He picks up the handset as he begins the conversation.

00:02:56	"Hi, K___, this is J___C___ (JC turns and moves hands to phone)
00:02:57	JC picks up phone, presses button to disconnect speaker, "good" (faces powerbook again, holding phone in left hand to ear) "how are you doing"
00:03:01	"sure" (JC is put on hold. He places phone in crook of neck, and continues to work on powerbook)

Figure 11. JC placing the telephone handset in the crook of his neck while continuing to work on the notebook computer.

Almost immediately after he picks up the handset, JC is put on hold. JC puts the handset in the crook of his neck and works on the computer during the forty seconds he is on hold (Figure 11). This appears uncomfortable; had he known that he would be on hold, it is likely that he would have left the speakerphone on and kept his hands free. JC continues to work on the computer as he is taken off hold and the conversation resumes. He also sips coffee from a mug on his desk.

00:03:41	"yes" (JC no longer on hold, continues to work on powerbook) "yes, yes. Did N____ send out, he was going to FedEx out... (conversation to confirm that a power of attorney document had been sent out, and that it was sent to his home. JC continues to work on powerbook during conversation. Takes sip of coffee.)
00:04:00	"yeah, sign the waiver in case no one's there" (types some more into powerbook)

As the phone conversation shifts to a question that K raises, JC turns from his desk to face the window on the left (Figure 12). This is something he does frequently when a call requires his concentration. By

turning to the window, JC shields himself from the distractive effects of items on his desk.

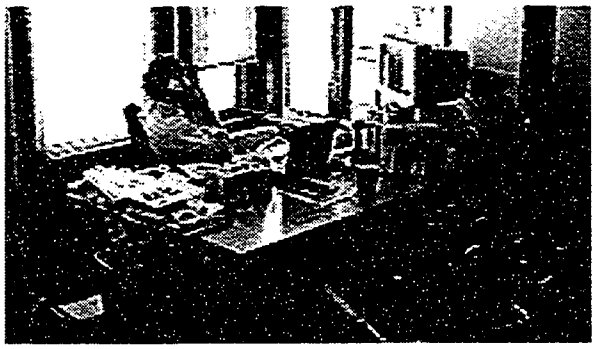


Figure 12. JC turns to face the window to his left, suspending his work on the notebook computer.

00:04:10	"great" JC takes sip of coffee, then turns away from desk, faces window at left, leans back in chair, continues conversation. "I know what it is, yeah" Conversation continues about a problem with a fine and fees owed to the city due to violations by a previous tenant. JC asks for advice on his liability and appeals he can make.

As the conversation draws to a close, he turns back to his computer and resumes working on it. But then K raises an issue which again requires his attention, and JC turns to face the window again. K asks JC to send him a copy of a billing statement. JC does not have a copy with him in the office, but says he could send one tomorrow.

00:08:32	"OK, K___" (preparing to end conversation, turns back to powerbook and starts working.)
00:08:49	"yup, em hmm" (now moves hands off powerbook again, takes sip of coffee, then turns from desk facing window at left)

00:08:58	"well, I don't have it in my office with me, so I would do that tomorrow, you mean like a regular billing statement that we would get from them" (conversation continues)

While JC is closing the conversation with K, his second line rings. JC jots a reminder to send the billing statement on the paper with K's number as the phone rings a second time. The phone ringing makes ending the first call more urgent. JC speaks quickly as he thanks K, and ends the call with a decisive "bye bye". He presses a button to answer the new call.

00:09:13	"right, right, right, will do" Second line of JC's phone rings. JC picks up pen and writes note on the paper he had consulted with K___'s phone number. "ok" Second line rings again. "Great, thanks so much, K___" <said quickly> Second line rings again. " bye bye"
00:09:24	reaches toward phone, presses button to switch lines, "J___ C____, S__ D__M__<company name>" <pause> "Hey, B___, how are you?"

After finishing the second phone call, JC worked on the notebook computer to prepare for the meeting. The following extract is from that period. It contains further examples of multitasking, and shows how encountering an item by chance can cue unplanned "While I'm At It" activities. It also illustrates the use of a pre-existing item as a reminder.

While writing the text of a press release he will discuss at the meeting, JC wants to consult a faxed document he received earlier that day. He rummages through the items on his desk as he looks for the document. While doing so, he returns several items to their established

places. He notices an advertisement for a computerized builders guide, looks it over, and decides to purchase the guide. He dials the number on the advertisement using the speakerphone. While the phone rings, he drinks a sip of coffee and takes out his credit card in preparation for ordering the guide.

00:23:15	looking through items on desk for faxed document he needs for the activity he is performing on the powerbook (lifts papers, moves tissue box back to far corner of desk, moves stapler from near right to front far right pile)
00:23:37	while looking, notices document advertising computerized building guide. JC picks up the document and looks it over
00:23:43	dials phone while consulting number on document (using speakerphone), takes sip of coffee. 2 rings heard on phone.
00:24:03	JC reaches into back pocket for wallet, takes wallet, removes credit card and places it on desk

The phone is answered by a voice menu system. During the greeting and introductory announcement, JC resumes his search for the document. He locates it, and places it to the side of his notebook computer. He starts to type on the computer. He hears the first menu selection, and presses the button on his phone with his left hand while keeping his right hand on the keyboard. (The phone is on his left side. JC is right-handed.) The voice menu system responds "please hold". JC props the advertisement upright (Figure 13) and returns to working on the powerbook.

00:24:08	phone answered by voice menu system. "Thank you for calling xxx multimedia. Please listen to the following instructions that will enable us to expedite your call" JC rearranges papers on desk, and finds one which he places to the left of his powerbook. He starts to type on powerbook, then hears: "If you have your credit card and are ready to place your order, please press 1 now."
00:24:17	JC presses button on phone with left hand, leaving right hand on powerbook keyboard
00:24:19	hears "please hold" lifts advertisement and props it upright, then returns to working on powerbook

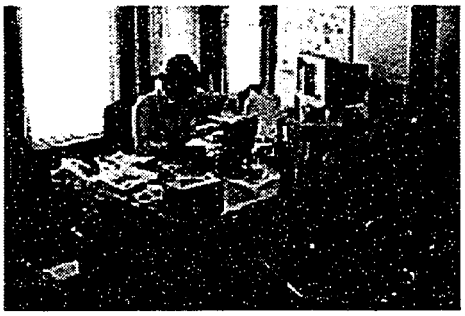


Figure 13. JC props the advertisement upright where he can see it, maintaining a visible representation of the topic of the phone call while he resumes work on the notebook computer.

Placing the advertisement upright makes it easier to locate should JC wish to refer to it during the call. It also marks the advertisement as current, letting it serve as a visible reminder of the topic of the phone call.

JC keeps typing as the phone is answered. He stops typing, says "Hi", and then "uhhh" as he looks at the document. He requests the guide.

00:24:27	(JC keeps typing) ring "Thanks for calling ___ multimedia. this is B___"

00:24:29	(JC stops typing) "Hi, uhhh (looks at advertisement) I would like to order the Builders Buyers Guide on CD ROM"

He is told that the new version of the guide is not yet available. He asks if he can place an advance order, but is told that he cannot. He asks when he should call back to order the new version and is told to do so in mid-August. Glancing at a calendar on the wall, he determines that this is about two weeks away. He thanks the salesperson and presses a button to end the call.

00:24:34	"the version that's available now is still the 1994 version, the 1995 is now due in about mid-August"
00:24:41	"mid-August..." (looks to calendar on wall) "can I put in my order now and you'll just send it to me as soon as it comes out?"
00:24:44	"well unfortunately there's no, I don't have a backorder list, if I put your name in now you'll still get the 1994 version automatically"
00:24:51	JC picks up the advertisement, looks on desk for something (apparently a pen). "what day should I call back in order..."
00:24:53	"well, we're hearing, the last I heard is mid-August"
00:24:56	"mid-August, that's about" (glances in direction of wall calendar) "two weeks from now"
00:24:58	"right, uh huh"
00:24:59	OK, good deal, thank you" (presses button to hang up speakerphone)

JC made this entire call using the speakerphone. As mentioned above, he prefers to use the speakerphone but refrains from doing so with people he fears offending. He did not see this as an issue with this call.

Although JC had hoped to complete the task of ordering the guide right away, the task must be suspended until the new guide is ready. He folds the ad in half and writes "call mid August for 1995 edition" on it, then pins the ad to his bulletin board as a reminder (Figure 14).

00:25:02	moves hand above desk as if looking for something, folds the ad in half, locates and picks up pen and writes notation on ad
00:25:18	stands and pins advertisement to top bulletin board, on the wall to the side of his desk.

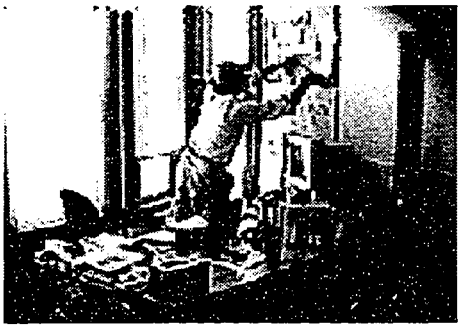


Figure 14. JC pins the advertisement to his bulletin board as a reminder to order the software it describes.

After pinning the advertisement to his bulletin board, JC sits down at his desk to continue his work on the notebook computer.

00:25:21	sits down, looks momentarily for papers he was using with powerbook, finds them, taps them on desk to straighten them, moves items on desk, types key on powerbook to turn screen back on, puts card back in wallet, puts wallet back in pocket

Actions to resume work on the computer (locating and straightening papers, turning the screen on) occur before he completes the final cleanup from the ordering activity (putting the credit card

away). Such gradual transitions between activities were seen at each of the sites.

I checked with JC three months after this extract was taped, and he still had not ordered the guide. The ad was still on his bulletin board. He said that he occasionally writes reminders to do something on a specific date on his calendar, but that the ad "had a graphic that was memorable, it was a magazine ad with bright graphics, would have a chance of standing out." Using the ad also let him create the reminder quickly. "It takes a second, a pushpin." This reflects an advantage to using existing items when creating reminders. The item already represents much of the meaning the reminder is meant to convey, reducing the amount of additional effort required to create the reminder. Here, however, the reminder was not effective. It did not lead JC to order the software at the desired time. The ease of encoding the reminder using the existing advertisement may have led him to use it even though it was not as effective as a dedicated structure, such as a calendar entry, might have been.

Summary

In this chapter, I discussed the office activity study I conducted. I discussed my major findings and presented examples to illustrate them. To summarize:

1. Subjects had difficulty delineating their activities. Although no single criterion was adequate in defining activities, subjects used

the amount of effort and attention required to determine if a set of actions should be considered a separate task.

2. All subjects had daily routines which included checking for accumulated communications (email, phone messages) at the start of the day, and this influenced their choice of activities to pursue.

3. End of day routines included cleaning up from the debris of the day's work, externally representing information that had been stored internally, and creating reminders for pending activities.

4. Subjects used interruption free periods for planning, to complete activities, and for activities that required intensive concentration.

5. Subjects planned their activities in differing amounts, but all reported frequent departures from plans they did make. Interruptions and unanticipated issues limited the extent to which they could make accurate detailed plans.

6. Subjects relied on the external environment to cue their activities, and modified the environment so it would do so.

7. All subjects used the spatial organization of meaningful items to represent task relevant information. Locations acquired meanings, and items placed in those locations were associated with those meanings.

8. Subjects used dedicated artifacts to remind them of time-critical activities, where there was no existing physical item associated with an activity, and as a focus for planning and prioritizing their activities.

9. Traditional paper artifacts have affordances which led subjects to prefer them over computerized tools in many situations. Paper offered the ability to place information flexibly within spatial schemes. Paper was also valued for its portability and the permanent physical record it could provide.

10. Subjects developed routines to insure that they would encounter the external artifacts on which they relied. Although subjects did not always follow the routines they reported, they relied upon them in determining how to leave reminders.

11. All subjects performed "While I'm At It" activities, in which an item encountered while performing one activity leads to performance of another.

12. Subjects performed routines which stabilized their environment. These routines made multitasking easier and minimized the disruptive effects of interruptions.

13. Subjects modified the external environment in preparation for scheduled and unexpected interruptions.

14. All subjects engaged in multitasking, in which they performed several activities at the same time. Furthermore, subjects developed routines which increased their ability to multitask.

In the next chapter I look at one episode in depth, and show how these phenomena combine dynamically to shape behavior.

Chapter 5

Activity Management in a Dynamic Environment: Twenty Minutes in Detail

In this chapter, I present a detailed analysis of one segment a subject's workday. My goal in presenting a continuous segment of behavior spanning several activities is to clarify how the placement of physical items, the establishment of locations with which meanings are associated, and the existence of regular routines interact in real-time to support the management of multiple activities. This segment represents twenty minutes in the life of subject KF, the financial officer of an academic department in a large university.

The specific segment discussed here contains examples of many of the issues of interest to me. These include the handling of interruptions, the use of existing physical artifacts as reminders of outstanding goals, the use of location to mark items with task-relevant meanings, and preparation by the subject for a brief separation from the physical and cognitive contexts of work. The segment itself is not exceptional; it is indicative of the activities and interruptions I observed

throughout the time I recorded this subject. Furthermore, the general phenomena seen here are illustrative of those seen with other subjects as well.

Background

At the time of the study, KF was the administrative analyst for an academic department at the University of California at San Diego. She was responsible for managing contracts and grants, and general accounting for the department. She oversaw the areas of purchasing, staff and personnel although these are primarily done by other employees. KF also maintained the department's software library. In addition to her stated responsibilities, KF served as a general resource on many other departmental issues, as will be discussed further below. At the time of the study, KF had worked at her university for thirteen years. She had held her current position for six years, and has been in the same office during that time. She estimated that about 50% of her work involved other people, though this varied from day to day. She had one scheduled meeting with her supervisor each week, was on four committees that each met once a month, and attended additional meetings during the academic year. On average, she attended two to three scheduled meetings each week.

KF's work with grants and budgetary matters required that she obtain information from, and disseminate information to, many other people within and outside the department. These included investigators listed on grants, faculty who had budgets under their names, staff

members in the department responsible for personnel and other matters, graduate students with funding concerns, and her counterparts in other academic departments. She dealt regularly with people in the university's offices responsible for accounting, purchasing, grant administration, research, and travel. She also exchanged documents with the different granting agencies.

KF estimated that she was interrupted ten to twenty times each day, mostly due to people stopping by her office. She received approximately 40 email messages each day, 20 letters and other printed correspondence, and between 2 and 10 telephone calls.

Social and Organizational Issues

Although it is not the purpose of my research to study issues of social organization in detail, KF's position in the larger organizational setting in which she worked clearly influenced how she determined her goals and handles interruptions. I will therefore discuss briefly the overall role KF played in the department as a whole.

Much of KF's perceived value to the organization stemmed from her ability to provide useful information and assistance with a wide variety of different problems. This was stated both in her own description of her function in the department during the interview at the start of the study and in discussions with other members of the department regarding her work. It was confirmed during the observational stage of the study, as different people approached KF

regarding a range of matters, many of which were not directly related to her primary job description as the department's financial officer.

KF had expertise in many areas owing to the long amount of time that she had been with the department and the variety of different positions she had held. This expertise ranged from knowledge of general university guidelines and procedures to specific information about department projects and personnel. She had interacted with many people throughout the university over the years, so she generally knew who to contact to resolve a problem.. Maintaining good working relationships with such people was important to KF; it added to her own value to the department but also influenced how she conducted her own work. So, for example, she would take the printed adding-machine tape from her own calculations when she totaled receipts submitted for travel reimbursement and attach it to the receipts when she submitted them to the travel department. This saved the travel department work, and likely made them more responsive to her requests.

Because KF was able to assist with many of the matters that others were working on in daily operation of the department, she was interrupted frequently throughout the day. She tended to accept such interruptions. Based on the discussions with her, her ability to serve as a general resource for incidental and unanticipated matters was important to her own perceived value. It should be noted that the department had an "open-door" policy for it's staff members, emphasizing the need for

staff-members to make themselves available to others who need their assistance throughout the day.

It is also beyond the scope of this study to investigate the individual personality differences between people that influence their willingness to assist others at the expense of interruptions to their own work. Suffice it to say that such differences undoubtedly exist, and that, at least informally, KF was seen by others as being quite willing to interrupt her work to help others. Of primary importance to me is not obtaining a comprehensive understanding of the factors that contributed to KF's allowing herself to be interrupted, but rather understanding how she handled such interruptions when they occur. It should be noted, however, that KF's willingness to interrupt her work to help others may have contributed to–and was itself encouraged by–her development of mechanisms which minimized the potential harmful effects of interruptions.

Office Layout

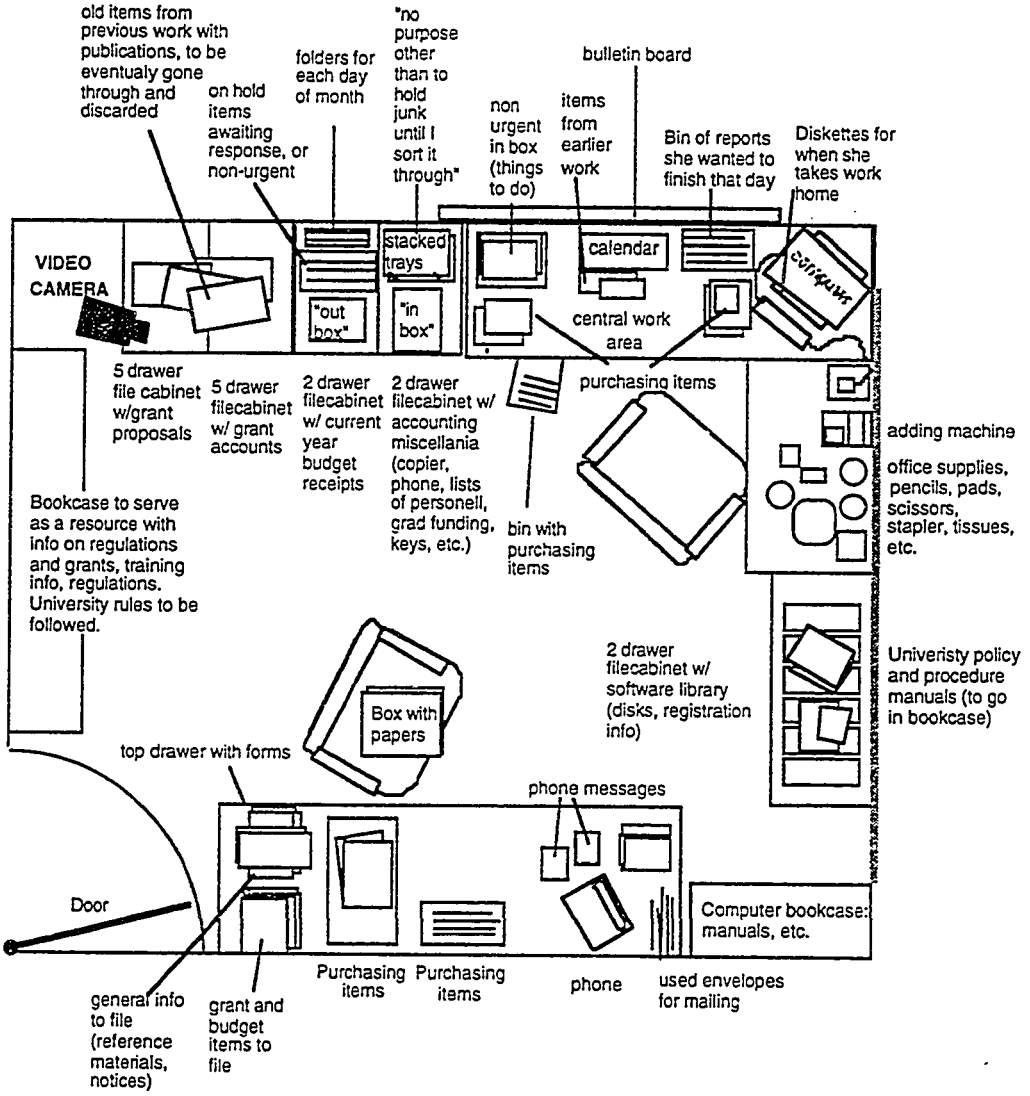
It is important to understand the layout of KF's office (Figure 15) as its structure plays a significant role in shaping her behavior.

KF's main work area is in the corner of her office farthest from the door. The corner contains a desk on which her computer and several piles sit. The central area of the desk is the "current work area" on which she does most of her work paper documents. The area to the right of her

desk contains a typing return on which a printing calculator, pens, pads of paper, and other office tools sit.

Figure 15. KF's office at the start of the segment, showing the placement of the video camera.

KF Office Sketch



A bulletin board above the desk is filled with general memos and notices she refers to in the course of her work. To the left of her desk, on top of two low file cabinets, are four bins. The front bin closest to her desk is her "in box"; it holds incoming mail and other items that are to be brought into her main work area for processing. Next to it sits her "out-box bin", which contains items that are to be removed from her ongoing work area. These include a folder of items to be filed, and above it items that will be removed from her office and mailed or given to other people. Behind the in box bin is a tray with less urgent items she will sort through when she gets a chance. Behind the out-box bin is an upright bin of folders labeled with the days of the month. KF keeps meeting announcements and other date-specific reminders here.

On a file cabinet beneath KF's window are binders containing University policies and procedures. A bookcase in the corner holds computer manuals, magazines, and related literature. A desk on the wall beside this bookcase has stacks with the grant proposals she is currently assembling. Her phone is also on this desk, with several paper phone messages on the surface in front of it. At the time of the study, the staff member responsible for purchasing had recently left the department. KF was handling many of his duties, and piles of purchasing related items were on both desks and in a bin on the floor.

The office opens onto a hallway along which are the offices of the other department staff members. The main entrance to the building is at one end of this hallway. The department mailroom is a short distance

around the corner at this end. The mailroom has open bins labeled with the names of the faculty, students, and staff members mounted along one wall. It also contains boxes for outgoing mail, a copier, assorted office tools (e.g. a paper cutter, a staple remover, tape) and the department's fax machine. KF takes the top items from her out bin when she leaves her office on an errand that will take her near the mailroom, and she stops by the mailroom to see if anything has been left for her when she returns to the department.

Description of the Segment

I now describe the events that transpire during the twenty minute period discussed in this chapter. The detailed transcript of this segment appears in Appendix C.

The segment begins with KF returning to her office after an absence of approximately 1 hour during which she attended a meeting with another staff member. While returning from the meeting, KF stopped in the department's mailroom and removed items that had been placed in her mailbox. She enters her office carrying these items in her hand (Figure 16), places them on her desk, and sits down. (Note: Tape counter numbers supplied with the figure headings show the time from the start of tape KF2, and correspond to the numbers in the first column of the transcript in Appendix C.)

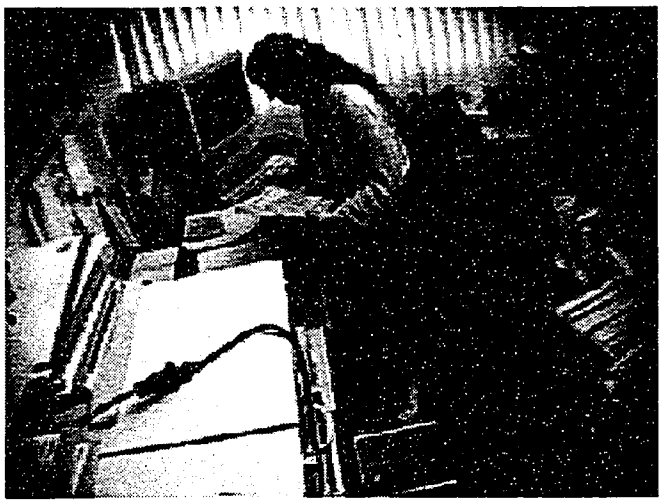


Figure 16. KF arrives at her office with mail. (Counter: 18:30)

KF begins to go through the items of mail, one by one, rearranging their order a bit as she works. She selects one item of mail, a bill from the university's photocopying service, which she opens with a staple-opener and starts to read (Figure 17).

Figure 17. KF with photocopying bill. (Counter: 18:34)

She is then interrupted by a member of the front office staff who comes by to deliver a phone message. KF stands to take the phone message, still carrying the photocopying bill (Figure 18).

Figure 18. KF takes phone message. (Counter: 19:15)

She drops the bill on top of a box of files on a chair near the door (Figure 19) and moves to the phone to see if the caller had also left her a voice mail message.

Figure 19. KF drops photocopying bill on box. (Counter: 19:24)

While checking the voice mail, someone appears at her doorway. KF announces that she is "on voice mail".

After checking her voice mail, KF places the yellow phone message on her desk (Figure 20), and exits her office to deal with the person who had dropped by. She is gone for about three minutes.

Figure 20. KF drops phone message on desk. (Counter: 20:22)

Upon returning to her office, KF moves the phone message to the surface on the side desk by her phone. She then sits at her desk in front of the pile of mail. She takes a set of blue grant allocation sheets, and opens them with the staple opener.

She is then interrupted by a professor (Figure 21) who comes by to inquire about a human-subjects approval document that she received, drop off a new copy of a letter requested by the human-subjects committee, and inquire about a purchase-order invoice that had been left in her box.

Figure 21. KF is interrupted by a professor. (Counter: 24:10)

They determine that KF will add a note to the new copy of the letter, make a copy for her files, and send it on to the human subjects committee (Figure 22). The letter is left overhanging the edge of the desk.

Figure 22. The professor shows KF a letter. (Counter: 24:33)

As the professor prepares to leave, she pages through the papers in her hand to see if there is anything else she needs to discuss (Figure 23). While this occurs, KF notices the Federal-Express delivery person in the hallway; she calls out to verify that there's nothing he needs her to sign.

Figure 23. The professor prepares to leave. (Counter: 24:44)

The professor leaves the office. KF moves the blue grant allocation sheets further away on her desk, and opens another item from the mail pile. This is a yellow copy of a bill from the graphics department. KF unfolds the graphics bill and places it in her folder of things to file, underneath the other items in her "out-box" (Figure 24).

Figure 24. KF inserts the bill in a folder in her out-box. (Counter: 25:14)

She then opens the blue grant allocation sheets and, seeing that they contain two sets of sheets, checks to see if they are two copies of the same documents (Figure 25).

Figure 25. KF compares the grant allocation sheets. (Counter: 25:46)

After determining that they are, KF notices that amount on the grant allocation sheets is greater than she expected. She searches through a stack of papers in her in-box (Figure 26) and retrieves white award notice forms from the granting agency that correspond to the grant referenced by the grant allocation sheet.

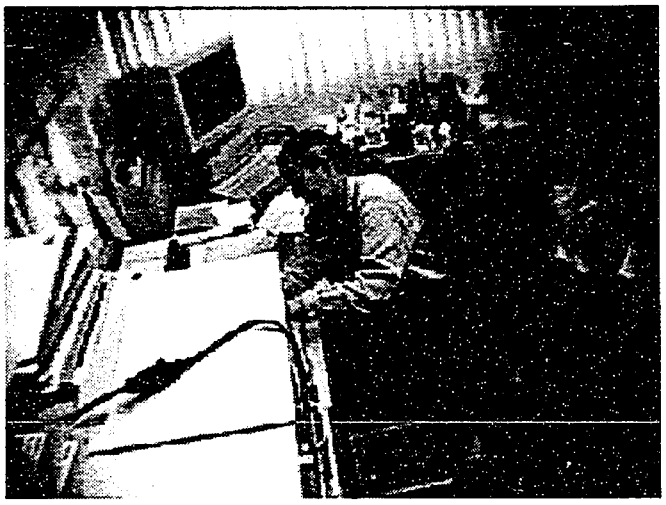


Figure 26. KF searches for the award notice forms. (Counter: 26:10)

At this point, I entered KF's office to discuss the videotaping and plans for removing the equipment at the end of the day. She stands at one point to check the video camera (Figure 27). KF continues to hold the white award notices and occasionally glances down at them.

Figure 27. KF stands to check the video camera. (Counter: 26:23)

After I leave, KF compares the award notices and allocation sheets and determines that the granting agency has transferred funds for the second year of the grant together with the first. KF opens the account and personnel file drawer beside her desk, dropping the allocation sheets on the stack of papers on top of the drawer to free her hands (Figure 28).

Figure 28. KF drops the allocation sheets as she opens the file drawer. (Counter: 28:42)

KF looks in the drawer for a copy of the original grant letter to determine if a progress report or other documentation was supposed to be submitted to the granting agency (Figure 29).

Figure 29. KF looks for a copy of the original grant letter. (Counter: 28:48)

She does not find the letter in that drawer, so she stands and looks in the taller file cabinet which holds files for individual grants. She locates the letter in this drawer and reads it while standing. She then goes to get up the allocation sheets, looking first at the central working area of her desk (Figure 30). When she does not see them there, she turns and retrieves them from the pile where she dropped them.

Figure 30. KF looks for a the allocation sheets in the current work area at the center of her desk. (Counter: 29:48)

KF glances through the documents and then puts one copy of the award allocation sheets into the "to be filed" folder at the side of her desk (Figure 31).

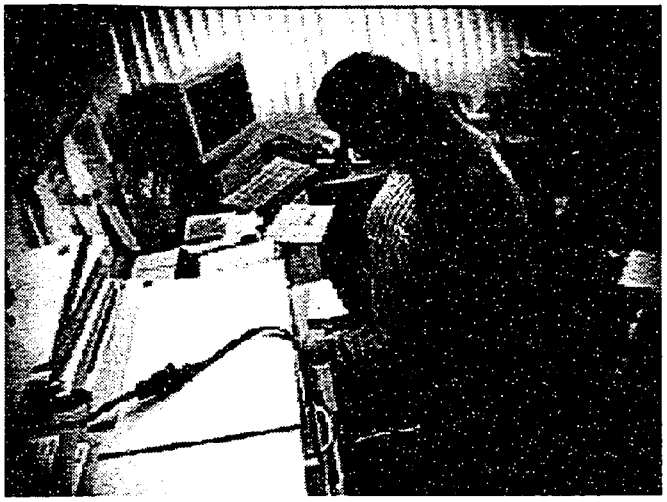


Figure 31. KF puts a copy of the award sheet in her "to be filed" folder. (Counter: 29:50)

KF inserts the other copy into the grant drawer along with the documents related to the grant that she had retrieved. As she returns to her desk, she notices the photocopying bill she had left on top of the box of files on the chair (Figure 32). She picks it up and starts to page through it while still standing up.

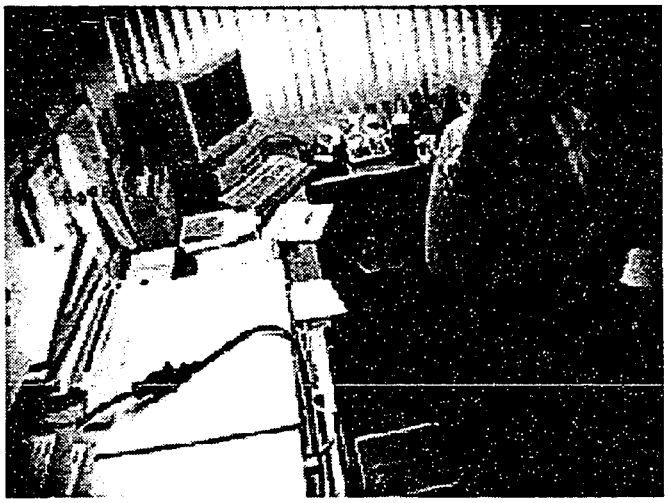


Figure 32. KF notices the photocopying bill. (Counter: 30:27)

While checking the bill, another staff member knocks on the door and then enters to discuss hotell reservations for a prospective faculty member the department will be hosting (Figure 33).

Figure 33. KF is interrupted by a staff member. (Counter: 30:35)

While the other staff member discusses the hotel room reservation, KF finishes reviewing the photocopying bill and places the bill in the "to-be-filed" folder (Figure 34).

Figure 34. KF places the bill in the to-be-filed folder. (Counter: 30:44)

KF discusses the dates and rate for the hotel room reservation, moving to look at a sheet of paper with calculations that the staff member is holding (Figure 35), and then suggests using her personal credit card to guarantee the room.

Figure 35. KF moves to look at the sheet with the hotel calculations. (Counter: 31:27)

KF then gets the a set of keys from its place in a cup on the other side of her office, moves across her office, and unlocks the file drawer in which she keeps her purse (Figure 36).

Figure 36. KF unlocks the file drawer. (Counter: 32:12)

While KF is opening the drawer, a second staff member stops by to ask if KF has plans for lunch. KF makes plans to join the second staff member for lunch, removes her purse, and asks the staff member in her office if she would like to join them as well. The staff member says she had other plans.

KF reads her credit card number aloud for the other staff member and returns the card and her purse to the drawer, which she locks. The staff member then says "one other thing..." and begins to ask about a call she had received from a different department about arranging a payroll transfer form for a researcher who's funding was switched from one

department to another. After determining how the staff member should proceed with the matter, the staff member leaves the office.

KF notices the yellow phone message she had left by her phone, mumbles "Oh, I need to see if this guy...", walks to the phone, and dials the number of the person who had left the message. While in the corner near the phone, she retrieves the key for the drawer with her purse, and moves to the cabinet with the keys in her left hand, the phone message in her right, and the phone handset held in the crook of her neck (Figure 37).

Figure 37. KF moves to her file cabinet while talking on the phone. (Counter: 34:59)

She places the phone message on top of the file cabinet, unlocks the drawer, drops the keys on top of the file cabinet, and then removes her purse and some paper money from her pocketbook inside the drawer (Figure 38).

Figure 38. KF removes her purse from the drawer. (Counter: 35:07)

She picks up the phone message and leaves a voice-mail message for the person who had called while unfolding the paper money and walking to the other side of her office. After leaving the voice-mail message, KF hangs up the phone, picks up the keys, and closes the file drawer while glancing at the phone message. She locks the file drawer and returns the keys to their place. She places the phone message on the side desk beside her phone.

KF puts the paper-money in her purse and drops it on her desk. She sits down at her desk, returns the staple opener to its place with the other office tools (Figure 39), and picks up a small pad of post-it notes from the same area.

Figure 39. KF returns the staple opener to its place with the other office tools and picks up a small pad. (Counter: 36:01)

She writes a note on the post-it pad (Figure 40), and then affixes it to the human subjects consent letter that the professor had left earlier.

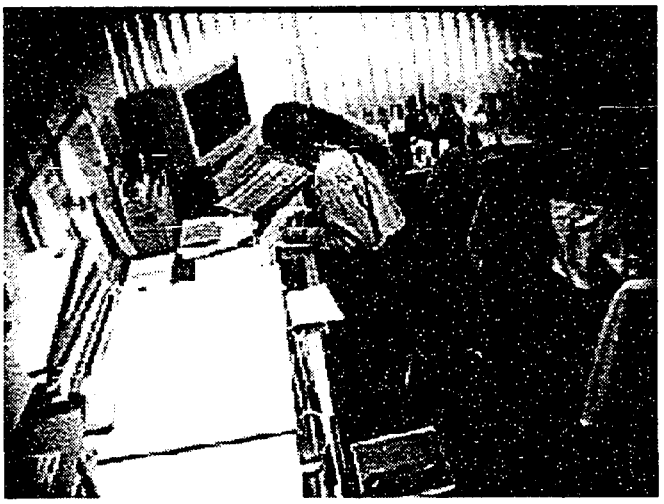


Figure 40. KF writes a note on the post-it pad to affix to the letter. (Counter: 36:04)

She opens the file cabinet beside her and retrieves a folder with information related to the professor's grant (Figure 41).

Figure 41. KF retrieves a folder with information related to the professor's grant. (Counter: 36:28)

She places the letter with the post-it note on top of this folder, and puts the folder on the "in-box" pile on her desk (Figure 42).

Figure 42. KF puts the folder on the in-box pile. (Counter: 36:34)

She returns the post-it pad to its place with the office tools and supplies. She then selects an item from the pile of mail she had brought

in, looks at it briefly, and places it in a bin of files on the floor containing documents related to purchasing (Figure 43). (The person who had been responsible for purchasing had left the department several days earlier, and KF was handling portions of his work.)

Figure 43. KF places an item in the "purchasing" bin. (Counter: 36:45)

She selects a catalog from the mail, pages through it on her desk, and then places it and another item of mail in the to-be-filed folder. KF picks up the pen she had used earlier to write the post-it note, and returns it to its place at the back of her desk. She holds her purse in her hand, tamps it on her desk three times, pauses, says something to herself, and then takes a pen and a pad from the office tools area (Figure 44).

Figure 44. KF reaches for a pen and a pad. (Counter: 37:19)

After taking a piece of paper from the pad and returning the pad to its place, she writes a note (Figure 45) to remind herself to perform a task that had been requested of her earlier and that she needs to accomplish that day. She underlines the note several times, and leaves it at the center of the desk where she wrote it.

Figure 45. KF writes a note as a reminder to herself. (Counter: 37:30)

She returns the pen to its place, picks up her purse, and stands to leave. She pauses for a moment facing the side desk with the telephone, glancing over it's surface (Figure 46).

Figure 46. KF peruses the area by her telephone. (Counter: 37:38)

She then moves to the phone and calls the staff member with whom she had arranged to have lunch. After hanging up the phone, she takes several blue folders from on top of her out-box, check's her watch, announces to the camera that she is going to lunch, and leaves.

Interruptions

Interruptions Resulting from the Study

Several interruptions occur as a result of the videotaping for this study. When she first returns to her office, KF announces that she is "back from meeting with M." Soon after, KF pauses to check to be sure the videotape camera is still running. She checks it again a bit later, after another brief absence from her office. At one point, the researcher enters

to discuss the taping and plan for removal of the video equipment at the end of the day. And, at the end of the segment, she addresses the camera to announce that she will be out to lunch as she leaves her office.

These interruptions related to the study raise the question of how accurately the period observed reflects what would be normally occurring in KF's office on a day when no study was being conducted. They show at least an intermittent awareness by KF that the videotaping was going on. Might this awareness have led her to behave in ways that were significantly different from her normal behavior? On one level, the answer to this is an unqualified yes; if there would not have been a video camera in her office, KF would not have checked it to see if it were running. One visitor to her office did appear to prefer to remain off camera and talk in a lower voice than usual. But on the level of general mechanisms for managing tasks and handling interruptions, the videotaping did not appear to significantly change what KF did. Because KF's office is in the same building as mine, I had many opportunities, both before and after the videotaping, to informally observe KF working in her office. I noticed no clear effect of the videotaping on how KF worked in her office or handled interruptions. Had the presence of the video camera significantly altered her routines, it is unlikely that she would have been able to continue to perform her duties as well as she did. Cicourel has suggested that (Cicourel, personal communication) people cannot deviate greatly from their normal procedures and still maintain a competent level of performance. From the point of view of

my study, interruptions related to the videotaping are treated as data. KF had to contend with them as with the other interruptions that arose, and she continued to perform the work she needed to despite them.

Layers of Interruption

There are several instances in which interruptions occur while KF is already handling an interruption. For example, during the period when KF is discussing the grant letters and purchase orders with the professor who stopped by, she notices a delivery person in the hall outside her door. She asks him if there is anything she needs to sign.

00:24:32	JM takes sheet of paper she is holding (a copy of a purchase order; the document that had been on top of the pile when JM first walked in) and holds it out in front of KF. JM: "Did you put this in my box, do you want it back, or what?..." KF: "oh, it's a copy, if you guys like to keep copies, I actually meant to put it in L's [box]"	
00:24:42	JM turns to leave, holding papers, says "I'll put it in L's, because she [turns to look at KF] probably has been, she's keeping obviously closer track than I."	
00:24:43	JM looks through papers quickly before she leaves, while finishing prior statement	check to be sure she has done all she has to so with KF
00:24:44	meanwhile, KF notices someone (FedEx delivery man) at door, makes signing motion with hand, says "would you like me to sign for that?" as JM starts to leave. male voice: "no, you don't have to, it's all taken care of". KF: "OK, thank you very much"	handles interruption
00:24:51	JM: "yeah, cause she's here all the time" KF: "yeah, I'm sorry, I must've just put it in the wrong box." [motions with hands as if inserting papers in two boxes]	L's box is 3 below JM's in the department mail room

Similarly, while MS is in KF's office discussing reserving a hotel room for a visitor, AD stops by to ask if KF wants to join her for lunch. KF is standing, preparing to give MS her personal credit card number to use to reserve the room. She handles AD's interruption while continuing to perform actions to give the number to MS. KF invites MS to join them for lunch; it is not clear if she would have done so (or done so at that time) had MS not already been in her office to discuss another matter.

00:32:06	KF turns to get key from cup on shelf, says "Let me give you my credit card"	
00:32:12	unlocks drawer in which her purse is locked, at same time, AD enters doorway to ask about going to lunch	invitation to lunch is an interruption to the interruption
00:32:15	KF looks at watch on right hand, drops key from left hand onto top of file cabinet, says "I don't know"	
00:32:18	opens cabinet. KF: "what, are you going to have lunch today?" AD answers [inaudible]	
00:32:24	KF: "I'll go to the price center with you" while opening top drawer, reaching for purse	multitasking
00:32:30	takes out purse, asks MS if she wants to join them for lunch while finding credit card in purse. MS says that she was planning to grab something...	
00:32:39	KF: "ready" and reads credit card info which MS writes down.	

Bundling Interruptions

In two instances, visitors seemed to bundle together unrelated matters into a single interruption. For example, the professor who came

to discuss grant matters also used the opportunity to ask KF about purchase orders left in her box. Similarly, after MS finished discussing the visitor's hotel reservation with KF, she brought up another, unrelated issue.

00:33:16	MS: "one other thing, I had a voice mail from MN at neurosciences that she's sending a PET (payroll expense transfer) for BN but she wanted to talk, she said to me [inaudible] so do you know what she'd be talking about at all?" KF: no, but why don't you give it a stab and talk, - call her up, she may just be calling you, - I don't know what kind of PET they would be doing, we just started funding her the first of January." (more discussion of PET)	"one other thing" further interruption following initial interruption.

Bundling interruptions has benefits both for the interrupter and the interruptee. For the interrupter, the effort required to establish contact with the interruptee (e.g. a trip to the interruptee's office, a telephone call, etc.) is performed only once. For the interruptee, the effort to disengage resources from the current activity and to later reestablish the context of the interrupted activity occurs once. The benefits to the interruptee of bundling interruptions may encourage the interrupter to do so in an attempt to be less disruptive overall.

Bundling can also occur when, in the course of the primary interruption, the interrupter is reminded of additional matters requiring the interruptee's attention. The interrupter may recognize this as an opportune time to handle the other matters as well.

Evaluating Interruptions

At the start of an interruption, it is not always clear what commitment to the new activity will be necessary. KF evaluated interruptions when they occurred to determine how much she needed to free herself from existing activities. When visitors arrive at her door, this evaluation begins with an initial glance to determine the identity of the visitor. The evaluation continues during the visitor's initial description of the topic of the interruption. KF continued to maintain contact with the resources involved in her current activity for as long as possible during an interruption. This can lead to problems, as I will discuss further below.

KF also took actions to inform others of her ability to be interrupted. For example, she notified a person who glanced in to her office that she was "on voice mail".

00:19:36	dials number to check own voice mail to see if the person had left a message. says "thank you" to person who brought the message	
00:19:49	says "I'm on voice mail" to person in her doorway	notifies visitor of her ability to be interrupted ("on voice mail", not "on hold")
00:20:19	hangs up phone (without leaving message)	

Gradual Transitions Between Activities

The desire to maintain contact with the resources of an activity for as long as possible as interruptions are evaluated and handled means that transitions between activities are often gradual. Such transitions were marked by periods in which KF's attention was divided between two activities. For example, she continued to hold, and occasionally glanced down to, the documents in her hand when I entered to discuss the videotaping and she rose and moved to the camera.

Another example occurs later, when MS stops by as KF is reviewing the photocopying bill. KF performs actions to complete her work with the bill while looking to see who is at the door, greeting her, and listening to the start of MS's discussion.

00:30:34	knock at door, turns to see who is there, KF says "Hi there" while glancing back down to pages (photocopying bill)	starts to handle interruption while still performing current activity
00:30:40	MS enters with papers in hand, starts to discuss sending in an advance to guarantee a hotel reservation for a future visitor to the department	
00:30:43	KF puts papers together, places them into the out stack (using right hand to lift top items)	completes prior task while already engaged in interruption

Preparation for Interruptions

Before KF leaves for lunch, she prepares for this foreseen, though relatively short, interruption from her work setting. This preparation is aimed at minimizing the detrimental effect of the interruption on her activities. One way she prepares is by creating external representations of internally held information. After she takes the purse from her desk, she sits down at her desk. She taps the purse on the desk several time. KF later said that she was thinking about whether there was anything else she had to do before she left. She recalls a task involving calculating summer salary that she had been told about earlier in the day. Until this point she had not created an external reminder of that task, but now, as she prepares to leave, she writes a note and leaves it in the center of her desk in her "current work" area.

KF similarly left the phone message in the central area of her desk when she left to speak to the person who had dropped by her office earlier, leaving a reminder of the uncompleted activity (Figure 47).

Figure 47. KF drops the phone message on the central area of her desk before she leaves to handle an interruption. (Counter: 20:22)

When she returns to her office she immediately moves the message to the surface by her phone. This change in the position of the reminder reflects her decision, made only now, to postpone further work with the phone message to a later time.

Before leaving her office for lunch, KF stands and faces the side desk with her phone, and pauses again, scanning the area to see if anything reminds her of a task she must do before she leaves. This is also a preparation for the expected interruption, aimed at insuring that her absence from the office will not harm any of her activities. When she tapped her purse on the desk she reviewed her internal representations of pending activities. Now, by looking around her office, she reviews the external representations of such activities.

Multitasking

As with the interruptions described above, there were many instances in which KF engaged in more than one activity at a time. A clear example of this came as she was calling the person who had left her the phone message. This is triggered by her noticing the yellow message she had left by her phone. While she makes the phone call, KF unlocks her file drawer, removes her purse, and extracts money to take with her to lunch.

00:34:45	KF notices yellow phone message she'd placed near phone before, mumbles "oh, I need to see [inaudible] this guy [inaudible]", walks to phone, dials number	noticing artifact prompts action
00:34:53	while in corner with phone, picks up key to file drawer	actions to prepare for lunch interleaved with phone call actions
00:34:59	moves to file cabinet with phone under chin, message in right hand, keys in left. places yellow phone message on top of file cabinet with right hands while picking correct key with left	holds items related to both activities
00:35:02	unlocks top file drawer, touches yellow message for an instant, moving it a small distance further back, places keys on top of cabinet	
00:35:04	opens drawer, reaches in back for purse	
00:35:09	takes out purse, places it on top of open files	open files afford support, freeing her hands
00:35:12	removes money (bills) from pocketbook, goes to other corner of office, walks back toward file cabinet	

00:35:20	leaves voice mail "Hi M, this is K, I got a message that you called me about the NSF incentives for excellence program, just give me a call when you have time, my number is <number>. Thanks a lot, M, bye." meanwhile: (1) unfolds bills, (2)walks to other corner, hangs up	multitasking
00:35:36	returns to file cabinet	
00:35:38	takes purse	
00:35:39	picks up keys in left hand, yellow message in right (which is already holding purse and bills)	
00:35:42	closes file drawer while looking at yellow phone message	
00:35:43	locks file drawer with left fist	
00:35:46	returns to other corner, drops keys in cup	
00:35:51	leaves yellow phone message by phone	leaves message by phone even though she has returned the message because "the issue is still open"

Actions related to the two activities occur simultaneously, as can be seen in Figure 48. Items related to the two activities are placed in proximity to each other because the activities are performed together. Items are also placed in non-standard locations. For example, the phone message would not normally be placed on top of the file cabinet, yet it is because the other activity KF was performing brought her there and required that she free her hands.

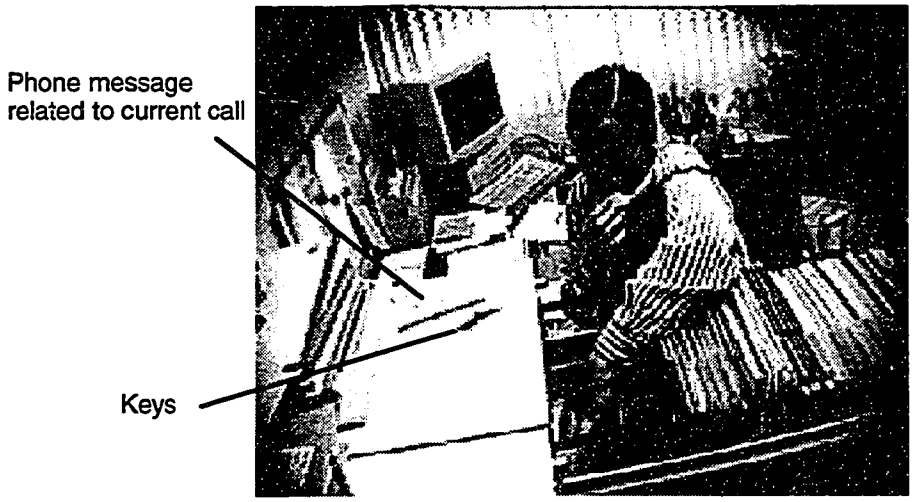


Figure 48. Items related to unrelated activities are brought into proximity when KF performs activities simultaneously. Such multitasking can cause items to be placed in non-standard locations, as with the phone message. (Counter: 35:07)

Role of External Artifacts

The extract illustrates the role of physical items as representations of KF's activities. Throughout the extract, the course of her activities is influenced by the items she encounters. In turn, her activities influence the placement of items she uses, thereby affecting when she will encounter them again. KF places items deliberately in specific locations, intentionally marking them with the associated meanings. When multitasking and during interruptions, however, the placement of items is influenced more heavily by physical affordances and constraints.

Physical Manifestations of Activities to Perform

Many physical artifacts play a role in representing and cueing KF's activities. They include:

1. The stack of mail she carries in with her at the start of the segment. The order of the items in the stack represents a possible ordering of activities. While the initial organization of the stack influences the order in which she performs her activities, KF modifies this ordering by rearranging items within the stack. Items of lower priority (e.g. the catalogs) are move to the bottom of the stack as she selects other items (e.g. the bills and grant sheets) to handle. The stack serves as an external representation of activities KF must perform, and also as an efficient mechanism for her to reorder these activities. The stack affords the ability to compare and reorder its physical components easily, supporting KF's reordering of the activities they represent.

2. The phone message handed to her by another staff member. This message is held in her hand when she engages in the activity it represents. When she must free her hands to retrieve her purse for an unrelated activity, the message is left in a visible location, close at hand. When she engages in other activities, she leaves the message out in a location where it will serve as reminder, first on the main desk and then on the surface by the phone.

3. The updated letter brought in by the professor, to be copied and forwarded to the Human Subjects Committee. KF leaves this letter out on top of her desk, between her current work area and the "in-box" pile which contains items representing pending activities. The letter is left overhanging the edge of the desk

(Figure 49). This makes it more prominent and attention catching, and signifies that the letter is to be dealt with before the other items in the pile.

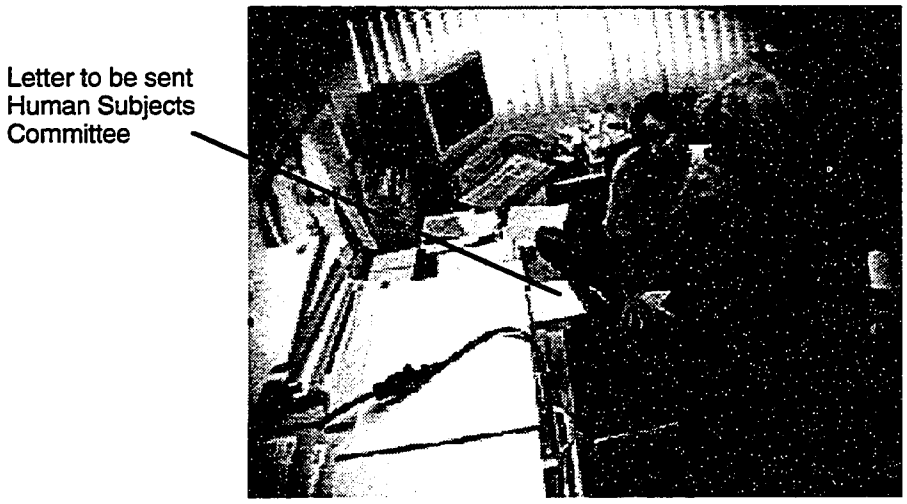


Figure 49. A letter to be handled later is left overhanging the desk, serving as a reminder of the pending activity. (Counter: 24:33)

Before she leaves for lunch, KF affixes a note to the letter, places it on a folder she retrieves from a file drawer, and leaves it on her "in-box" pile. This leaves an external representation of the pending task of copying and filing the letter and sending it to the committee. While she could have waited to remove the folder from her drawer until later, doing so now will remind her that she must file a copy of the letter before she sends it off.

4. Items placed in the "out-box" stack. KF places items on the top of this stack so they will be encountered when she leaves her office on an errand that will take her near the mailroom. She places items in the "to be filed" folder at the bottom of the stack so they

will be encountered when she performs her filing. This depends on her following her established routines. Because the "to be filed" folder contains items that KF has received recently she knows to search for such items there before looking in her files.

5. The note she leaves in the center of her desk before leaving for lunch. KF creates this reminder to protect against forgetting an activity that until then was only represented internally. Placing the reminder in the central area of her desk marks the activity as one to perform soon. In fact, KF begins work on the activity as soon as she returns to her office.

The extract also contains examples in which external artifacts affect the activities of others. For example, the professor who enters to discuss the grant carries a stack of papers with her. The stack includes the purchase orders that had been left in her box, reminding her to ask KF about them. Before she leaves, the professor leafs through the items in her hand to be sure that she has covered all the desired items.

In addition to serving as reminders of pending issues, external artifacts serve as visible manifestations of current activities. This is especially important when multitasking, and provides robustness against interruptions. As mentioned above, KF carries the phone message with her and leaves it in view when she goes to the file cabinet to retrieve her purse. She glances at it as she leaves her voice mail message, refreshing her internal representation of the details of the call. This is similar to

how JC props the ad upright as he works on his computer while waiting to speak to a sales representative (see discussion in Chapter Four).

Disorder

At times of multitasking and interruptions, the placement of items may be determined more by physical constraints and affordances than by the meanings associated with individual locations. This can lead to disorder as items are placed in locations where they do not meaningfully belong. This disorder can reduce the likelihood that items will be encountered at appropriate times and make it harder to locate items later. The disorder is partially due to the desire to maintain contact with the resources of the existing activity for as long as possible during an interruption. The person may be in an atypical location when these resources must be freed to handle the interruption.

An example of this occurred when KF was reviewing a photocopying bill and was interrupted by a staff member with a phone message. KF stands to take the message. She carries the bill in her hand, reminding her that they are the object of her current work and preserving her place in the bills (Figure 50).

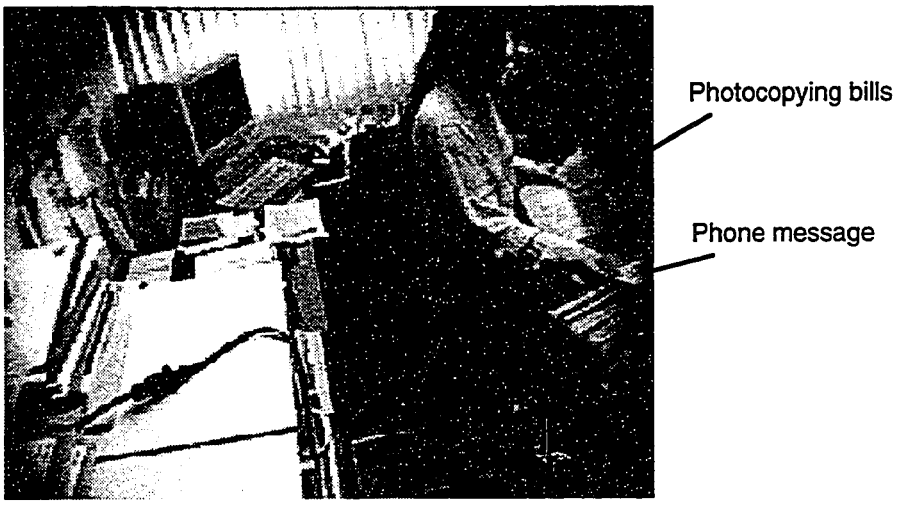


Figure 50. KF holds onto items related to her current activity as she stands to handle an interruption. (Counter: 19:15)

After KF takes the phone message, she decides to check her voice mail to determine if a message regarding it had been left. Dealing with the phone message is now her primary activity, and KF must free her hands to proceed with it. She drops the bill on the nearest surface that affords support, a box of papers on a chair (Figure 51). The bill has no relationship to the items in the box; it is dropped there only because of the box's physical affordances and proximity.

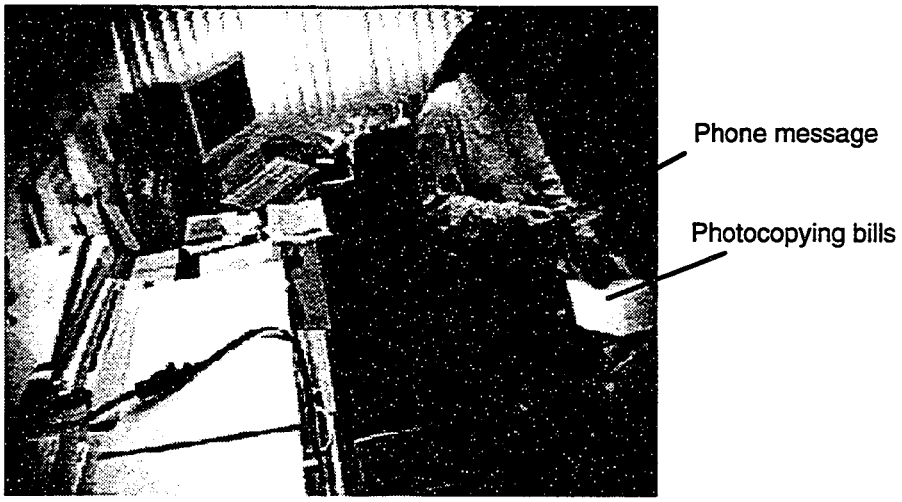


Figure 51. KF drops the items in a non-standard location because of the support it affords as she frees her hands to deal with the interruption. (Counter: 19:24)

She is further interrupted by a visitor who appears at her door while she checks her voice mail. She leaves her office to speak with the visitor after she checks her voice mail. When she returns, she does not resume her review of the photocopying bill. She does not notice them in their place on the box. Instead, she proceeds to work with the other items in the central area of her desk where current work is usually left.

A similar phenomenon occurs when KF is reviewing the grant allocation sheets that arrived in her mail. She is surprised to see that funding for two years was provided together, and moves to the file cabinet to her side to extract a folder with related information. She carries the sheets in her right hand as she does so. As she opens a drawer with her left hand, she drops the sheets on the pile on top of the cabinet (Figure 52). This pile is her "out box" pile with items to be removed

from her office or filed. She drops the allocation sheets here because it affords the proper support, letting her free her hands and keeping the sheets at hand so she can compare them with the information in the drawer.

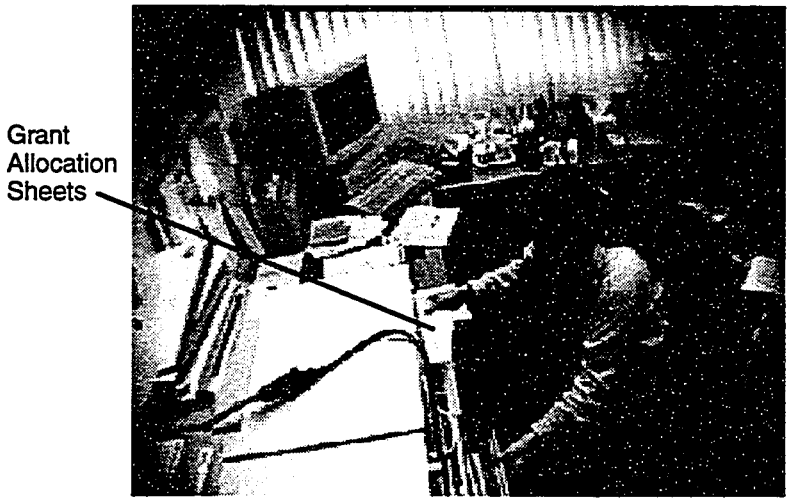


Figure 52. KF drops the grant allocation sheets on a pile because of the support and proximity it affords, despite the fact that the pile signifies an undesired meaning. (Counter: 28:42)

KF does not find the information in the drawer by her desk, so she stands and looks in one of the taller file cabinets. She extracts the desired folder and then goes to retrieve the allocation sheets. She first moves toward the central area of her desk where she expects to find materials related to current activities. When she does not see them there, she looks over toward her "out-box" pile and retrieves the sheets.

Figure 53 shows the state of KF's office while she is looking through the drawer by her desk. Many of the external items involved in her activities are visible. Some of these, such as the pile of mail, the phone

message, and the professor's letter are in meaningful places which signify their place in the overall management of her activities. Other items, such as the photocopying bill and the grant allocation sheets, are in places in which they were left due to the physical constraints and affordances of the locations in which she performed her activities.

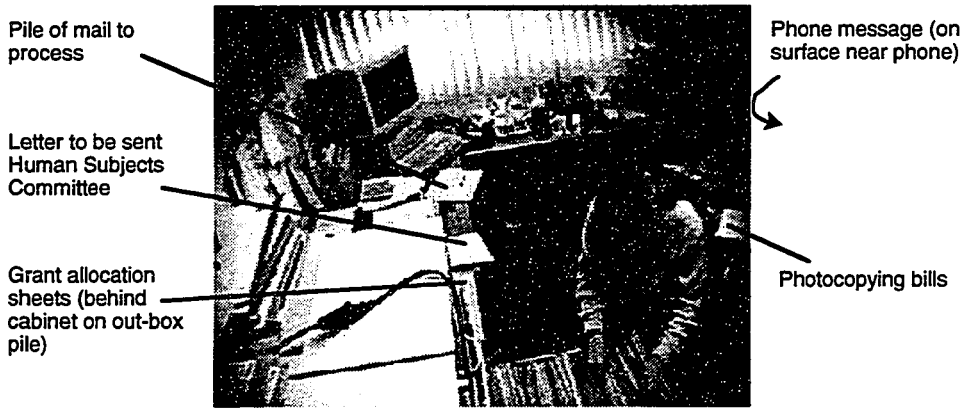


Figure 53. The state of KF's office in the middle of the segment, showing the locations of the items used in her activities. (Counter: 28:48)

Cleanup and Stabilization

KF engages in additional operations to compensate for the disorder that results during multitasking and interruptions. During my review of the tape with her I asked why she left the photocopying sheets on top of the box. She replied:

> "Uh... well from the tape before, I just dropped them on there when somebody else came in and talked to me and then I forgot they were there" [KF laughs] "It happens all the time"

When I asked what she meant, she replied:

> "I put things down when somebody comes in and then I don't think about them again until I sort of peruse the room and see that I've left something somewhere where it doesn't belong."

In my review of the tapes, there were numerous occasions in which KF scanned her work area as she described. Her standing and looking over the area with the phone before she leaves for lunch is one such example.

KF also engages in stabilization activities, in which she performs actions that increase the efficiency and robustness of her other activities. For example, KF routinely returns tools to their expected places. This has clear benefits in that she can quickly retrieve a needed tool without searching.

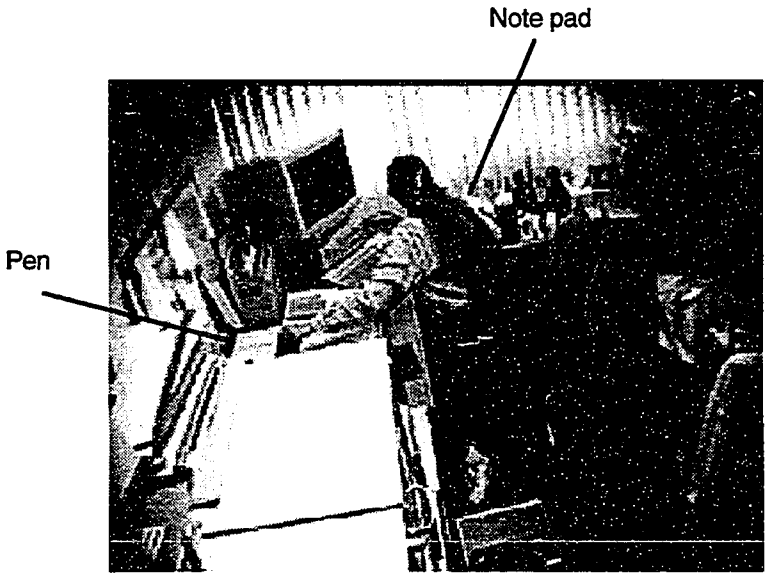


Figure 54. KF reaches for a pen and note pad at the same time, to leave herself a reminder. Because they are in expected places, she can retrieve them quickly, without searching. (Counter: 37:19)

In Figure 54, KF prepares to leave a reminder for herself by reaching for a note pad and pen. Because these tools are in their expected places, KF can reach for them at the same time, without looking.

Such stabilization activities occasionally lead to extra work. For example, KF returns her purse to its place in her drawer after checking her credit card number even though she will need the purse soon after when she prepares to go to lunch. On many occasions she returns her pen to its place only to take it again moments later. Locally, these actions may appear inefficient, yet they can lead to better performance overall. Such actions can also minimize the effort required to handle interruptions, increasing the overall robustness of the system. Eliminating these actions would require cognitive effort to recognize that the tools would be used again, and to keep track of their placement in non-standard locations. The complexity and situated nature of KF's activities makes it hard to predict when tools will be used again. KF's simpler heuristic is to always return tools to their places after use.

Summary

This chapter presented one contiguous segment of behavior in detail, showing how activities and the external structures that support them interact to shape behavior in a dynamic, interruption rich environment. The segment illustrated the different kinds of interruptions that can occur, and showed how interruptions are often bundled together.

The segment also illustrated the gradual transitions between activities that often occur, especially during interruptions. There is a desire to maintain connection to the resources of the current activity for as long as possible while an interruption is evaluated. When multitasking and during interruptions, internal resources are taxed and behavior is determined by the interacting demands of multiple activities. At such times the placement of items is influenced heavily by physical affordances and constraints. The desire to maintain contact with the resources of an activity and the increased influence of physical affordances and constraints can cause disorder as items are left in non-standard places. Routines are developed to ameliorate the detrimental effects of this disorder and stabilize the environment to improve its overall efficiency.

In Chapter Six I present my overall conclusions, and draw on them to answer the questions posed at the start of the dissertation.

Chapter 6

Conclusions: The Distributed Nature of Activity Management

In this chapter I summarize my conclusions from the studies I conducted, and draw on them to answer the theoretical questions raised in Chapters One and Two.

My studies shed light on the structure and dynamics of everyday activities, the ways people manage activities and handle interruptions, and the role of external structures. Together, they suggest that the management of everyday activities is a distributed process which relies heavily on the placement and manipulation of meaningful physical items. Because of the complex and situated nature of everyday activities, detailed traditional planning is often not possible. Instead, a distributed form of planning occurs in which spatial configurations come to represent the order in which activities should be performed. This planning relies on routines which insure that the proper configurations arise, and routines which insure that external structures will be encountered at appropriate times and the desired activities cued.

Because of its reliance on external structures, activity management is susceptible to a form of *representational determinism* (Zhang, 1995; Gruen, Zhang, Norman, 1996) in which the form of the physical structures influences the course of activities. Especially during interruptions and when multiple activities are performed together, physical constraints and affordances can determine the placement of task relevant items. Cleanup and stabilization routines arise to compensate for the disorder that this causes.

Summary of Major Findings

Delineating Activities

A practical question raised in Chapter One was how to divide an episode of behavior into distinct activities. It became clear throughout my studies that no one set of criteria was adequate for people to delineate their own activities. It is therefore important to look at the extent to which people conceptualize their own behaviors as distinct activities, regardless of the factors that cause them to do so. Equally important is the concept of an *issue*, used by several subjects in discussing their behavior to describe an aspect of the external environment they wished to keep in mind. The term was used to describe an item or matter that had come to their attention and for which they might have some responsibility, but which did not necessarily require any specific action on their part. Even when issues did not require action on the part of the subject, they did require monitoring in case action was required. Subjects took steps to insure that issues for which they were responsible were

represented externally so they would not be forgotten. For example, one subject spoke of leaving a window open on her computer desktop to remind her of an issue that had not been resolved; another spoke of saving written phone messages to remind her of issues that were still open. This subject saved phone messages even when she had returned the call and there were no remaining actions she was required to perform.

Gradual transitions from activity to activity

During transitions from one activity to another, the point where one activity is suspended and another begins is often not clear. Instead, there is a gradual relinquishing of involvement with the resources involved in one task as processing is shifted to another. This can lead to multitasking and the potential for interactions between the resources involved in the two activities.

Multitasking

Periods in which people engage in more than one activity at a time abound. These generally involve different processing codes, as predicted by Wickens (1991). Furthermore, people develop procedures which increase their ability to multitask by freeing resources for use in other activities. The use of a speakerphone to dial a call "hands free" is one example of this.

Evaluation of interruptions

At the start of an interruption, there is a period of evaluation during which the details of the new task are still being understood. Even if the interruption does not lead to an immediate switch to the new activity, there is a need to determine the urgency of the interruption and the resources it will require. This information is important in determining when the interrupting activity should be performed.

In the early stages of an interruption, it is not always clear what commitment of resources to the new activity will be necessary. There is a tendency to hold onto (sometimes quite literally) the cognitive structures involved in the current task for as long as possible. This preserves as much of the context of the current activity as possible, minimizing the cost of the interruption.

Negotiation of interruptions

The handling of interruptions involving other people is often negotiated. Determining how to handle such interruptions is a distributed problem in the sense that the information required to make the determination is divided among the different parties. The interrupter knows the urgency of the interruption, its importance, and the cost of postponing it to a future time. The interruptee knows the urgency and importance of their current activity and the cost of suspending it. The interruptee may also know of other opportunities to handle the interruption when its detrimental effects would be lower.

Even when both parties have common goals, determining how to handle an interruption requires that information be shared.

Periods when people are "open" to interruption

There are periods when people are free from intensive involvement with other tasks, and consequently more open to interruption. These include times when they are walking through halls, are on the way to lunch, or at the start or end of the day. People routinely try to gauge another's openness to interruption before interrupting them. People perform actions to inform others of their openness to interruption, for example by stating that they are "on hold" or raising a finger to postpone an interruption until they finish typing a sentence.

Bundling interruptions

Frequently, a number of unrelated interruptions are bundled together and handled at one time. Bundling interruptions has benefits both for the interrupter and the interruptee. For the interrupter, the effort required to establish contact with the interruptee is performed only once. For the interruptee, the cost of suspending the current activity is incurred once for all the interruptions. People may bundle interruptions in an attempt to minimize their intrusive effects on others. Bundling also occurs when, in the course of the original interruption, the interrupter is reminded of additional matters requiring the interruptee's assistance.

Preparation for interruptions

People modify their environment to minimize the cost of scheduled and unscheduled interruptions. People prepare for scheduled interruptions by transferring internally held information to external representations. There was evidence that the effort spent to externally represent information varies with the length of the anticipated interruption. For example, subjects took measures to prepare for absences from their workplace over a weekend which they did not take for absences overnight.

People come to anticipate the kinds of unscheduled interruptions they are likely to receive. People prepare for such interruptions by insuring that the tools and information they require will be retrievable with minimal effort.

External manifestations of activities

People desire external manifestations of current and pending activities. They depend on the external environment to remind them of their activities, and modify the environment so it will do so. Furthermore, they develop routines to insure that they will encounter the items they rely upon to cue their activities.

Preference for using items already involved in activities

There was a clear tendency to use existing meaningful items to represent the state of activities. Such items already carry task relevant

meaning and significance, minimizing the amount of new information that must be transferred to external media.

Use of spatial arrangements to manage activities

The placement of physical items is used to represent many classes of information relevant to the management of multiple activities. Space can be used to identify the current activity, to represent pending activities, and to represent the priorities, time dependencies, and interdependencies of multiple activities. Space allows existing items to be used as reminders, and can insure that required information is encountered when needed. As a practical matter, effective placement helps insure that the physical items required for an activity will be in expected places or close at hand, minimizing search and retrieval costs and their disruptive effects. Space can also be used to minimize interference between activities by keeping their physical resources distinct.

Spatial representations allow existing items to be used in flexible ways to represent task relevant information. They allow the use of non-verbal processing channels that may not already be taxed by an activity. Furthermore, the use of spatial representations employs mechanisms believed to be central to many higher cognitive processes (Lakoff, 1980; Langacker, 1987; Mandler, 1992; Kirsh, 1995).

Spatial locations can attain meaning

Spatial locations can acquire specific meanings and significance. The juxtaposition of an item with a location can be used to label the item with the meaning associated with the location. The meanings of spatial locations are acquired both through intentional design and incidentally as activities are performed. The meanings of spatial locations can evolve over time. Initially, the placement of an item may be incidental, based more on low level features of the situation than on a deliberate decision to establish a meaningful location. As additional related items are placed nearby, the association of meaning with the location is reinforced.

Dedicated representational structures are used for specific reasons

Despite the cost of creating new representations of task relevant information and the consequent preference for using items already involved in a task, cases exist in which people do create new symbolic representations of their activities and goals. Such representations are created for several reasons. There may be no existing physical objects associated with an activity, or other factors may control their placement. The need to represent several different concepts can lead to conflicting decisions on where an item should be placed. Occasionally, an item will be duplicated so it can be placed in more than one place, but this is not always possible or efficient. Dedicated representations are also used for their portability and permanence.

Dedicated symbolic representations also afford the ability to perform comparisons and manipulations that are important for planning, without disturbing existing spatial configurations. Dedicated representations are also used to label existing items with information not conveyed by the item or its location, or to override the information conveyed by the item or location. For example, a post-it note may be affixed to a document left in an out-box to indicate that it should be handled in an atypical way.

Informational concerns and physical affordances interact

The informational concerns which influence the placement of items interact with the physical constraints and affordances of the settings where activities are performed. Especially during interruptions and multitasking, when processing demands are high, physical affordances can predominate in determining where items are placed. Zhang (1995) has described the phenomenon of *representational determinism,* in which the format of a representation determines what can be derived from the representation. My research extends this to show how the physical features of the environment influence the external representations that will be constructed, and the consequent effect this can have on how activities are performed.

Disorder can arise

The influence of physical affordances and constraints can lead to disorder as items are placed in locations which do not convey

appropriate meanings. This problem can be greatest during interruptions and multitasking when demands on resources are high and the person's location is influenced by different activities. The problem is exacerbated by the desire to hold on to the resources involved in an activity for as long as possible while interruptions are evaluated and handled.

Cleanup and stabilization routines

Routines are developed to compensate for the disorder that arises in the spatial schemes people use. These including scanning the environment to insure that misplaced items are noticed, and cleanup routines which return items to their more appropriate places. Cleanup routines are triggered at specific times, such as before leaving the office or after completing an activity. Cleanup routines were also triggered by failure, such as when a needed item could not be located. Individual differences were seen in the priority given to cleanup routines, although these were not investigated in detail.

Stabilization routines are used to maintain the environment in a state which efficiently supports other activities. Stabilization routines include returning tools to their expected places after use, insuring an adequate supply of materials needed for tasks, and filing materials so they can be retrieved quickly when needed. Stabilizing the environment can minimize the disruptive effects of interruptions. For example, insuring that a pen and note-pad notes are in their expected places

minimizes the cost of an interruption that requires jotting down information or creating a reminder.

Stabilization routines are triggered at specific times, because of the need to perform an activity they will make more efficient, after failures, and through directly perceivable features of the environment. For example, filing can be triggered at the end of the week, before a certain report must be created, whenever it takes more than a certain amount of time to find a document, or when the stack of material to file grows beyond a certain thickness.

When time is short and resources are taxed, cleanup and stabilization routines are often neglected because they are not directly necessary for current activities.

Idealized routines are not adhered to, but are used as a resource

People establish routines to insure that they will come into contact with the external structures on which their activities depend. Although they can report an idealized version of their routines, they do not always adhere to the routines they report. Despite this fact, people rely on their introspections of their routines, and the belief that they will be followed, in determining how to structure their environment to support their activities.

Planning

Although some subjects did engage in limited planning, they all reported frequent deviations from any plans they did make. Accurate, detailed planning is often impossible because of the complexity and unpredictability of the environment, and because of the situated nature of people's activities. Instead, a form of *distributed planning* occurs, in which creation of the plan is distributed over time, and the plan itself is distributed over space. Through the application of routines which govern where items are placed, the spatial configuration of physical items comes to represent the order in which activities should be performed. This creates a distributed plan which is read through routines which insure that structures will be encountered at appropriate times and the desired activities cued. This planning does not involve a discrete continuous process, or create a plan which lends itself to explicit examination. It does satisfy the conditions for planning that require that a representation of the sequence of actions be stored, that this representation be consulted, and that consulting the representation leads to performance of the specified actions in the indicated sequence.

Theoretical Implications

At the start of the thesis I appealed to three theoretical approaches to real world human activities: activity theory, situated cognition, and distributed cognition. I will now address the implications of my findings on these approaches. Although my work is consistent with many of the points of activity theory, situated cognition, and distributed cognition, it

supports a wider point of view than any single one of those approaches. This is largely due to the methodology I used, which allowed me to track in detail how people purposely structure their environments to support interleaving activities over longer periods of time than have been the focus of prior studies.

Activity Theory

Activity theory is based on the notion that all human activities can be traced to their motivating goals. In practice, however, this approach is inadequate for delineating and understanding observed behavior in naturalistic settings.

One problem arises from the difficulty in attributing observed actions to specific goals. This problem arises for several reasons. First, there is often no one-to-one mapping between behaviors and goals. One set of actions can further a number of goals, and a single goal can be furthered by a number of different actions. Second, it is often hard to determine the specific goals that motivate an episode of behavior. This is true both for the person engaged in the activity and, even more so, for an outside observer. Third, activity theory does not prescribe how broadly or narrowly goals should be delineated.

An additional problem derives from the inability of the goal-based approach of activity theory to account for the role of external structures in influencing the course of behavior in dynamic settings. The specific course of the behaviors I observed was based as much on the specific and

often incidental details of how their environments were structured as on some set of internal goals. Understanding the mechanisms through which the external environment is shaped and in turn shapes behavior is therefore at least as important as trying to account for the often unknowable forces that internally motivate behavior.

Situated Cognition

My studies support the situated cognition view that sees intelligent behavior resulting from the continual interaction of an agent and the external environment. The role of the external environment was clear in shaping both the course of individual activities and the choice of which activities to pursue.

My research goes beyond the bulk of prior situated cognition investigations in two ways. Firstly, my studies looked in great detail at the specific forces that dynamically influence the structure of the environment in complex situations. They reveal how informational concerns interact with physical constraints and affordances to structure the environment, and the effects this interaction can have on the actions that later take place. They also show how people take an active role in structuring their environment to support their situated activities. Through this structuring a form of distributed planning does in fact take place; such planning is ignored by traditional situated cognition theory.

Secondly, my studies expand the assumed unit of analysis from focusing on individual tasks to looking at complex episodes of real world

behavior in noisy environments. They therefore reveal the interactions that occur when multiple activities are performed together and when interruptions occur. Interruptions and multitasking are often the norm, not the exception. My work thus shows the applicability of situated cognition frameworks in a broader set of naturalistic domains, and demonstrates clearly why traditional planning is often not possible in everyday life.

Distributed Cognition

Much of the past work in distributed cognition has looked at the performance of individual tasks in rigid, highly structured environments. The subjects I studied had the flexibility to more freely modify their environments and the routines they used. My work therefore shows the applicability of distributed cognition analyses to more typical areas of everyday life. Furthermore, by showing how subjects modified their environments over longer periods than are usually studied by distributed cognition researchers, my studies illustrate mechanisms that can drive the evolution of distributed cognitive systems.

Hutchins (1990, 1995) categorizes cognition as a distributed phenomenon involving the transformation of representational state across different media, though he does not directly address the cost of transforming these representations. My work goes beyond past work by showing the effects of these costs in the clear preference for using existing

physical structures and spatial relationships in the representation of task relevant information. This minimizes the time and effort required to transform internally held representations to external media.

As with prior studies, my research shows the practical value of the distributed cognition approach. By adopting the distributed cognition view that sees an agent and the external environment as a single cognitive system, I was able to observe directly the cognitive work accomplished through the manipulation of physical items. This allowed me to recognize instances of cognition and planning that otherwise would have gone unnoticed.

The Role of Observational Studies

With any cognitive inquiry, questions arise about the extent to which conclusions can be generalized to other people, settings and behaviors. Such questions are commonly voiced about observational studies such as mine which focus in great detail on a limited number of subjects in their naturally occurring environments. Because of the effort required to study each setting, it is not feasible to perform such studies with hundreds or thousands of subjects. Researchers used to the large number of subjects and controlled settings of traditional experiments sometimes question the validity of using findings from observational studies as representations of the population behavior at large.

Although I studied a limited number of subjects, each in their own unique settings, my results point to commonalties in the problems they

faced and the mechanisms they used to overcome them. These stem from the universal nature of human capabilities and common elements in the tasks they performed. All subjects shared limitations on memory and processing. All needed to keep track of the existence and state of their multiple activities and perform them despite unexpected interruptions. All subjects faced similar constraints on their ability to plan their activities in detail.

In Chapter Two I discussed Kidd's (1994) attempts to define categories of workers. These included knowledge workers whose primary function is to use their expertise to understand a body of knowledge and generate new information based on that understanding, communication workers who collect, distill and distribute information, and clerical workers who apply procedures and policies to maintain the smooth and efficient operation of an organization. Each of the workers I observed performed all of the functions Kidd describes, though in varying amounts. For example, although the architect could be characterized as a knowledge worker in many ways, his work also involved distributing information, maintaining records, and processing documents according to legal policies and procedures. Despite differences in the specific activities of each of the subjects, on a more abstract level they all performed similar kinds of work.

Observational and experimental studies raise orthogonal questions of generalizability. With observational studies like mine, one can ask how to generalize from the limit number of subjects observed to the

population of people at large. With experimental studies, one can ask how to generalize from discrete fragments of behavior studied in isolation in contrived settings to how those components combine to determine complex intelligent behavior in naturally occurring situations.

There is clearly a need for both observational and experimental studies, with each type of research inspiring and informing the other. Experimental studies can help isolate specific cognitive processes and determine their capabilities and limitations. Observational studies can suggest the issues that are important, and show if and how the principles discovered in experiments reveal themselves in everyday life.

Implications for Design

As stated at the outset, one of my goals in conducting this research was to apply knowledge of how people handle their multiple activities in the real world to the design of computer systems that will be used in noisy, interruption filled environments. Seven guidelines emerge from my findings:

1. Systems should support gradual transitions between activities.

Systems should allow users to gradually vary the amount of information and level of detail with which items related to different activities are displayed. Users should be able to control the transition between activities fluidly, through extensions to the existing metaphors they use to organize their work.

2. Systems should maximize the use of existing items to represent information.

Systems should maximize the extent to which users can use existing items to represent the state of their activities. The information conveyed by icons in current systems is generally quite limited. Systems should be designed so the visible, manipulatable representation of a file or document more meaningfully depicts its contents and relevance. Users should be able to augment the information conveyed by the representation as easily as they can scrawl a note or add a post-it to a paper document.

It is important that users can extract the meaning of these representations efficiently, without the need for additional manual operations. Subjects repeatedly described the value of reminders that conveyed the desired information "at a glance".

3. Systems should support the intelligent use of space

Systems should increase the flexibility with which users can spatially manipulate items. Current graphical user interfaces afford few degrees of freedom for users to manipulate icons and other items on screen. Interfaces which allow increased spatial control, including the ability to specify tilt, three-dimensional-stacking, and grouping should be explored. These increase opportunities to represent meaningful information through spatial configurations.

The combination of meaningful visual representations and increased spatial control also increases the extent to which the incidental effects of activities can represent task relevant information. Systems should support the use of spatially represented information in other operations, for example allowing the use of spatial proximity as a search criterion or to organize the results of a search. Users should be able to "undo" spatial operations performed in error as easily as they can undo other informational operations.

Computerized systems can make spatial representations portable, allowing users to access the spatial configurations they use from many physical locations. Compact, portable devices can also allow an integration of computer-based information into the physical spatial schemes people use for their other tools and artifacts.

4. Systems should increase opportunities for multitasking.

Systems should increase the user's ability to perform several activities at one time. This can be accomplished by expanding the number of channels available for human computer interaction. Multi-modal interfaces which allow the use of a number of channels for interaction increase the chance that resources needed for other activities can be freed. This increases opportunities for users to perform several activities simultaneously on their computers, or to perform activities on their computers along with non-computer based activities. As a simple example, imagine a system that allowed users to respond verbally to a

question posed in a dialog box. A user organizing documents in a different part of the room could respond to the dialog box without letting go of the documents or moving to the computer.

5. Systems should support the evaluation of interruptions

Systems should support the evaluation of computer-based interruptions with minimal disruption to the user's current activities. During the evaluation of interruptions, users determine the extent to which they must release resources they are currently using. It is counterproductive if the evaluation process itself requires the use of these resources.

A simple way in which this can be accomplished is through the use of large screens, which allow information describing interruptions to be displayed without obscuring information used for current activities. Another is through the use of multi-modal interfaces, which would allow for information on interruptions to be obtained through channels not used for current activities. For example, a system which audibly notifies the user when e-mail is received could provide increasingly detailed information on the amount of mail, the senders, and the contents of individual messages in response to verbal requests by the user. This would allow the user to determine how much to interrupt the current activity to read the e-mail, and parallels the way messages are frequently handled with human assistants.

6. Systems should support easy suspension and resumption of activities

As suggested by Miyata and Norman (1986), systems can minimize the detrimental effects of interruptions by reducing the time and effort to suspend an activity, preserving information on the state of activities so they can be easily resumed, and reminding users of the existence of suspended activities. Increasing the meaningfulness of representations and allowing more flexible use of space can further these goals, as preserving the spatial configuration of items will increasingly preserve task relevant information.

7. Systems should automate cleanup and stabilization operations

Although the constraints and affordances of computer represented items are different from those of physical items, they do exist, and have the potential to lead to disorder. The increased use of spatial representations should be accompanied by routines to automate cleanup and stabilization. Such routines could be triggered on demand, at scheduled times, or in response to events or circumstances that arise.

Future Directions

Two directions for future research suggest themselves. Firstly, studies such as mine should be conducted in additional settings, especially shared ones in which the use of space is determined and negotiated by several people. My observations were made primarily in individual offices, in which the placement of items was controlled almost exclusively by the subject. Furthermore, a significant portion of

the subject's work was performed within these settings. The use of spatial configurations to represent information would likely be different in shared spaces, where the activities of multiple agents affect the placement of items. It would also likely be different in situations in which no single setting existed in which the majority of activities were performed, or in settings where the use of space was tightly constrained. Studies in additional settings could explore the routines and procedures people develop when their use of space is limited by social or physical constraints.

Secondly, the design suggestions I raised in this chapter should be evaluated through the development and testing of prototypes. This should lead to direct benefits in the development of systems which are better suited for use in busy, interruption-rich settings. It will also lead to further understanding of how physical artifacts are used to support multiple activities. Prototypes can serve as the basis for real world examinations of the theoretical ideas on which they are based.

Conclusions

My research adds to the body of evidence describing the role of external representations in cognition. My work shows the importance of external structures not just in the performance of a single activity, but in the management and performance of multiple activities. It also illustrates how the spatial organization of meaningful items can efficiently represent important information.

External representations change the nature of the cognitive tasks people face, emphasizing perceptual processes and allowing limitations on memory and internal reasoning to be overcome. The integral role of external representations means that the management of activities is susceptible to the influence of physical affordances and constraints. Just as interference can arise between internal cognitive processes that use the same resources, interference can arise between distributed cognitive processes and the external structures they use. Especially during interruptions and when activities are performed together, disorder can arise in the external configurations on which people depend. This leads to the need for additional actions to stabilize and order the external environment.

Overall, my research supports the view of the external world as not just the stage on which intelligent behavior takes place, but as a constant participant in shaping that behavior.

APPENDIX A

The Questionnaire Used in the Office Activity Study

Activity Profile -- Questions / Procedure

Based on survey developed by Dan Russell, Tom Erickson & Dan Gruen -Mar 1, 1995

Methodological Note: There are three types of questions in this survey: normal questions, grand tour questions, and probe questions. It is important to understand the relationship between the latter two types. Grand tour questions encourage the interviewee to give a lengthy, in depth description of some domain (e.g. a typical day; layout of the office); probe questions follow most grand tour questions, and are there to ensure that answers to specific questions relevant to the grand tour are obtained. Grand tour questions are identified by a •• (and are in boldface); probe questions are identified by »; and normal questions by •.

Intro: I'm conducting a study to aimed at understanding what people do in their everyday work life. I'm going to ask you a set of questions about what you typically do and how you do it. The answers you give us will be kept in complete confidence and not made public without your explicit permission. We don't know of any reason for this, but if at any point you should feel uncomfortable or want to stop the interview for any reason, that's perfectly OK.

BASIC INFORMATION

- Date of Interview ___
- Name_____
- Place of work _____
- How long have you been working here_____
- Age (roughly) _____
- Sex ___

WORK PRACTICE QUESTIONS

WORK PRACTICE /General & work-pattern questions

- What do you do? What's your job title? What are your responsibilities? (In general terms, I'll ask more specific questions later.)

- How much do you work with other people (coworkers; and clients/outsiders)?

- Does your work have a natural rhythm to it (seasonal, monthly, weekly, daily)? Or is its pace governed by individual projects. (describe it briefly)

•• **Please describe a typical day to us, starting when you get up....** (e.g.,...what do you do when you first arrive at work, ..., what do you do at lunch, just after lunch, just before you leave, on the way home...)

» Planning in Advance: Do you generally know what you're going to be working on when you come in on a given day? When do you figure that out?

» Predictability: How frequent are departures from your plan (if you have a plan)?

» 'Maintenance activities': What sort of administrative things do you need to do--stuff that you have to do but isn't part of what you (garbage question)

» 'Interruption-Free Periods': Do you have, or give yourself, periods of time that are relatively quiet and free from interruptions, and what kinds of things do you do in them?

_____

_____

_____

WORK PRACTICE /Task-centered questions

- What goals (if any?) do you have for the day?

  _____
  _____
  _____
  _____

- What tasks do you expect to work on today? Is this a typical number? (If not, what is?)

  _____
  _____
  _____
  _____

- How many tasks would you say you have all together? _____

WORK PRACTICE /Interaction profile

- How many scheduled meetings will you go to today? _____
- How many informal meetings might you go to today? _____
- How often do you get interrupted a day? _____
- How many of the following do you expect to get today:

  phone calls: _____

  email: _____

  letters:_____

  faxes: _____

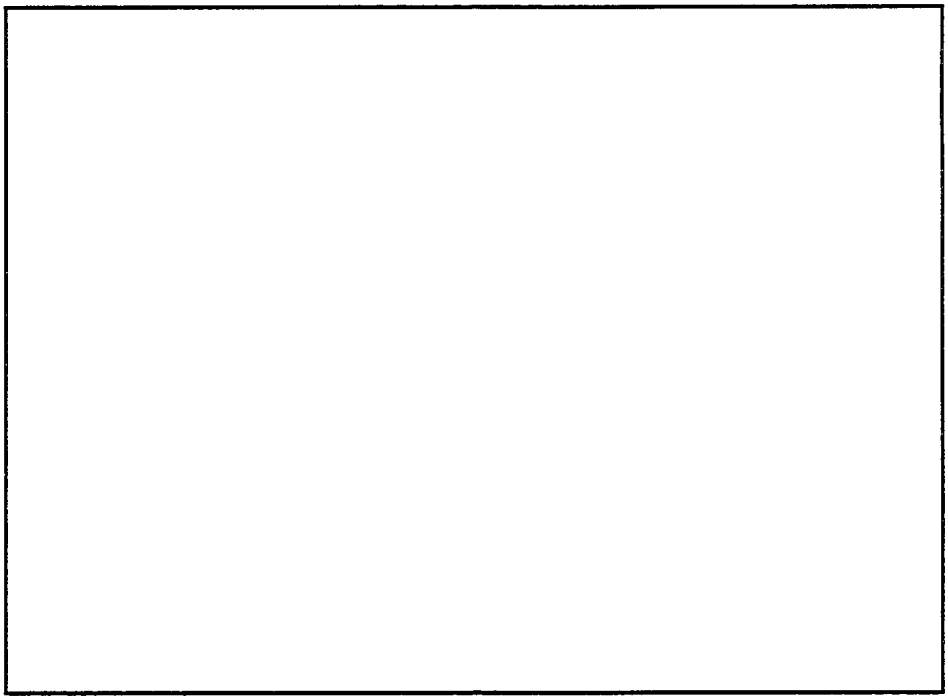
  conversations _____

PHYSICAL ENVIRONMENT QUESTIONS

PHYSICAL ENVIRONMENT/Static Organization

- Has your office been set up like this for a while?

•• **Grand tour of the office...** [usually useful to draw an annotated map here]



» How many reminders do you have around your office? _____

» How do you organize your physical piles...

_____

_____

_____

» What are the functional areas of the office...

_____

_____

_____

PHYSICAL ENVIRONMENT/Dynamics of use

- How often do you have to search for things? _____

- What items do you use to manage your time and activities? [If they can't think of anything, ask about: To Do lists; notes; calendars; business cards laid out on desk tops; ...]

  _____
  _____
  _____
  _____

- What other things do you use as reminders? How many are there?

  _____
  _____
  _____
  _____

_____

COMPUTER ENVIRONMENT

COMPUTER ENVIRONMENT /Static Organization

- Computer familiarity. How long and how much have you used computers? Are you a user only? Do you write scripts or programs?

_____
_____
_____
_____

- • **Give me a grand tour of your computer(s)**
  Specific info to be sure to get:
  kind of machine _____
  RAM _____
  Disk Size _____
  #/size monitor(s) _____
  # icons on desktop/top level _____
  # applications running _____

_____
_____

  - How do you use computers in your work?

_____
_____
_____
_____
_____

  - » How do you organize your files—how do you decide what goes where? (on the desktop? deeper in the hierarchy?)

_____
_____
_____

  - » Do you have problems in organizing your work on the computer?

_____
_____
_____

» How many applications do you have on your computer that you don't use?

_____

_____

_____

» Do you use email? How often do you check it? How are your email messages organized? What is your procedure for filing them?

_____

_____

COMPUTER ENVIRONMENT /Dynamics of Use

- How many searches for files or information do you do in a typical day?

  _____

  _____

  _____

- How many applications do you usually have running at once? _____

- How often do you spend time 'getting ready to work' on the computer (e.g., opening and positioning (or closing) windows and documents, starting or quitting applications, etc.?)

  _____

  _____

  _____

_____

POST OBSERVATION QUESTIONS

- Was this period a pretty typical one, or was it unusual in any way?

  _____

  _____

  _____

- Were there any major interruptions?

  _____

  _____

  _____

- Did you accomplish all the things you planned to do? (If not, why?)

  _____

  _____

  _____

- Did you accomplish other things you hadn't anticipated?

  _____

  _____

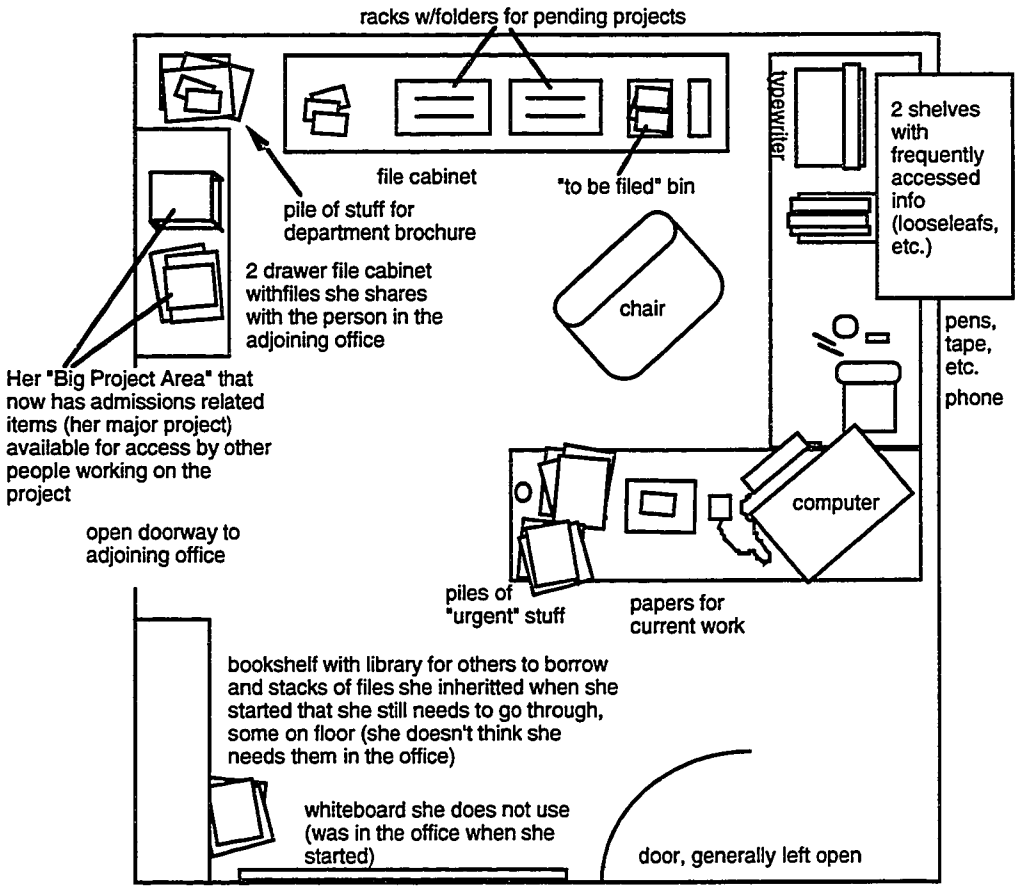
  _____

Additional notes:

APPENDIX B

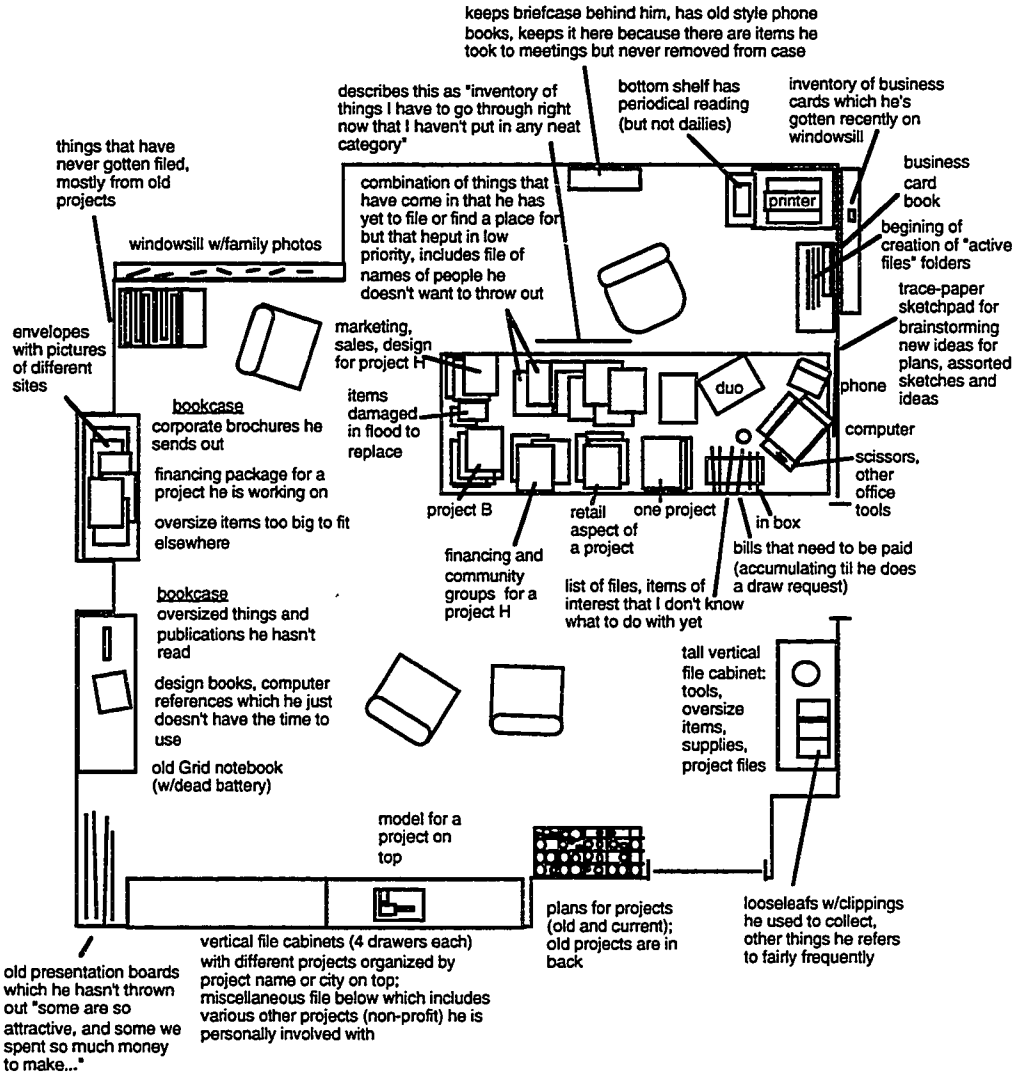
Maps of Subjects' Workspaces from the Office Activity Study

Subject AD


racks w/folders for pending projects
file cabinet
"to be filed" bin
typewriter
2 shelves with frequently accessed info (looseleafs, etc.)
pile of stuff for department brochure
2 drawer file cabinet withfiles she shares with the person in the adjoining office
chair
pens, tape, etc.
phone
Her "Big Project Area" that now has admissions related items (her major project) available for access by other people working on the project
computer
open doorway to adjoining office
piles of "urgent" stuff
papers for current work
bookshelf with library for others to borrow and stacks of files she inheritted when she started that she still needs to go through, some on floor (she doesn't think she needs them in the office)
whiteboard she does not use (was in the office when she started)
door, generally left open

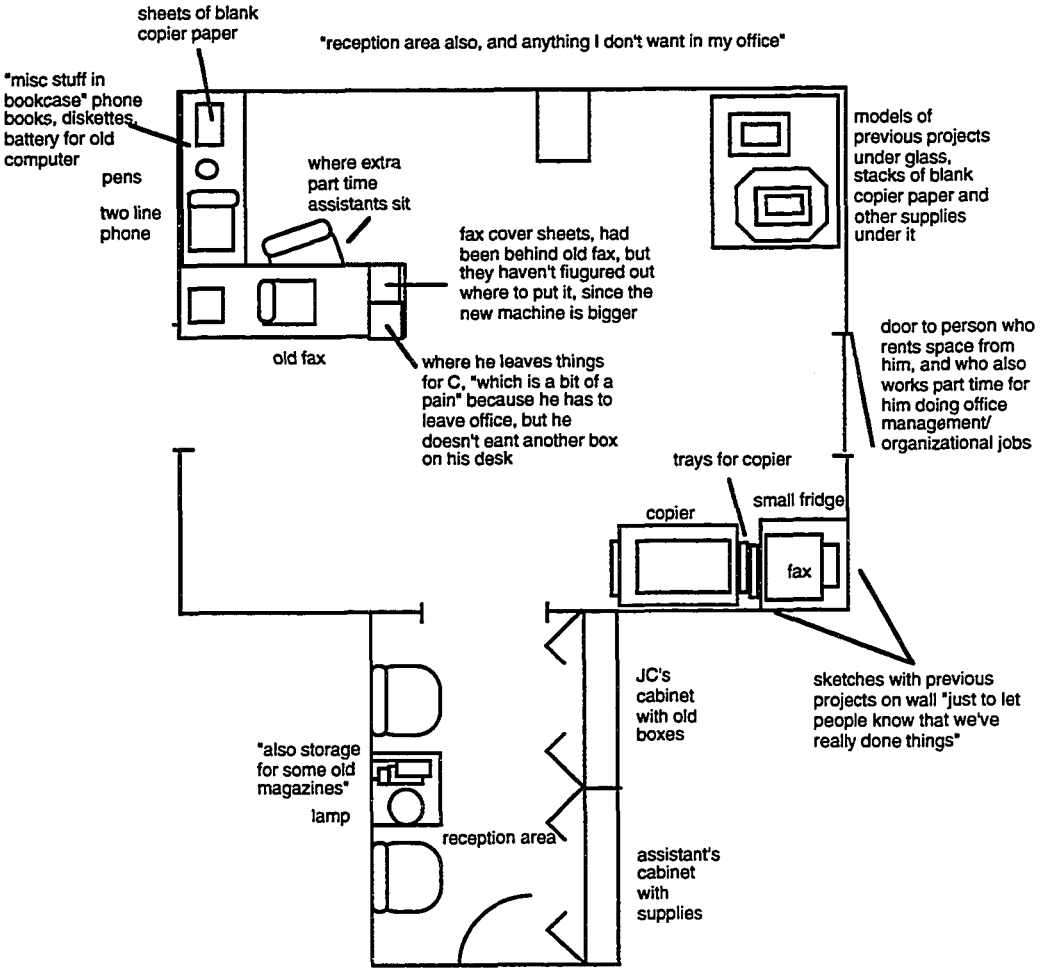
Subject JC

Main Office

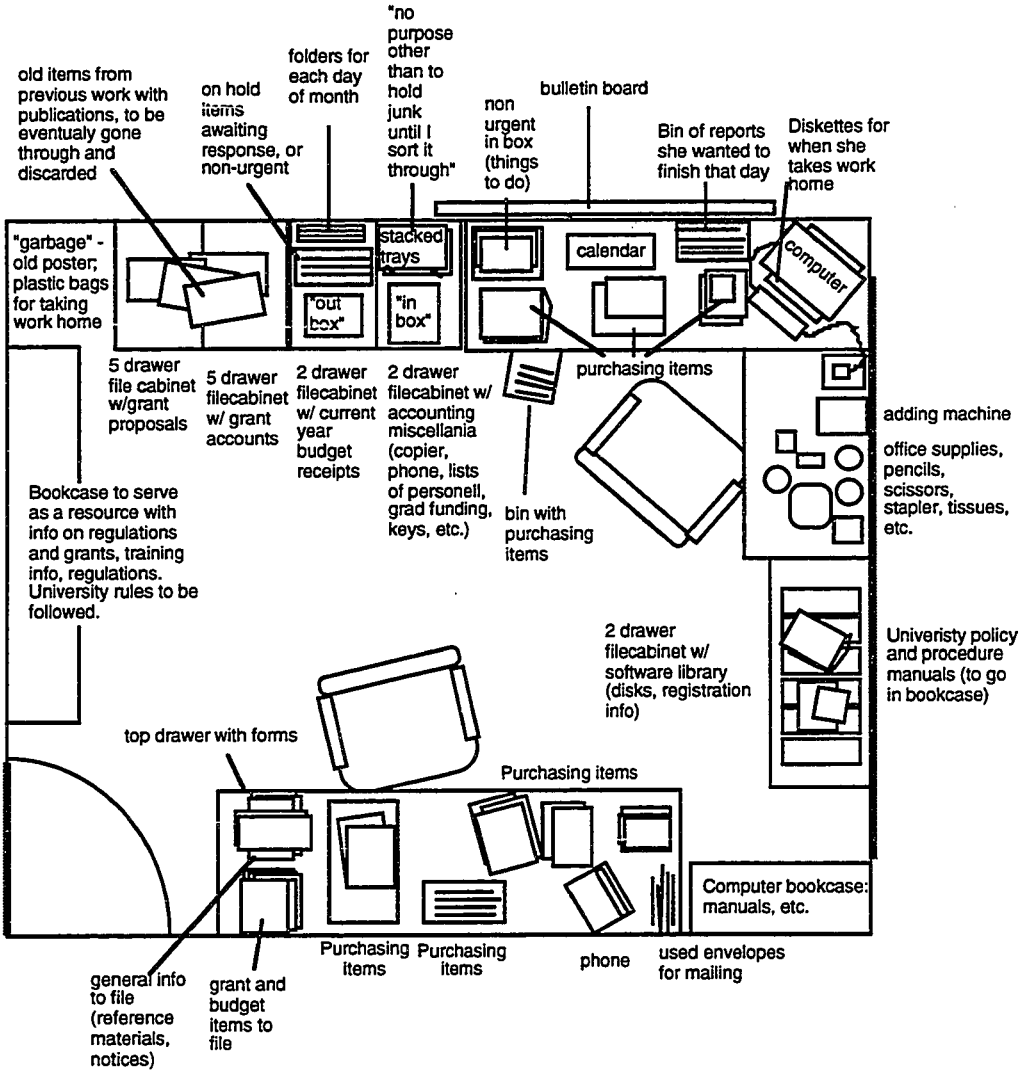


Subject JC

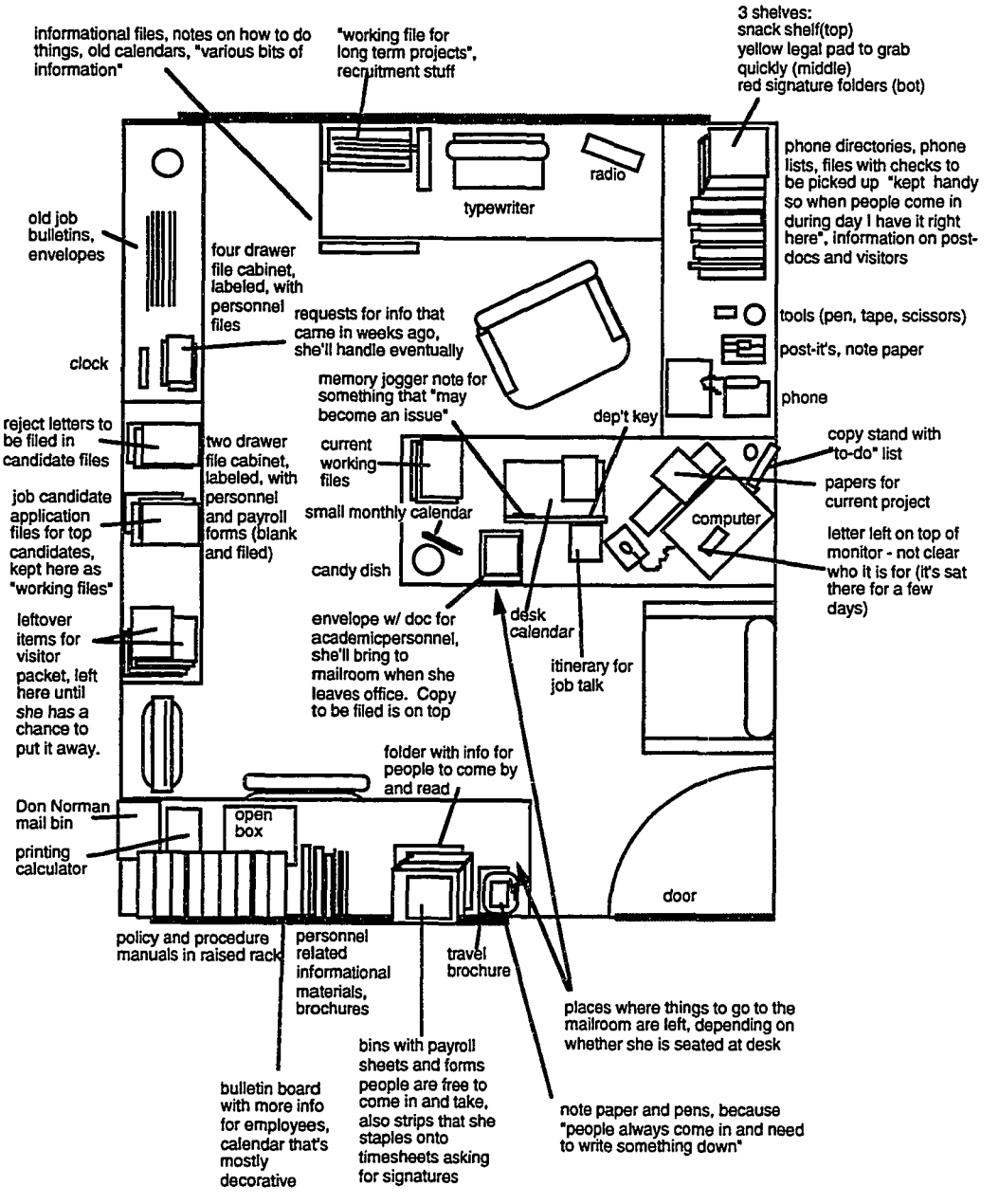
Entrance Area



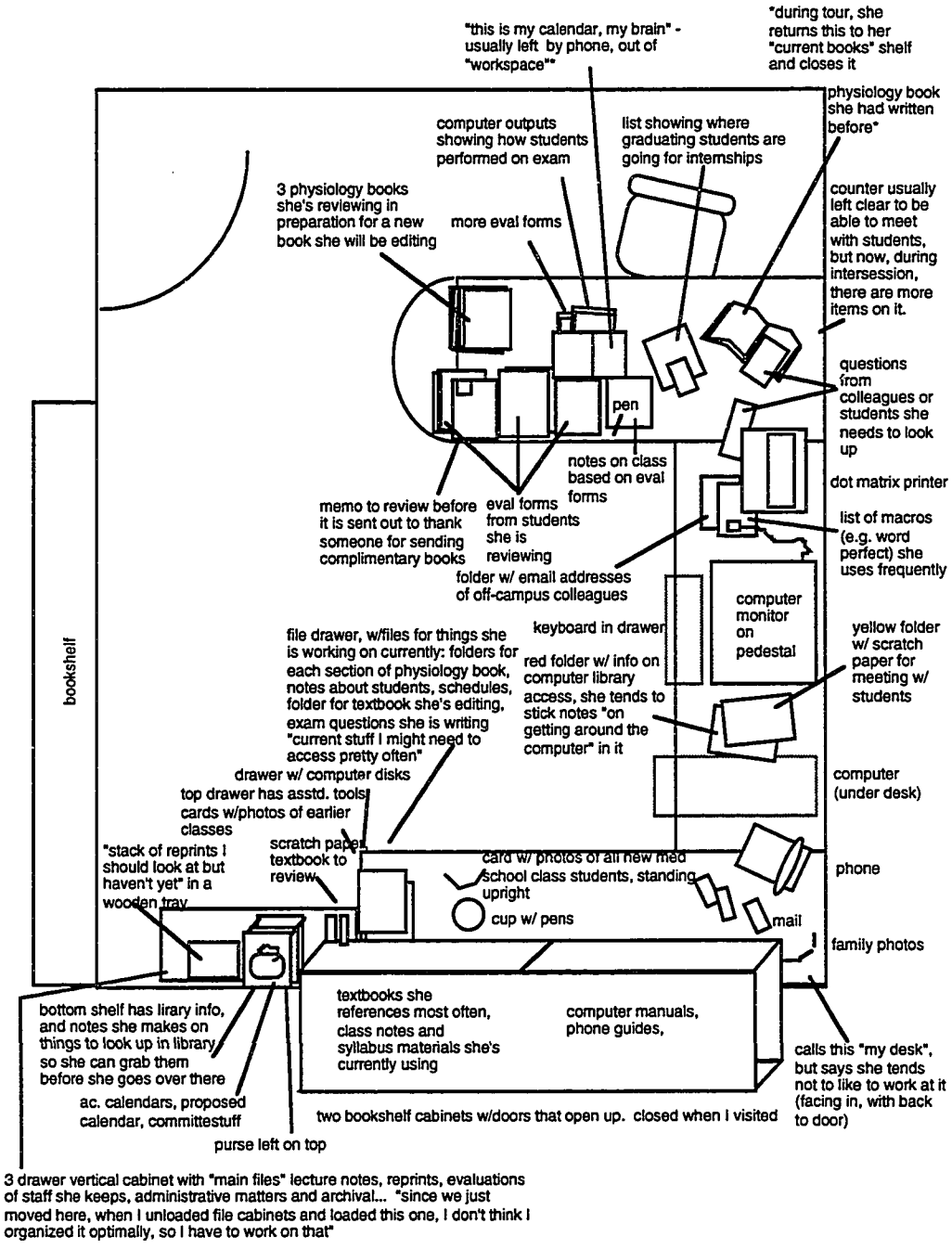
Subject KF


old items from previous work with publications, to be eventualy gone through and discarded
on hold items awaiting response, or non-urgent
folders for each day of month
"no purpose other than to hold junk until I sort it through"
non urgent in box (things to do)
bulletin board
Bin of reports she wanted to finish that day
Diskettes for when she takes work home
"garbage" - old poster; plastic bags for taking work home
stacked trays
"out box"
"in box"
calendar
computer
5 drawer file cabinet w/grant proposals
5 drawer filecabinet w/ grant accounts
2 drawer filecabinet w/ current year budget receipts
2 drawer filecabinet w/ accounting miscellania (copier, phone, lists of personell, grad funding, keys, etc.)
purchasing items
adding machine
office supplies, pencils, scissors, stapler, tissues, etc.
bin with purchasing items
Bookcase to serve as a resource with info on regulations and grants, training info, regulations. University rules to be followed.
2 drawer filecabinet w/ software library (disks, registration info)
Univeristy policy and procedure manuals (to go in bookcase)
top drawer with forms
Purchasing items
Computer bookcase: manuals, etc.
Purchasing items
Purchasing items
phone
used envelopes for mailing
general info to file (reference materials, notices)
grant and budget items to file

Subject MS

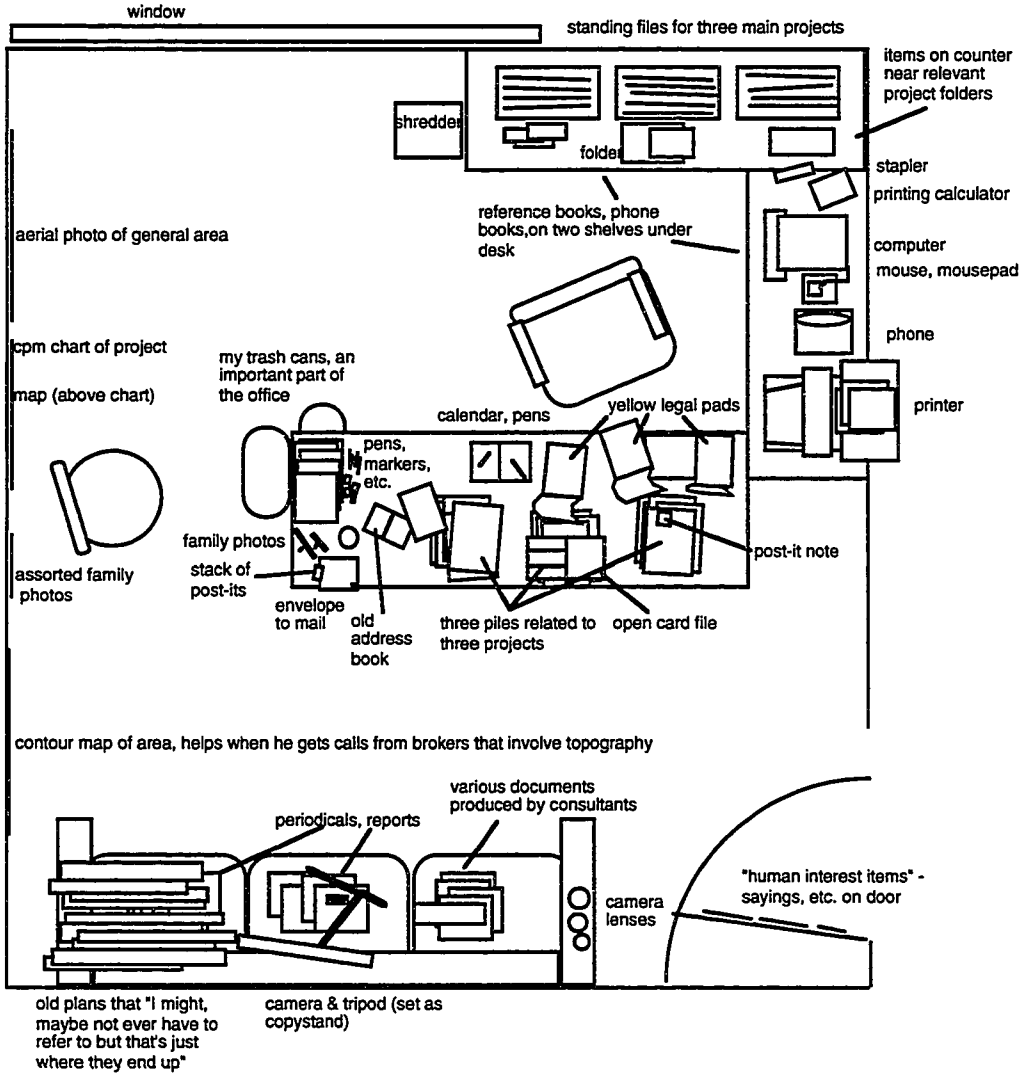

informational files, notes on how to do things, old calendars, "various bits of information"
"working file for long term projects", recruitment stuff
3 shelves: snack shelf(top) yellow legal pad to grab quickly (middle) red signature folders (bot)
radio
typewriter
phone directories, phone lists, files with checks to be picked up "kept handy so when people come in during day I have it right here", information on post-docs and visitors
old job bulletins, envelopes
four drawer file cabinet, labeled, with personnel files
requests for info that came in weeks ago, she'll handle eventually
tools (pen, tape, scissors)
post-it's, note paper
clock
memory jogger note for something that "may become an issue"
phone
dep't key
reject letters to be filed in candidate files
two drawer file cabinet, labeled, with personnel and payroll forms (blank and filed)
current working files
copy stand with "to-do" list
papers for current project
job candidate application files for top candidates, kept here as "working files"
small monthly calendar
computer
letter left on top of monitor - not clear who it is for (it's sat there for a few days)
candy dish
leftover items for visitor packet, left here until she has a chance to put it away.
envelope w/ doc for academicpersonnel, she'll bring to mailroom when she leaves office. Copy to be filed is on top
desk calendar
itinerary for job talk
folder with info for people to come by and read
Don Norman mail bin
open box
printing calculator
door
policy and procedure manuals in raised rack
personnel related informational materials, brochures
travel brochure
places where things to go to the mailroom are left, depending on whether she is seated at desk
bins with payroll sheets and forms people are free to come in and take, also strips that she staples onto timesheets asking for signatures
bulletin board with more info for employees, calendar that's mostly decorative
note paper and pens, because "people always come in and need to write something down"

Subject NL


"this is my calendar, my brain" - usually left by phone, out of "workspace"
"during tour, she returns this to her "current books" shelf and closes it
physiology book she had written before"
computer outputs showing how students performed on exam
list showing where graduating students are going for internships
3 physiology books she's reviewing in preparation for a new book she will be editing
more eval forms
counter usually left clear to be able to meet with students, but now, during intersession, there are more items on it.
questions from colleagues or students she needs to look up
pen
notes on class based on eval forms
dot matrix printer
memo to review before it is sent out to thank someone for sending complimentary books
eval forms from students she is reviewing
list of macros (e.g. word perfect) she uses frequently
folder w/ email addresses of off-campus colleagues
computer monitor on pedestal
keyboard in drawer
file drawer, w/files for things she is working on currently: folders for each section of physiology book, notes about students, schedules, folder for textbook she's editing, exam questions she is writing "current stuff I might need to access pretty often"
red folder w/ info on computer library access, she tends to stick notes "on getting around the computer" in it
yellow folder w/ scratch paper for meeting w/ students
bookshelf
drawer w/ computer disks
top drawer has asstd. tools cards w/photos of earlier classes
computer (under desk)
"stack of reprints I should look at but haven't yet" in a wooden tray
scratch paper
textbook to review
card w/ photos of all new med school class students, standing upright
phone
cup w/ pens
mail
family photos
textbooks she references most often, class notes and syllabus materials she's currently using
computer manuals, phone guides,
bottom shelf has lirary info, and notes she makes on things to look up in library so she can grab them before she goes over there
calls this "my desk", but says she tends not to like to work at it (facing in, with back to door)
ac. calendars, proposed calendar, committestuff
two bookshelf cabinets w/doors that open up. closed when I visited
purse left on top
3 drawer vertical cabinet with "main files" lecture notes, reprints, evaluations of staff she keeps, administrative matters and archival... "since we just moved here, when I unloaded file cabinets and loaded this one, I don't think I organized it optimally, so I have to work on that"

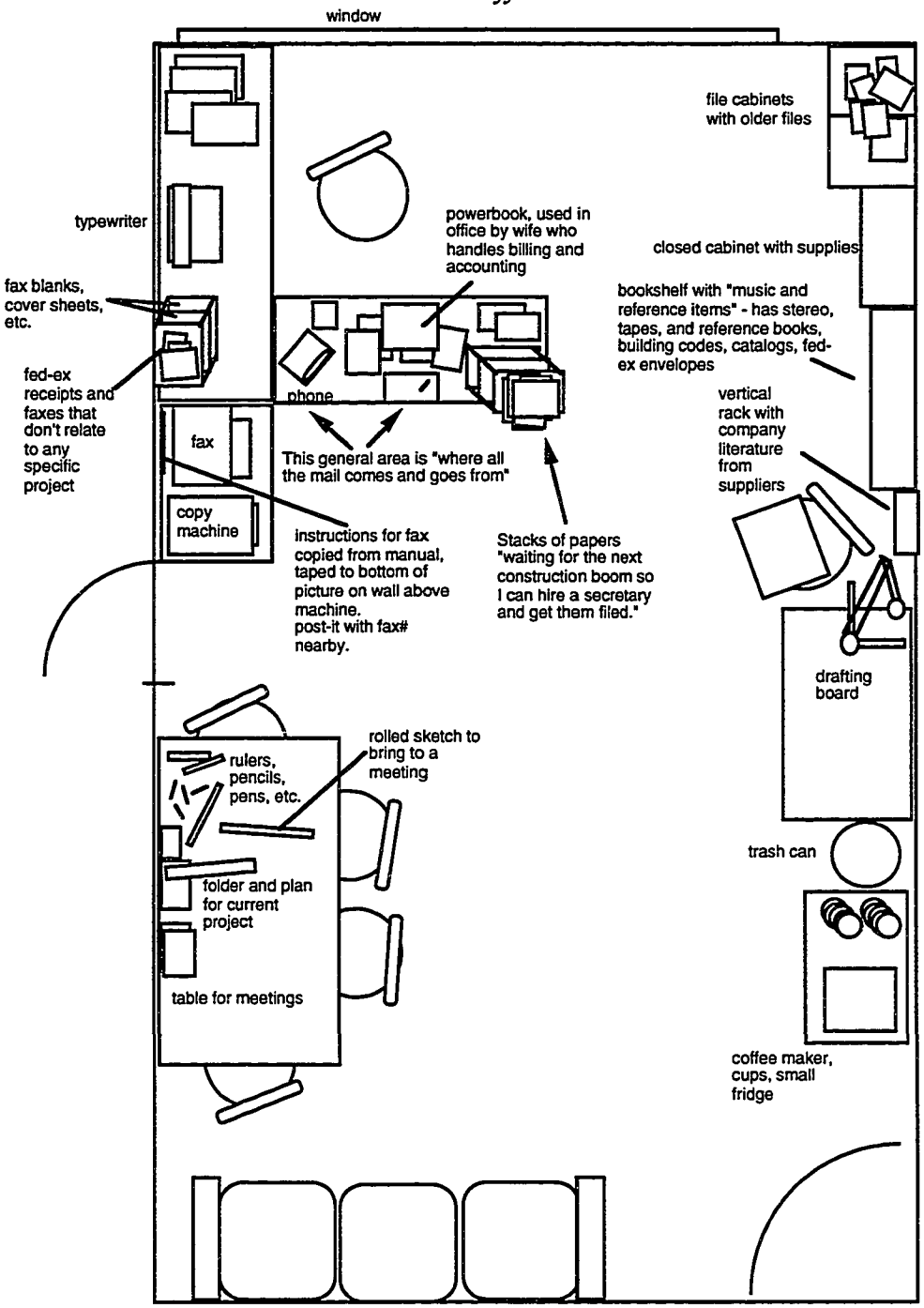
Subject RW

Inner Office



Subject RW

Outer Office



APPENDIX C

Extract of Transcript with Activities of Subject KF

Extract of KF2 Tape with Office Activities of Subject KF, Recorded 2/24/95 from 11:30 AM-1:30 PM.

Descriptions of items in the transcript, shown in parentheses, are based on protocols from the review of the tape with the subject and verified through subsequent inspection.

Counter	Transcript	Notes
00:18:15	KF returning from meeting with R, voices in hall	handling interruption in hall as she returns from meeting
00:18:30	enters office with papers (mail) in hand, places on desk	new stack of items to handle
00:18:34	takes white item of mail (photocopying invoices) from beneath blue one (award allocation sheet) on top of it, turns it over to prepare for reading it, places it on her desk on top of the pile of mail, with her hands on it, preparing to open it	
00:18:38	glances at video camera, says "oops, you turned off" and gets up to check video camera, leaving the white paper (photocopying invoices) on her desk, tries to determine if camera is on, then says "if you're still on, I'm back from R's" as she returns to desk	influence of videotaping
00:18:54	picks up paper (photocopying invoices) again, sees that it's stapled	
00:18:56	places it (photocopying invoices) back on desk as she reaches for a staple opener	finds stapler in expected place without searching
00:18:58	opens document with staple opener, throws out staple, starts to page through the white document	
00:19:12	turns and stands up as someone enters room, holding the white document (photocopying invoices) in both hands	interruption, maintains contact with resources from existing task

00:19:16	says "oh, a message" as she reaches with her right hand to take a yellow phone message being held out for her, continuing to hold the white document (photocopying invoices) in her left hand	holds on to items related to current activity during interruption
00:19:20	reads message, "M___ [a first name] 4 0 3 1 2 ?" [number changed for privacy]	wonders aloud about the source of the message
00:19:23	drops the white document (photocopying invoices) she had been holding on top of box of files on her second chair, then goes to phone with yellow message in her hand. discusses call with person who left message ("was it important? they just called you? oh, they called the front line... bizarre...")	attention now shifts to phone message; the invoices are dropped in the nearest available spot with proper physical affordances
00:19:36	dials number to check own voice mail to see if the person had left a message. says "thank you" to person who brought the message	
00:19:49	says "I'm on voice mail" to person in her doorway	notifies visitor of her ability to be interrupted ("on voice mail", not "on hold")
00:20:19	hangs up phone (without leaving message)	
00:20:22	places yellow message on her desk, leaves office, conversation in hallway (inaudible)	
00:23:30	returns to office holding white paper (for unrelated matter) in hand. looks at camera, says "is it on?" and jumps in front of camera several times, clicks something on camera, says "there"	influence of videotaping
00:23:42	goes to seat with white paper (for unrelated matter) in hand, places it in recycle bin	
00:23:46	picks up yellow message from desk, goes towards phone, leaves message by phone	phone-related items frequently left near phone

00:23:59	returns to seat, uses staple opener (left by mail) to open blue document (award allocation sheets)	
00:24:07	JM says "Hello" in doorway KF, turns and looks up, says "Hello" still holding blue document (award allocation sheets) in right hand. lets go of document (award allocation sheets) as JM, holding papers in her hand, enters. KF moves chair with box further back to make room for JM.	holds on to items at start of interruption, until she sees who it is
00:24:13	JM places one paper (human subjects approval form) on desk, says "now these are mine to keep, I take it?- referring to the paper on the desk"	
00:24:16	JM leaves first paper (human subjects approval form) on desk, holds out another paper (updated consent letter) to KF, says "now here's my new letter"	
00:24:18	KF takes new letter, JM says "can you send this to...?"	
00:24:23	KF puts new letter on her desk, JM picks up first letter (human subjects approval form), holds it out to KF, says "do you need a copy of this to go with it?" KF: "I made a copy of this (human subjects approval form) already, so I'll just, I'll send this (updated consent letter) and I'll attach a note" JM: "OK"	pending task: send form to human subjects committee with note
00:24:30	JM takes back first paper (human subjects approval form) and puts it back on papers she is holding	
00:24:32	JM takes sheet of paper she is holding (a copy of a purchase order; the document that had been on top of the pile when JM first walked in) and holds it out in front of KF. JM: "Did you put this in my box, do you want it back, or what?..." KF: "oh, it's a copy, if you guys like to keep copies, I actually meant to put it in L's [box]"	
00:24:42	JM turns to leave, holding papers, says "I'll put it in L's, because she [turns to look at KF] probably has been, she's keeping obviously closer track than I."	
00:24:43	JM looks through papers quickly before she leaves, while finishing prior statement [check to be sure she has done all she has to]	

00:24:44	meanwhile, KF notices someone (FedEx delivery man) at door, makes signing motion with hand, says "would you like me to sign for that?" as JM starts to leave. male voice: "no, you don't have to, it's all taken care of". KF: "OK, thank you very much"	handles interruption
00:24:51	JM: "yeah, cause she's here all the time" KF: "yeah, I'm sorry, I must've just put it in the wrong box." [motions with hands as if inserting papers in two boxes]	L's box is 3 below JM's in the department mail room
00:24:56	KF turns back to desk	
00:24:58	picks up blue paper (award allocation sheets), moves it from central area of her desk	
00:24:59	picks up white item from mail pile, rotates it so it is facing right side up, looks at it for a moment	
00:25:01	picks up yellow item (bill from graphics services) of mail, puts white item back on mail pile and the yellow item on top of it, unfolds the yellow item, then stands up with it and	
00:25:14	places yellow item (bill from graphics services) in folder of receipts to file (in "out box" pile), lifting items that were above the folder	marks bill as "item to be filed"
00:25:16	returns to desk, picks up white papers again, then puts them down	
00:25:18	picks up blue item (award allocation sheets) from before, reads it "[under breath] what is this?". pages through blue pages	surprised to see two sets of sheets
00:25:42	separates one set of pages from the rest	
00:25:46	holds one set of pages in right hand, rest of pages in left, glances from one to the other	looking to see if they are duplicates or different sheets
00:25:54	places pages from left hand on desk	
00:25:58	looks through pages in right hand	

00:26:04	picks up both pages, taps them on desk to straighten them	
00:26:10	fingers through stack("in box" stack) on desk with one hand, then	looking for documents with information on the award, either budget pages or award notice from granting agency
00:26:11	places blue pages (award allocation sheets) on desk so she can use both hands to search through stack of files	
00:26:19	retrieves white papers (award notice from granting agency), holds with fingers separating top sheet	award notice had recently come in mail; they were still in "in box". (notice still had routing slip attached.)
00:26:20	looks up as experimenter enters to discuss taping "I changed the tape in there..."	interruption due to study
00:26:23	KF gets up, holding white pages in both hands, goes to camera, discusses taping with experimenter	holds on to items related to current activity during interruption
00:26:31	KF sits down again, holding white papers in lap, with top pages still separated by fingers. experimenter continues talking about taping	fingers preserve place in award activity
00:27:01	KF glances down once to papers while experimenter continues talking about taping. short discussion on when to change tapes and retrieve equipment	action related to award activity (the glance) occurs during interruption
00:27:48	experimenter leaves, KF turns back to desk, separating top pages (of award notice) into right hand, others in left	
00:27:50	drops pages from left hand onto desk, drops pages from right hand onto keyboard	

00:27:53	glances at second page of papers on desk, then at second page of papers on keyboard. (for several seconds, uses both hands to lift top pages up) then looks at pages on keyboard	
00:27:54	lets go of pages on desk, uses both hands to go through pages on keyboard	
00:28:13	picks up blue papers (award allocation sheets) with left hand, holding papers from keyboard with right hand.	
00:28:20	drops blue pages (award allocation sheets) on desk, then drops white pages (notice from granting agency) from keyboard on top of other pages [closer to blue pages]. looks from one to the other, using hands to page through white pages	
00:28:27	[undertone] "oh, they gave us a second year's funding"	determines that funding for both years was sent at same time
00:28:28	picks up bottom white pages (award notice) with left hand, places top white pages (copy of award notice) in right hand beneath it. looks through top white pages, then at blue pages	comparing amounts on allocation sheets with award notice
00:28:34	picks up blue pages in left hand, looks from one to the other	
00:28:40	puts blue pages on top of all white pages, hits them on edge of desk to straighten them, slides chair to file cabinet	
00:28:42	opens file drawer while dropping pages down on top of pile near and above the drawer	pages do not "belong" in this pile; they are dropped there so they will be close at hand. (location selected for physical affordance of support)
00:28:43	looks at pages while holding file drawer (with budget folders) open	

00:28:48	looks through several folders in file drawer	
00:28:56	closes file drawer	
00:28:58	pauses	thinking about where to look?
00:29:00	gets up, goes to other file cabinet (which holds grant folders)	
00:29:04	opens file drawer, retrieves folder (for grant), pages through papers, mumbles several numbers under breath (checking to see if they should have sent in a progress report or new budget to get second year funding)	
00:29:48	walks back to desk [to get blue pages], goes first towards main work area, then back to where she had moved blue pages	initially looks in "current work area" where the papers "belong"
00:29:50	picks up blue pages (award allocation sheets), goes back to open file drawer	
00:29:53	pages through blue pages at open file drawer, mumble "oh, ok... ok"	
00:30:11	takes top blue pages in left hand, uses right hand to lift top papers in stack ("out box") at left of desk	
00:30:15	inserts pages from left hand into folder in stack under raised papers	
00:30:19	returns to open grant file drawer with other pages, inserts them in folder in file drawer, closes file drawer	
00:30:26	moves to return to desk, notices white papers (photocopying invoices) left on top of files in box on chair left before (in 00:19:23)	encountering items dropped before leads her to process them
00:30:30	picks up white pages (photocopying invoices), holds them in both hands and starts looking through them while standing	

00:30:34	knock at door, turns to see who is there, KF says "Hi there" while glancing back down to pages	starts to handle interruption while still performing current activity
00:30:40	MS enters with papers in hand, starts to discuss sending in an advance to guarantee a hotel reservation for a future visitor to the department	
00:30:43	KF puts papers together, places them into the out stack (using right hand to lift top items)	completes prior task while already engaged in interruption
00:30:47	discussion on guaranteeing room continues, KF first considers how long it would take to get a check to them, then suggests using her personal credit card to hold the room until the a check can be sent	
00:31:23	MS reads off exact amount the room will cost from the pages in front of her, KF moves over to look at the papers MS is holding. MS says "I better double check that, I did it very quickly"	papers MS holds are object of shared attention
00:31:32	KF starts to move back, says "yeah, if you check that and you send me email so then I'll do the form and get it over to travel and see if I can get it to them - when is she arriving? Tuesday night?" MS:"[reading from papers] Tuesday at noon." KF: "and she's staying Tuesday night and Wednesday night? MS: "yeah, she leaves Thursday" More discussion on holding room	
00:32:06	KF turns to get key from cup on shelf, says "Let me give you my credit card"	
00:32:12	unlocks drawer in which her purse is locked, at same time, AD enters doorway to ask about going to lunch	invitation to lunch is an interruption to the interruption
00:32:15	KF looks at watch on right hand, drops key from left hand onto top of file cabinet, says "I don't know"	
00:32:18	opens cabinet. KF: "what, are you going to have lunch today?" AD answers [inaudible]	
00:32:24	KF: "I'll go to the price center with you" while opening top drawer, reaching for purse	multitasking

00:32:30	takes out purse, asks MS if she wants to join them for lunch while finding credit card in purse. MS says that she was planning to grab something...	
00:32:39	KF: "ready" and reads credit card info which MS writes down.	
00:33:02	MS: "and this will be destroyed after I give it to her" KF: "oh, right, just scribble it out"	
00:33:05	KF returns purse to drawer, closes it	returns items to their places (even though she will need purse again soon for lunch, in 00:35:04)
00:33:12	picks up key from top of cabinet while pressing lock shut, returns key to place	returns items to their places
00:33:16	MS: "one other thing, I had a voice mail from MN at neurosciences that she's sending a PET (payroll expense transfer) for BN but she wanted to talk, she said to me [inaudible] so do you know what she'd be talking about at all?" KF: no, but why don't you give it a stab and talk, - call her up, she may just be calling you, - I don't know what kind of PET they would be doing, we just started funding her the first of January." (more discussion of PET) KF: "you can't do a PET anyway, if she says oh we're doing a PET for the January payment give her my number or transfer her to me cause I think..." (more discussion of PET)"you can't transfer a sub-zero to sub-three, she has to talk to somebody in payroll, but I can deal with that, this is just to give you some background." MS: "ok, get a few more details on this PET" KF: Yeah, just see, -is that ok?" MS: "yeah" KF: "it's a chance for you to get more familiar with that stuff too." MS: "ok" KF: "ok, good. thanks"	"one other thing" further interruption following initial interruption.
00:34:44	MS leaves	
00:34:45	KF notices yellow phone message she'd placed near phone before, mumbles "oh, I need to see [inaudible] this guy [inaudible]", walks to phone, dials number	noticing artifact prompts action

00:34:53	while in corner with phone, picks up key to file drawer	actions to prepare for lunch interleaved with phone call actions
00:34:59	moves to file cabinet with phone under chin, message in right hand, keys in left. places yellow phone message on top of file cabinet with right hands while picking correct key with left	holds items related to both activities
00:35:02	unlocks top file drawer, touches yellow message for an instant, moving it a small distance further back, places keys on top of cabinet	
00:35:04	opens drawer, reaches in back for purse	
00:35:09	takes out purse, places it on top of open files	open files afford support, freeing her hands
00:35:12	removes money (bills) from pocketbook, goes to other corner of office, walks back toward file cabinet	
00:35:20	leaves voice mail "Hi M, this is K, I got a message that you called me about the NSF incentives for excellence program, just give me a call when you have time, my number is <number>. Thanks a lot, M, bye." meanwhile: (1) unfolds bills, (2)walks to other corner, hangs up	multitasking
00:35:36	returns to file cabinet	
00:35:38	takes purse	
00:35:39	picks up keys in left hand, yellow message in right (which is already holding purse and bills)	
00:35:42	closes file drawer while looking at yellow phone message	
00:35:43	locks file drawer with left fist	
00:35:46	returns to other corner, drops keys in cup	

00:35:51	leaves yellow phone message by phone	leaves message by phone even though she has returned the message because "the issue is still open"
00:35:54	opens purse, puts bills in it, closes purse	
00:35:58	drops purse on desk	
00:35:59	sits on chair (pushing it back with right hand) while picking up staple opener with left	
00:36:01	puts staple opener back with other desk tools, picks up small post-it note pad from same area	returns tool to place
00:36:03	turns back to face desk, reaches forward and picks up pen in left hand while putting post-it pad down on the work surface in front of her	
00:36:04	writes note (to human subjects committee telling them that this is an updated consent form) on post-it pad	
00:36:14	takes top post-it, places it on letter JM had left	labels letter with its significance to human subjects committee
00:36:17	opens top file drawer, searches for relevant folder	
00:36:28	removes folder (with JM's experimental protocol)	
00:36:33	places JM letter on folder	KF will need to make a copy of the letter to put in the folder
00:36:34	places folder, with JM letter (and post-it) on top of pile ("in box")	represents pending tasks (copy letter for folder, send it to human subjects committee)

00:36:35	returns post-it pad to desk tools area	returns tool to place
00:36:38	takes top item of mail (newsletter) in left hand, item below (catalog) in right, looks at item in right hand	
00:36:41	drops item in left hand (newsletter) on desk	
00:36:42	places both hands on item (catalog) that had been in right hand, looks at it briefly	
00:36:44	puts item (catalog) in bin of (purchasing related) files on floor, behind several other folders which she moves with her other hand	bin has catalogs and other items the purchasing person handled before he left the department.
00:36:55	looks at next item of mail (color catalog), pages through it on desk	
00:37:06	picks up that item, and item she had left on desktop (00:36:41)	
00:37:08	places them in pile on left (in "to be filed" portion of out box) , after lifting several items from on top of the pile	
00:37:11	picks up pen, returns it to place on desk	returns tool to place
00:37:12	moves purse to center of desk, tamps it on desk three times	recalling if there is anything she has to do before she leaves for lunch?
00:37:16	pauses, looking at purse, says something [inaudible]	
00:37:19	reaches for pen with left hand and large pad with right hand (at same time)	because tools are in their expected places, she can quickly access them without searching
00:37:22	takes top sheet from pad, turns it upside down	

00:37:22	returns pad to desk tools area	returns tool to place
00:37:24	writes note (reminder to calculate summer salary for a grant, something she had been asked to do earlier that morning), underlining bottom back and forth several times	creates reminder of pending project before she leaves (until then, the need to do this project was represented only internally)
00:37:32	returns pen to back of desk, leaves note in center of desk where she wrote it	returns tool to place. reminder is left in central "current work" area
00:37:34	picks up purse and gets up to leave	
00:37:35	turns around, pushes chair back, pauses for a moment facing area with phone desk, moves left hand to face	scanning to see if there is anything she has to do before she leaves
00:37:40	moves toward phone	
00:37:42	calls ad, asks if she wanted to go then or later to Price Center. KF: "yeah, now is fine. ok. bye."	
00:38:06	hangs up phone, goes to out box pile glancing at desk as she passes it.	
00:38:10	takes blue folders from "out" stack to place in people's mailboxes	one of KF's regular routines is to take items from the top of her out pile when she leaves her office and will pass near the mailroom
00:38:18	check's watch, announces to camera that she is off to lunch	evidence of effect of videotaping
00:38:24	leaves	

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