DESIGN TO HANDLE INTERRUPTIONS IN HUMAN-COMPUTER INTERACTION

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ABSTRACT

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by Chiao-Yu Lu

Interruptions have become a concern in Human-Computer Interaction as proactive technologies are ubiquitous in our daily lives. Nowadays, a computer system cannot rationalize the effect of interruptions to humans, nor can it provide sufficient support to facilitate users. However, interruptions could reduce work productivity or cause human error.

This thesis includes literature review on how interruption affects human cognition and work activities. Interruption issues of communication tools such as emails and instant messaging are also addressed. This thesis further proposes a peripheral display and reminder system for computer desktop in user interface mockups. The display allows users to set interruption modes, and the reminder system is designed to help users recover after interruptions. Finally, implications of the findings and directions of future designs are discussed.

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1. INTRODUCTION

1.1 OBJECTIVES

This chapter will introduce a rising topic among the Human-Computer Interaction communities – interruptions. The objectives of this chapter are: to state the nature of interruption, to explain problems caused by interruptions, to explore motivation, and to summarize research goals of the thesis. Although the topic of interruption has been gradually recognized among groups such as computer science, psychology, sociology, and aerospace technology, there are very few design guidelines or solutions targeting the issues of interruptions. The design scope of the thesis is focused on the user interface of personal computers.

1.2 STATEMENT OF PROBLEM

1.2.1 INTERRUPTIONS – DEFINITIONS

The word "interruption" is defined as: "to break the continuity or uniformity of," "to hinder or stop the action or discourse of someone by breaking in on," "a breach or break, caused by the abrupt intervention of something foreign," or "obstruction caused by breaking in upon course, current, progress, or motion" (dictionary.com). These general definitions from common dictionaries provide useful descriptions of what an interruption is to English-speaking people, and these definitions also describe common phenomena of interruptions. In Human-Computer Interaction research, Cooper and Franks (1993) define human interruptions as "any disturbance to the normal functioning of a process in a system" (p. 4). In studies for peripheral information displays, Bailey, Konstan and

Carlis (2001) identify "An *interruption* was a peripheral task presented to a user while performing a primary task" (p. 593). McFarlane in his dissertation (1998) further asserts a general unifying definition of human interruption as "a process of coordination, abrupt change" (p.120), and "a change in people activities" (p. 122). These definitions also describe common phenomena when humans interact with machines.

1.2.2 INTERRUPTIONS – CONCERN IN HUMAN-COMPUTER INTERACTION (HCI) COMMUNITY

The concept of ubiquitous computing is gradually accepted, and intelligent technologies are embedded into our lives anywhere and anytime. However, all these high tech devices are competing for our attention. The demand for attention can cause more interruptions. HCI researchers foresee that interruptions could be the challenge of human cognition, and it is their duty to mediate and balance the interaction between human and machine. Therefore, many HCI communities start to include interruptions as part of the discussion topics. Well-known conferences such as CHI 2004 hold by the ACM's Special Interest Group on Computer-Human Interaction (ACM SIGCHI), invited researchers to give talks and workshops about their effort and findings on the topic of interruption. Other conferences such as CSCW, the ACM Conference on Computer Supported Cooperative Work, hold a paper session "May I Interruption?" in 2004. Many research groups at companies are also interested in the issues of interruptions. Eric Horvitz and Mary Czerwinski at Microsoft Research conduct extensive studies on interruption effect of desktop applications, such as email and instant messaging. Lockheed Marin Advanced Technology Laboratories also dedicate research effort on alert-based interruptions for Navy, and it is called Human Alerting and Interruption Logistics-Surface Ship (HAIL-SS) system. These HCI researchers try to advocate the importance of interruptions and raise awareness in the user interface design communities.

1.2.3 INTERRUPTIONS IN WORKSPACE

Interruptions are unpredictable and irresistible in normal working environment. Webpage pop-ups, phone calls, emails, instant messaging, and social events such as chat with colleagues can often interrupt work activities. Interruptions can also be disruptive when people need to concentrate on certain tasks. For instance, when interruptions occur, such as phone calls, a person has to shift attention to the interrupting cue – the phone, and very often, the person has to stop the current task in order to accept the incoming interrupting task. After answering the phone, the person might leave momentarily to operate other tasks. When resuming back to the very first task – the one before the phone call, the person might forget the uncompleted task or simply does not recall the last place where he/she worked on. The termination of the current task – interruption, could affect work efficiency and quality. Frequent interruptions can even cause significant performance issues. Preece et al. (1994, p. 105) define that interruptions are unanticipated requests for switching between different tasks during multitasking. The resumption of the task can be difficult between unanticipated task switching, and humans may need to try to remember what the old task is. Interruptions are often associated with negative effects: resuming to tasks after interruption is difficult and can take a long time (Cutrell, Czerwinski, & Horvitz, 2000); interrupted tasks are perceived as harder tasks than uninterrupted ones (Baily, Konstan, & Carlis, 2000); interruptions cause more cognitive workload for human information processing system such as memory, and interruptions are annoying and frustrating because they disrupt people from completing their work (Zijlstra, Roe, Leonova, & Krediet, 1999).

Not all interruptions bring negative impact: awareness systems such as alarm and alert systems effectively shift our attention to matters that need immediate care. Walji, Brixey, Johnson-Throop, & Zhang (2004) showed examples of interruptions that could also bring beneficial outcomes, such as warning, alerts, reminders, suggestions and notifications.

Some types of interruptions are also necessary for decision making. For example, a financial analyst may receive a stock quota from his colleagues via phone or emails in order to make decisions on stock purchase; a navy officer might receive some kind of signal or alert before firing a missile.

1.2.4 INTERRUPTIONS - CHALLENGE FOR HUMAN COGNITION

Human Cognition is Limited

In computer supported cooperative work (CSCW) office environments, a person is responsible for accomplishing two or more tasks at the same period time, and this behavior is called multitasking (Tsukada, Okada, & Matsushita, 1994). Multitasking has become a desired skill for most of job functions. And having the skill to multitask is developed through series of learning and familiarity with the tasks and the technologies that that tasks are operated on. Moreover, acquiring a skill requires frequent practice so the information can be encoded from short-term memory to long-term memory.

However, human cognition is limited. Human's short-term memory has very limited capacity, and it can only hold seven plus or minus two chunks of information at one time. When a person is learning a new skill, the new data is first stored in the short-term memory. And frequent rehearsals will help shifting the information from short-term memory to long-term memory. Nevertheless, any disruption occur during the memory encoding stage could cause memory loss (Oulasvirta & Saariluoma, 2004). And memory loss can affect the quality of learning. Thus, human cognition is limited to handle large amount of interruptions.

Technology is Growing

Technology is growing exponentially. "If there was a Moore's Law for user interfaces, it would state that the *number* of computers per user will double every two years" (Vertegaal, 2003, p. 31). Electronic devices such as fax, email, voice mail, cellular phones, computers personal digital assistants (PDAs) are communication tools that are frequently used in a normal working environment. Computer systems and mobile devices are supposedly to enhance work efficiency and facilitate collaboration between humans, but interacting with many electronic devices could be a burden to human cognition. It is because these technologies are not used solely alone, but in a complex, multitasking, and heavy-cognitive-workload environment. These technologies were designed to automate processes but also compete for users' attention. Emondson's (1989) asynchronous parallelism asserts that humans think in parallel but act in serial. This hypothesis implies that when each interruption occurs, tasks are handled only one at a time. Therefore, handling interruptions in multitasking environment with growing usage of technology has become a challenge for humans. These new technologies could bring new issues to the existing problems and also cause new side effects such as interruptions.

1.3 RESEARCH OBJECTIVES OF THE THESIS

Studies on interruptions have been researched in various Human-Computer Interaction areas: a) human cognition such as memory, learning, and decision making, b) aerospace applications such as cockpit and military defense design, c) multimodal interface design such as mobile applications, and d) desktop software applications.

Previous research works have been focused on the effects of interruptions and specific design approaches for displays and warning systems. Some research studies have shown social and psychological impact of interruptions, but there are very few studies done for desktop software applications. This thesis summarizes the interruption research done in various areas as mentioned in above, and it focuses on interruption effects for desktop applications such as email and instant messaging. A new personal computer user interface design for handling interruptions is proposed in this thesis. The design also follows user-centered design principles, and data from user research studies are served to improve different stages of the design. The user interface design has two parts: first, the design of a peripheral display that locates on the desktop and presents information to users. The peripheral display allows users to customize information they would like to monitor, and users are able to choose notification and interruption modes of each piece of the information. The second part of the design is a user interface mockup for a reminder system. Interruptions often cause forgetting, and one of the design goals here is to help users recover after interruptions. The reminder system allows users to retrieve the last active location of the mouse cursor in the software applications. These two UI designs together allow users to monitor more information at the same time while interruption effect is hopefully decreased.

1.4 LIMITATIONS

The domain of research proposed in the thesis work is focused on personal computer environment. However, the proposed design may be further studied for multimodal interfaces design or ubiquitous devices.

2. LITERATURE REVIEW

2.1 OBJECTIVES

This chapter summarizes interruption research done in the Human-Computer Interaction fields. Results from various psychology studies and theoretical models are served as foundations for the UI design in the next chapter.

Literature review on interruptions is discussed in different aspects: early findings, social implications, human cognition, aviation applications, software applications, current design supports, guidelines, and models. Readers should understand various research areas related to interruptions in Human-Computer Interaction.

2.2 INTERRUPTION RESEARCH STUDIES

K. Lewin and Zeigarnik first published their studies on interruptions in 1927. In their experiments, they found the relation between interruptions and selective memory. Their work is later known as "Zeigarnik Effect" (Van Bergen, 1968). Zeigarnik Effect is a psychological phenomenon that people tend to remember more about the interrupted tasks than uninterrupted ones.

2.2.1 SOURCES AND TYPES OF INTERRUPTIONS

Sources of interruptions can be external and internal (Miyata & Norman, 1986). External interruptions are caused by external entities, such as events in the environment, and internal interruptions are resulted from us, such as new thoughts in our minds. CubeSmart, Inc. (2002) conducted studies on office workers, and they found that there are several sources of interruptions: people asking for advice, the need for social interaction, and other interruptions from communication devices such as emails and phone calls.

Jett and George (2003) identify four types of interruptions - intrusion, breaks, distractions, discrepancies. "An intrusion is an unexpected encounter initiated by another person that interrupts the flow and continuity of an individual's work and brings that work to a temporary halt" (p. 4). "Breaks are planned or spontaneous recesses from work on a task that interrupt the task's flow and continuity" (p. 8). "Distractions are psychological reactions triggered by external stimuli or secondary activities that interrupt focused concentration on a primary task" (p. 12). "Discrepancies are perceived inconsistencies between one's knowledge and expectations and one's immediate observations that are perceived to be relevant to the task at hand and personal well-being" (p. 17). Each type has different causes and may generate positive or negative consequences.

2.2.2 INTERRUPTION EFFECTS AND MANAGEMENT

Latorella (1998) studied effects of interruptions and proposed a theoretically based model - Interruption Management Stage Model (IMSM). The model specifies four interruption effects – diversion, distraction, disturbance, and disruption. Diversion happens when attention is redirected away from the primary task. Distraction occurs after diversion when the interruption cue is being interpreted. Disturbance is further introduced when dealing with interruption – dealing with interruptions immediately or scheduling it for later. Disruption is the effect after the resumption of ongoing task. The model also introduces five interruption management behaviors: oblivious dismissal, unintentional dismissal, intentional dismissal, preemptive integration, and intentional integration. Latorella's IMSM is the first model that provides detail analyses, and it is useful for researchers to characterize interruptions and management behaviors with specific performance goals, such as flightdeck task management.

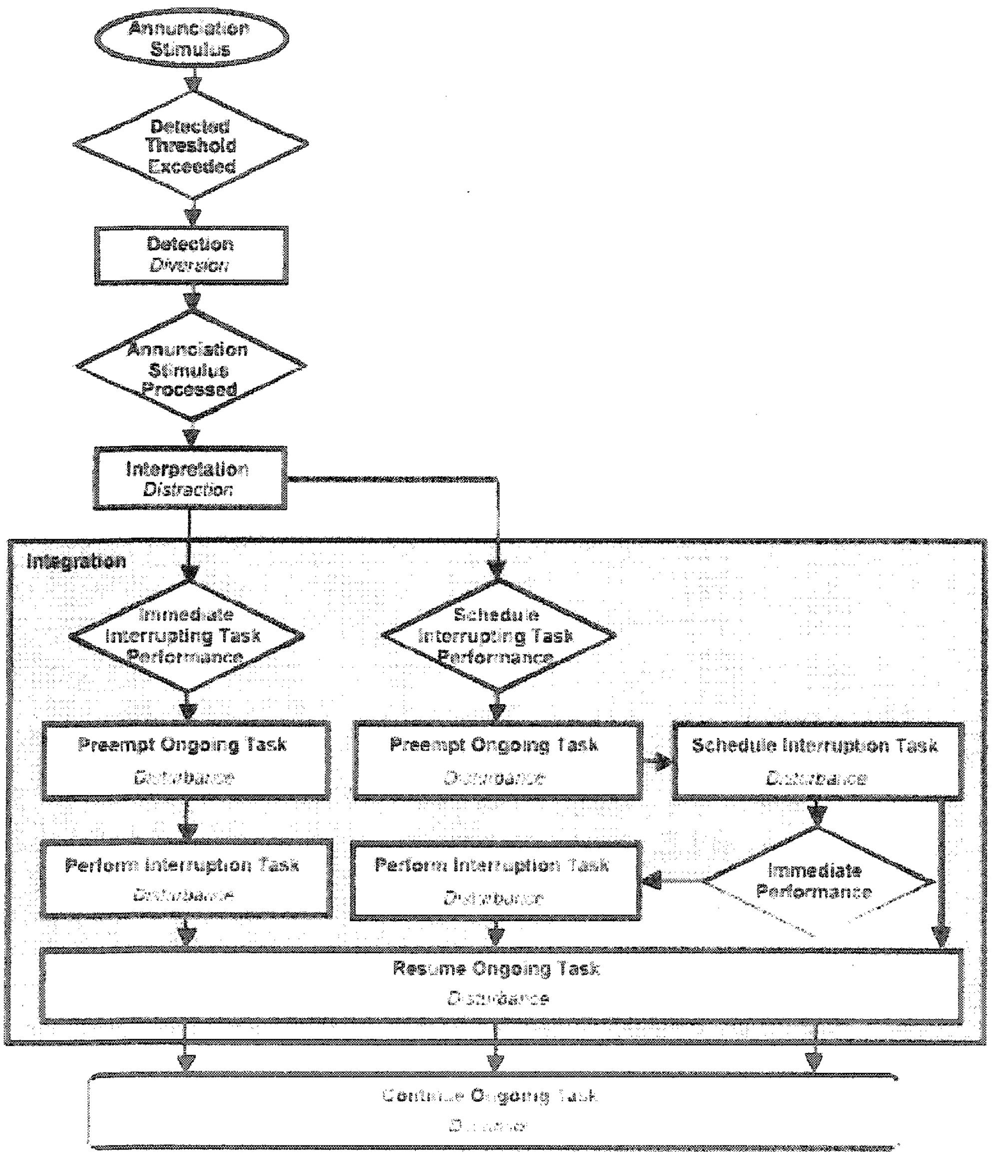

Figure 1: Interruption Management Stage Model
(McFarlane & Latorella, 1998, p. 16)

2.3 INTERRUPTIONS IN SOCIAL IMPLICATION – WORKSPACE

2.3.1 SOCIAL BEHAVIOR

It is often considered impolite and socially inappropriate to interrupt someone when the person is trying to concentrate on tasks or in a meeting. Reeves and Nass (1994) propose that computers are social actors and humans interact with computers in a sociable way. Thus interruptions from computer devices can also cause negative social effects. For instance, applications that generate interruptions can affect users behaviorally, and users may avoid using the applications in the future (Hudson, Christensen, Kellogg, & Erickson, 2002) and their attitude toward the application may change (Xia & Sudharshan, 2002).

In social psychology, distraction-conflict theory suggests that when people work in groups, they may have conflict feelings between tasks and other people whom they work with (Baron, 1986). It is because their divided attention leads to attention conflict, and it further causes psychological change such as arousal. Distraction effect such as arousal can influence task performance negatively, and that is called social inhibition. On the other hand, positive effect is called social facilitation. Here is the model of distraction-conflict theory (Hogg & Vaughan, 1998).

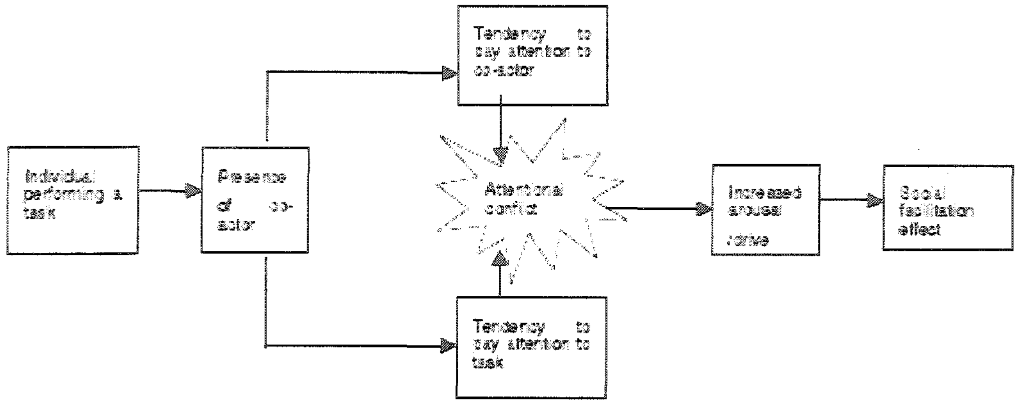

Figure 2: Distraction-Conflict Theory Model
(Hogg & Vaughan, 1998)

2.3.2 STRESS

Cohen (1980) studied how interruptions affect human social behavior and found that unpredicted interruptions could increase stress level. However, interruptions also occur frequently in workspace. 41% of interruptions can cause discontinuation of workflow, and people fail to resume back to the previous task (O'Conail & Frohlich, 1995). Carayon (1994) showed that interruptions could make job stressful in office environment.

2.3.2 COST OF TIME

CubeSmart, Inc. (2002) showed that average office workers spend 50% of their work time dealing with interruptions during their workdays. They are interrupted about 73 times everyday. They experience interruptions in every 8 minutes, and that is about 6 to 7 times per hour; each interruption takes 5 minutes on average. They spend more than 300 minutes dealing with interruptions everyday, and this does not include recovery time. 47% of the office workers spend 0 to 5 minutes to recover from interruptions.

2.3.3 TASK PERFORMANCE AND HUMAN ERROR

Many studies have shown that interruption can reduce task performance speed (Cellier & Eyrolle, 1992; Kreifeldt & McCarthy 1981). Bailey et al. (2000) conducted studies on web-based task interruptionS, and the results showed that: a) interrupted tasks can cause slower task performance than non-interrupted ones, b) different task categories generate different the disruptive effect, and the amount of interruptions show positive relationship with the memory load, and c) different interruption tasks induce similar disruptive effects on task performance.

Interruptions could also lead to incidents due to human error. Griffon-Fouco and Ghertman (1984) studied incidents in nuclear power plant, and they found that more than 25 % of the shut-down incidents were caused by interruptions.

However, interruptions could promote decision making and performance in simple-cognitive tasks (Speier, Valacich, & Vessey, 1997). Burmistrov and Leonova (2003) indicated that previous interruption researches gave inconsistent results, and they questioned if interrupted users always have slower task performance. They found that interruptions did not slow down performance in simple tasks; however, task performance was affected by interruptions during complex tasks.

2.4 INTERRUPTION AFFECTS HUMAN COGNITION

2.4.1 MEMORY

Hess and Detweiler (1994) studied the effect of interruptions on working memory. They found that interruptions may cause losing keeping track of the place in sequence because there are more demands on working memory. Also, interruptions are more disruptive during high memory workload.

Oulasvirta and Saariluoma (2004) conducted studies about long-term working memory and interrupting messages. They found that "interrupting messages can both disrupt the active semantic elaboration of content during encoding and cause semantic interference upon retrieval" (p. 53). They further found that message properties and context can affect types of errors in memory.

2.4.2 DECISION MAKING

Speier et al. (1997) found that interruptions can facilitate performance in simple task environment but negatively affect the performance in complex task environments. They suggest that interrupted environment can cause people making lower quality decisions. Cellier and Eyroole (1992) also found that interruptions could make task performance worse, and it takes longer time to make decisions.

2.4.3 EMOTION

Bailey, Konstan and Carlis (2001) found that interruptions can affect users' emotional states and cause annoyance and anxiety. Timings of interruptions can also influence levels of annoyance and frustration. Cohen (1980) found that the best moment to interrupt is between two coarse breakpoints, and interrupted tasks are easier to recall. Adamczyk and Bailey (2004) found that interruptions occur in the best moment for interruption can significantly reduce frustration and annoyance level.

2.5 INTERRUPTIONS IN AIR TRANSPORTATION APPLICATIONS

2.5.1 AVIATION ACCIDENTS

Interruptions can also cause fatal aviation accidents. A Northwest Airline pilot was doing the pre-flight checklist, and air traffic controllers interrupted the pilot with new instructions. After the instruction, the pilot forgot to resume back to the checklist. The plane took off without checking the flaps of the airplane. An emergency was declared after the flight took off because the flaps were in wrong position. The pilot could not identify the problem and the airplane crashed (NTSB 1988).

Sixty percent of aviation accidents are attributed to human error (National Transportation Safety Board, 1994). Boehm-Davis, Holt, Diez, & Hansberger (2002) built a NGOMSL (Natural Language GOMS) cognitive task analysis model to address problems with cockpit design and task intervention. Their eye-tracking data showed that pilots were not aware of the changes of the automation mode, and when intervention occurs, pilots often could not recall the goal of the tasks.

2.5.2 COCKPIT DISTRACTIONS

Dismukes, Young & Sumwalt (1998) identify four common activities that distract pilots:

(1) Communication: crews from sixty-eight out of total one hundred and seven aviation incidents reported they were distracted by communication, such as discussion or conversation between pilots and flight attendants. (2) Head-Down Work: NTSB indicated that thirty-one of thirty-seven incidents in a twelve years period were due to monitoring failure. (3) Searching for VMC Traffic: pilots' attention was taken away

when air traffic controllers told them to search for traffic. (4) Responding to Abnormal Situations.

To understand the causes of distractions in aviation incidents, the FAA in 1981 declared FAR 121.542 and FAR 135.100, known as Sterile Cockpit Rules. These rules regulate crews to follow specific procedures and to avoid unnecessary duties during flight activities, such as taxi, takeoff, and landing. Sumwalt (1993) at NASA studied sixty-three reports from the ASRS database and found that among fourteen percent of the problems were due to general distractions, and two percent of the problems almost led to mid-air collisions because of inattention and distractions. Furthermore, twenty-five percent of the problems were caused by interruptions such as interphone communication or when flight attendants unexpectedly entered to the cockpit.

2.6 INTERRUPTIONS IN SOFTWARE DESIGN

2.6.1 INSTANT MESSAGING

The increasing use of instant messaging could contribute to work performance issues and sociological impact due to distractions. A recent report by Pew Internet and American Life Project showed that instant messaging is increasingly used and eleven million Americans use instant messaging at work. Workers showed mixed feelings about instant messaging: forty percent of workers said instant messaging did not increase teamwork, fifteen percent thought instant messaging contribute to little gossip, twenty-six percent said instant messaging does not help them saving time (Mark, 2004).

Nielson (2003) indicates that increasing use of instant messaging (IM) is worse than email because of it demands real time attention. "IM is one more toxic spill that's directing our attention to short-term minor issues at the cost of procrastinating on important tasks that require more than a few minutes of uninterrupted thinking" (Nielson, 2003, p. 76). Nielson further claims that the internet tools such as the Web, email and instant messaging have become the information pollution in our society. Instant messaging immediately interrupts users' workflow, and it can cause loss in productivity.

Cutrell, Czerwinski & Horvitz (2000) at Microsoft conducted series of studies on interruptions of instant messaging on computing tasks. During the three phases cognitive processing – planning (think search terms), execution (enter search terms) and evaluation (make decisions), they found that interruptions of instant messaging during the evaluation phase can make task completion time much longer. Messages that are irrelevant to the context can cause more interruptions, and people need more time to resume back to tasks.

Many industries started to use instant messaging in the work environment. They thought that instant messaging could become an effective communication channel between workers and customers. However, using instant messaging in the workspace can bring up sociological issues among workers. It is often considered as impolite or rude when failing to reply to messages in a timely manner, because whoever sends the message is waiting for an immediate response. The person who receives the message is forced to accept the interruption and reply to the message. In addition, constantly attending to instant messaging may slow down work performance (Avrahami & Hudson, 2004).

2.6.2 EMAIL

Jackson, Dawson, & Wilson (2003) conducted studies at Danwood Group and found that employees took average 64 seconds to recover from email interruptions. They also took the same amount of the time to resume back to their work. Popular email providers such as Yahoo and Microsoft Outlook support immediate email notification systems. The systems notify users by popping up messages whenever they have new emails coming in. These immediate notification systems can help users receive information in real time. But pop-up messages are proactive and could be disruptive to users. Studies showed that frequent email interruptions as every five minutes could affect normal workflow (Jackson et al. 2001). Frequent email interruptions and the need to resume back to tasks can slow down the work performance and prolong working hours.

2.7 SOLUTIONS AND DESIGN SUPPORTS

2.7.1 HUMAN TRAINING

Training workers to handle interruptions is commonly seen in time management. There are many time management workshops that offer tips for office workers to prioritize tasks, to communicate with others effectively, and to handle and eliminate interruptions whenever it is possible.

Interruptions in complex environment such as flightdeck operation can cause serious operational error. Also, interruptions could be factors that lead to aviation incidents. However, training pilots to managing interruptions could be limited. Dismukes, Young & Sumwalt (1998) suggest six strategies for crews to manage cockpit resources and interruptions, and that include identify interruptions, recall tasks and decide resumption.

(1) Recognize that conversation is a powerful distracter.

(2) Recognize that head-down tasks greatly reduce one's ability to monitor the other pilot and the status of the aircraft.

(3) Schedule/reschedule activities to minimize conflicts, especially during critical junctures.

(4) When two tasks must be performed concurrently, set up a scan and avoid letting attention linger too long on either task.

(5) Treat interruptions as red flags.

(6) Explicitly assign Pilot Flying and Pilot Not Flying responsibilities, especially in abnormal situations.

(Dismukes et al., 1998, pp. 8-9)

Having preparation for interruptions can be helpful. In Hess and Detweiler's study (1994), they found that users showed better results in task performance when they were instructed and trained to deal with interruptions, but users may not develop strategies to handle and recover from unexpected interruptions.

2.7.2 NOTIFICATION SYSTEMS

Notification systems are lightweight alert systems that often reside in the background to support peripheral information. UI Designers and engineers apply rich design styles to current software applications such as animation and pop-up windows to catch human attention. And it is very often that notification systems are associated with interruptions. "Notification systems typically support awareness of presence, tasks and actions of collaborators, but they do not adequately support awareness of persistent and complex activities" (Carroll, Neale, Isenhour, Rosson, & McCrickard, 2003, p. 605). Designing good notification systems has been a challenge in the Human-Computer Interaction fields. It is because there are no guidelines regarding to the design of notification systems, and students nowadays receive very limited or no training in Human-Computer Interaction principles for user interface design. Therefore, Chewar and McCrickard (2003) at Virginia Polytechnic Institute and State University dedicate their effort in educating students Human-Computer Interaction principles and the design of notification systems. They develop a framework that conceptualizes three user goals, and they are comprehension, interruptions, and users' reaction toward the interruptions. The arrows in the framework are ratio indicators of Interruption (I), Reaction (R), and Comprehension (C) – IRC rating. These ratio indicators are helpful for designers to understand user goals, and the ratio can be used to assess the model of the design. For example, if a user is occasionally interrupted during the main tasks, but it takes very low or no effort to comprehend and to react to the interruption, the IRC rating will be 1/0/0. The number "1" indicates a small degree of effect, and the number "0" means no effect. The framework also serves as a design model for notification systems. They suggest that for a well-designed system, two of the IRC ratio indicators should be the same. However, different users or situations could lead to different needs for the design.

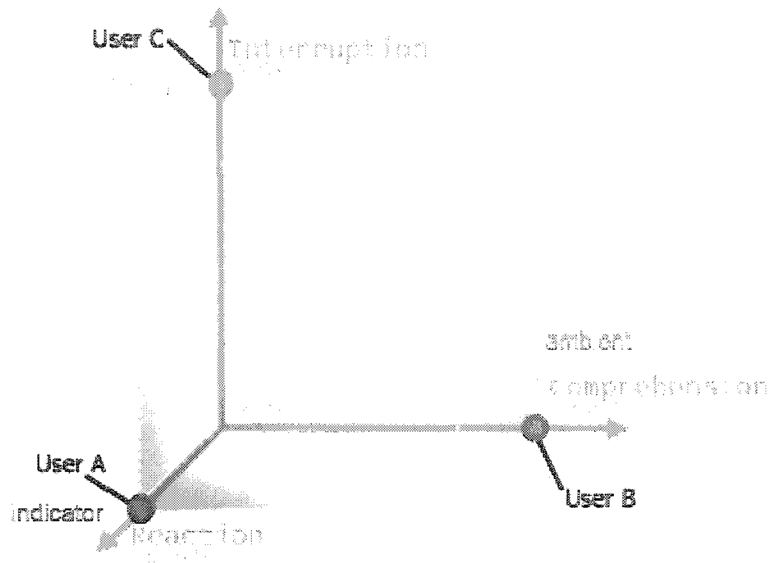

Figure 3: Interruption Reaction Comprehension Framework

Framework with IRC ratings. (Chewar & McCrickard, 2003, p. 281)

2.7.3 WINDOW OF OPPORTUNITY

Miller (2002) suggests a new strategy “Window of Opportunity” to handle interruptions. Window of Opportunity allows users to prevent the effect of memory lose after the interruptions. A window of opportunity is an interruption lag between an alert and an event (Altmann & Trafton, 2002). In the study, one group of people was instructed to rehearse the information they last worked on during the interruption lag, and the other group did not receive any instructions. The results showed that people who were instructed with rehearsal strategy tended to take longer time making decisions than uninstructed group. They also found that rehearsal strategy had no effect on users’ task performance.

2.7.4 PERIPHERAL DISPLAYS

Woods (1995) suggests that people have innate cognitive ability to handle attention, and which implies that people can manage their attention to handle peripheral information subconsciously. Woods further asserts that people could consume peripheral information, and peripheral information can help people concentrate on tasks.

Pop-ups, advertising banners and animated scrolling text displays are common peripheral information we see on web applications. Peripheral displays are widely used to help people monitor extra information, and besides peripheral information, there is a main task that needs the most of attention concurrently. Peripheral information is nonessential, and it is not a central part of the main task. To differentiate peripheral information from information in supervisory control, peripheral information "is not critical to task performance," and "inattention to peripheral information does not result in catastrophe, such as a nuclear meltdown or a plane crash" (Maglio & Campbell, 2000, p. 241). Peripheral displays show updated information through various ways: in simple sound such as beeping, in complex sound such as verbal speech, in visual cues such as flashing or highlighting, or in annotations such as symbols or text displays. Among those, using annotations is found to be less distracting for web applications (Maglio & Campbell, 1999). In Maglio and Campbell's studies on tickers - three single-line text displays and mental workload, they found that continuous scrolling text is more interruptive than non-scrolling ones. They suggest that using animation in peripheral display is not encouraged.

2.7.5 REMINDERS

Using reminders is an indirect way to handle interruptions. Since interruptions are unpredictable and unavoidable, reminders become solutions for us to prevent forgetting something after interruptions. A reminder is composed of two features – a signal and description (Dey & Abowd, 2002). Reminders as memory aides, can also raise potential interruption issues if signals are inappropriately introduced. Dey and Abowd further research on different reminder tools that are used frequently nowadays, such as paper to-do lists, e-mail mailbox, post-it notes, personal information management tools, and human assistants. Davies, Findlay & Lambert (1989) suggest that there are four types of designs for reminders depending on their notification (switching) mechanisms: normal switch, minimum switch, micro-switch, and information at the fixation point. In their studies, they also found that reminders could help people recovering from interruptions.

2.8 DESIGN GUIDELINES AND RESEARCH MODELS

2.8.1 TAXONOMY OF INTERRUPTIONS

When McFarlane started his dissertation research on Interruption of People in Human-Computer Interaction in 1998, he found very few guidelines or design principles that address issues of interruptions. Thus he proposed a general definition and taxonomy of human interruptions in his dissertation. In his taxonomy of interruptions, he found eight factors of human interruptions, including sources of interruptions, ways of coordination and effects of interruption. He also proposed four design solutions to coordinate user interruptions: immediate interruption, negotiated interruption, mediated interruption, and scheduled interruption.

Immediate interruption is a method that interrupts any ongoing activity immediately. The context of the interrupting task is introduced when a person is alerted by an interruption. This is the most proactive interruption method, and people are forced to accept or notice the interrupting tasks. Immediate interruption could be intrusive, but it is also effective to catch a person's attention. An example of immediate interruption is chatting on instant messaging and the online status is in available mode. The context of an incoming message is shown when the alert sound notifies users.

Negotiated interruption is a method that an interruption cue is introduced before interrupting tasks. This method informs people first before they accept or ignore interrupting tasks. McFarlane found that negotiated interruption is the best method among all. For example, a secretary notifies the boss there is a phone call, the boss can accept it or not.

Mediated interruption requires a mediator, such as software agent or secretary, who checks on a person's availability before interrupting. The mediator deals with the interrupting tasks or postpones the tasks if the person is busy. For example, a secretary checks the calendar and knows that the boss is busy in the morning, and the secretary rejects or postpones all meetings and phone calls.

Scheduled interruption is a method that interruptions are restricted in a timing manner. For instance, people can set their email systems to show new messages in every five minutes.

Factor of Human Interruption	Example Values
Source of interruption	Self (human), another person, computer, other animate object, inanimate object.
Individual characteristic of person receiving interruption	State and limitations of personal resource (perceptual, cognitive, and motor processors; memories; focus of consciousness; and processing streams); sex; goals (personal, public, joint); state of satisfaction of face-wants; context relative to source of interruption (common ground, activity roles, willingness to be interrupted, and ability to be interrupted).
Method of coordination	Immediate interruption (no coordination); negotiated interruption; mediated interruption; scheduled interruption (by explicit agreement for a one-time interruption, or by convention for a recurring interruption event).
Meaning of interruption	Alert, stop, distribute attention, regulate dialogue (meta-dialogue), supervise agent, propose entry or exit of a joint activity, remind, communicate information (illocution), attack, no meaning (accident).
Method of expression	Physical expression (verbal, paralinguistic, kinesic), expression for effect on face-wants (politeness),[a] signaling type (by purpose, availability, and effort), metal-level expressions to guide the process, adaptive expression of chains of basic operators, intermixed expression, expression to afford control.
Channel of conveyance	Face-to-face, other direct communication channel, mediated by a person, mediated by a machine, meditated by other animate object.
Human activity changed by interruption	Internal or external, conscious or subconscious, asynchronous parallelism, individual activities, joint activities (between various kinds of human and non-human participants), facilitation activities (language use, meta-activities, use of mediators).
Effect of interruption	Change in human activity (worth of this change is relative to the person's goals), change in the salience of memories, change in awareness (meta-information) about activity, change in focus of attention, loss of willful control over activity, change in social relationships, transition between stages of a joint activity.

Figure 4: Taxonomy of Interruptions
(McFarlane & Latorella, 2002, p. 19)

McFarlane's research effort on interruptions provides significant guidelines for the Human-Computer Interaction communities. McFarlane also works closely with Latorella in the research fields. Latorella's Interruption Management Stage Model (IMSM) as shown in section 2.2.2 and McFarlane's taxonomy are two different theoretical models. Latorella's IMSM identifies steps of cognitive workflow, and it is useful for researchers to understand sources and effects of interruptions. McFarlane's taxonomy serves as design guidelines for UI designers to address users' needs and to discover potential interruption factors in user interface designs.

2.8.2 STRATEGIES FOR PERFORMANCE

Based on previous researches, McFarlane and Latorella (2002) also summarize five strategies to handle interruptions and enhance human performance, and the strategies are training, incentives, personal selection, replace person with automation, and support HCI design. Each strategy has its pros and cons. Support HCI design approach shows more pros than other approaches, but cost is relatively high because it requires engineering and user interface redesign. Excessively rely on either humans or automation is not an ultimate solution because human cognitive capabilities are limited and automation can never be perfect.

Approach	Pros	Cons
Training	• Potential for measurable improvement	• Can be very expensive • Effectiveness is heavily dependent on training design and delivery • Doesn't produce consistent results across different people
Incentives	• Relatively easy to administer • Can cause quick improvements	• Unreliable effects • Potential to distract people from the real objectives • Can change the perceived meaning of work • Incentives may be difficult to design appropriately • Effectiveness degrades over time and incentives must be continually increased to remain effective motivators
Personnel selection	• Minimize variance in performance across different people performing the same task • Improve performance by selecting only those people least likely to make errors	• Can be extremely difficult to construct a valid and reliable predictive measure • Potential for work hiring discrimination issues especially if the predictive test tends to favor members of particular racial, ethnic, or cultural groups • Implementing a selection policy can have important effects on the work culture and work attitudes of team members • There are potential ethical, legal, and labor union issues in implementing a selection test in an already existing workforce

Completely replace person with automation	• Can be ideal if it is appropriate and actually works • Upgradable	• Many kinds of human tasks are inappropriate and unethical to delegate to automation because computers can not be accountable for failure • Automation has to be supervised and that's a new task for some person • Automation has its own reliability problems • For team tasks, replacing a person can affect the capability of the rest of the team
Design HCI support	• Directly supports people as they actually work on real tasks • Can prevent errors and increase effectiveness at the actual time and work context where this help is needed • Consistent and continual presence of support • Upgradable • Human retains necessary authority and accountability for success • Potential to engage various kinds of people's vast innate cognitive processing that would not have been invoked otherwise • Can improve the users perception of their responsibilities and attitude toward work	• Can be very expensive and complicated to develop and implement in a work context • Can have validity and reliability problems associated with any kind of computer system • May introduce meta-work for the user to manage the tool itself (Kirschenbaum et al., 1996) • Can be difficult to design well and poor HCI design can actually degrade performance • Support solutions may not scale well as tasks evolve over time • May include hardware requirements that are not already present in the work place (Brown & Levinson, 1987)

Figure 5: Approaches to Handle Interruptions
(McFarlane & Latorella, 2002, pp. 44-45)

2.8.3 UI SUPPORT FOR THREE PHASES OF INTERRUPTIONS

Latorella's Interruption Management Stage Model is used to identify three phases of interruptions. When there is occurrence of interruptions, there are three phases to manage interruptions: (a) before switching to other tasks, (b) during switch, and (c) after switching to other tasks. McFarlane and Latorella (2002) also suggest different UI support and design tactics for each phase.

Before switch phase is the period before interruptions happen. The design principle for before switch is to ensure appropriate ways to interrupt. Since interruptions can not be avoided, a better design solution is to minimize negative interruption effects. During switch phase happens when the person is switching between main tasks and interrupting tasks. The goal at this phase is to optimize task performance by shortening the time spent for interruptions and reducing cognitive workload. After switch phase is the post interruption period. A good user interface design should support users recovering from interruptions and help resume back to main tasks in an efficient manner.

Process model–interruption management stage model

- Facilitate appropriate exogenous cueing to interruption by designing annunciation stimulus salience commensurate with relative importance/urgency of interrupting task.
- Mininmize deleterious effects by announcing interruptions at cognitively appropriate points (e.g., between tasks rather than between activities) in an ongoing task set.
- Minimize deleterious effects by designing modalities of interruption annunciations in consideration of interrupted task modality.

Design space–definition and taxonomy of human interruption–coordination

Immediate	Semantically loaded warnings, brief delay to allow cognitive preparation, contextual bookmarking, multimodal interaction redundancy, maximize predictability of interruption. Explicitly mark task context where interrupted.
Negotiated	Maximize efficiency of user control in negotiating interruption by supporting (a) instant communication of meaning and requirements, (b) decision support for relevancy to current task, and (c) effortless quick command of negotiation interaction. Select appropriate channels, multimodal redundancy, maximize predictability and trust of interaction support.
Mediated	Maximize the intelligence of the automation to accurately infer useful ways to broker interruptions.
Scheduled	Visible clocks or other tools for increasing the predictability of scheduled transitions.

Figure 6: Design Suggestions for Before Switch Phase
(McFarlane & Latorella, 2002, p. 48)

Process model–interruption management stage model

- Minimize the long-term memory access time and errors by providing associations of annunciation with required interrupting task performance requirements.
- Provide support for rationally determining how best to integrate performance of interruptiong task and interrupted task set.

Design space–definition and taxonomy of human interruption–coordination

Immediate	Maximize UI support for interruption task to allow the user to get it done quickly; and maximize support for situational awareness (SA) of backgrounded tasks.
Negotiated	<same support as immediate>; and easy interactive controls for switching back to original task as needed.
Mediated	Maximize trust in automation through meta-information about status of expected services and accuracy levels of inference services.
Scheduled	<same support as immediate>; and status information about performance levels related to timing.

Figure 7: Design Suggestions for During Switch Phase
(McFarlane & Latorella, 2002, p. 48)

Process model–interruption management stage model

- Enhance memory of interruption position by external markers or by allowing rehearsal.
- Provide overview status of backgrounded taks.

Design space–definition and taxonomy of human interruption–coordination

Immediate	Bookmark recovery, context restore; replay capability with flexible user control; time compression summarization for replay; reminders of objectives and previous activities.
Negotiated	<same support as immediate> Display information verifying that interruption task was completed successfully.
Mediated	Intelligent constraints on user actions to enforce error-free resumption of original task.
Scheduled	<same support as immediate> Summary of amount of time spent away from original task.

Figure 8: Design Suggestions for During Switch Phase
(McFarlane & Latorella, 2002, p. 49)

3. METHODS

3.1 OBJECTIVES

The aim of this chapter is to explain design tactics and user research methods used in the thesis. McFarlane and Latorella's theoretical models, as described in previous chapters, are design guidelines for the user interface mockups in this thesis. Research problems and questions are revisited this chapter to clarify research goals. This chapter also describes user-centered design methods that are increasingly advocated in the software design industries nowadays. User-centered design methods, different from traditional user interface design, target on different users' needs and difficulties in their workflows. User research methods such as interviews and surveys are addressed in this chapter. Finally, usability methods are used to examine the preliminary design and final assessments. Readers should understand the methods and processes of user-centered design after reading this chapter.

3.2 RESEARCH PROBLEMS AND QUESTIONS

3.2.1 RESTATE RESEARCH PROBLEMS

From previous chapters, we know that interruptions are part of our everyday lives. Our understanding on interruptions is very limited, and very often, we are not aware that interruptions have caused so much impact in our lives. We also have very limited strategies to handle interruptions. We try to learn new skills to deal with interruptions, such as learning to recognize types of interruptions and responding to it accordingly, or relying on reminders to help us keeping track of things. No matter how hard we attempt to handle interruptions, the effects of interruptions could be very serious such as costing human lives in aviation accidents, or not very serious such as decreasing work efficiency. And the sources of interruptions could be unpredictable – from self, other people, or computer devices. For the scope of this study, I focused on interruptions that happen between people and their personal computers.

Some research studies reviewed in the preceding chapters only touched upon on interruptions from one single source such as emails or instant messaging, or specific tasks such as text editing. However, software applications are not used solely alone in the normal working environment. This also implies that a personal computer as a single source may generate multiple types of interruptions. Also, previous studies only focused on the effects of interruptions from one source or certain types of tasks, and the effects of interruptions from multiple software applications have not been studied. These are research problems that I intended to focus on in the study.

3.2.2 RESEARCH QUESTIONS

From the literature review in the previous chapters, interruptions of multiple software applications have not been researched in the past. To understand the problems better, these are some research questions proposed in this thesis:

1. What are the general challenges people face in their daily jobs?
2. What are possible sources of interruptions for different business verticals?
3. How do people handle interruptions?
4. How do they recover from interruptions?
5. What are the overall difficulties people have with their personal computers?

The following graph illustrates some external factors of interruptions between people and computers.

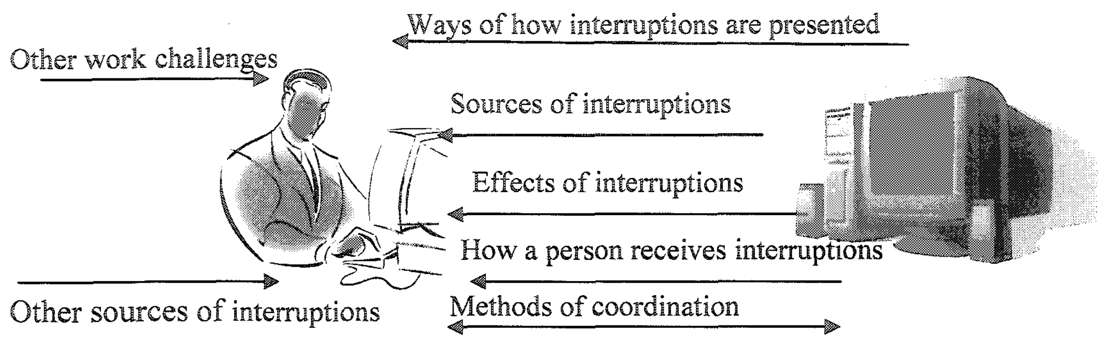

Figure 9: Interruptions Between People and Computers

These general questions are used to understand if interruptions are part of contributing factors to users' work challenges and if people are aware that interruptions are causing pain in their workflow. Some interruptions are very demanding or already become part of daily lives, and it is possible that people are not aware that they are dealing with interruptions. Thus it is important to collect subjective opinion on what people think about interruptions, and it is also critical to identify interruption-related problems from their work challenges. Specific questions regarding to user experience are addressed in the surveys that were used to interview people from different business verticals. Please see section 3.6 Survey for detail questions.

3.3 DESIGN PROCESS: USER-CENTERED DESIGN

3.3.1 WHAT IS USER-CENTERED DESIGN?

User-Centered Design (UCD) has been a trend in the design community. It is a design philosophy that focuses on users' needs. Users become the purpose of design, not the products. Users are also being considered at the beginning of the design process.

UCD also focuses on the interaction between users and design artifacts, and cognitive factors such as human memory, decision-making, learning, emotion, and design factors such as usefulness and usability are also important in the UCD process. To target on different users' needs, it is essential to analyze users' tasks and goals in the UCD process.

3.3.2 WHY DID I CHOOSE USER-CENTERED DESIGN?

People in different business verticals could have different problems caused by interruptions. To understand the difficulties that people face in different verticals, UCD methods could reveal potential user issues and further facilitate the design process. When there is no adaptation of UCD, designers and engineers base on their intuition to develop software products. Designers and engineers might not know the exact needs of users because they do not have the same experience as users, thus their intuition might not be correct. Designers and engineers might not receive any user feedback to improve their design, and the results of products may not be useful or usable to users. Therefore, I applied UCD and user research methods in this thesis to analyze a person's: (a) role in the company, (b) job duty, (c) daily workflow, (d) tasks, (e) goals of the tasks, (f) work challenges, (g) software usage.

3.3.3 USER-CENTERED DESIGN GUIDELINES

Technology giants such as IBM have been advocating UCD for years. They suggest six User-Centered Design principles for the design of software applications: "set business goals, understand users assess competitiveness, design the total user experience, evaluate designs, manage by continual user observation" ("User-Centered Design

Principles,"n.d., para. 1). Also, Katz-Haas (1998, para. 3) suggests some questions to keep in mind during the UCD process:

1. Who are the users of this Web site?
2. What are the tasks and goals of these users?
3. What experience levels do the users have with
4. Computers?
5. The Web?
6. This interface and interfaces like it?
7. The domain (subject matter)?
8. What are the users' working or Web-surfing environments?
9. What hardware, software, and browsers do the users have?
10. How can the design of this interface facilitate users' cognitive processes? How do the users discover and correct errors?
11. What are the users' preferred learning styles? How much training, if any, will the users receive?
12. What relevant knowledge and skills do the users already possess?
13. What functions do the users need from this interface? How do they currently perform these tasks? Why do the users currently perform these tasks the way they do?
14. What information might the users need and in what form do they need it?
15. What do users expect from this Web site? How do users expect this interface will work?

I also applied heuristic evaluation as one of the usability techniques to examine my design. Jakob Nielson's (n.d., para 2) ten usability heuristics are commonly used in the user research and usability fields, and his heuristics serve as guidelines in this thesis. The ten usability heuristics are:

1. Visibility of the system status
2. Match between system and the real world
3. User control and freedom
4. Consistency and standards
5. Error prevention
6. Recognition rather than recall
7. Flexibility and efficiency of use
8. Aesthetic and minimalist design
9. Help users recognize, diagnose, and recover from errors
10. Help and documentation.

3.2.3 DESIGN GOALS

Besides applying the UCD and user research methods, these are the goals to be achieved in my design:

1. Users first. People in different verticals may have different information they would like to monitor. Users can customize pieces of information according to their preferences. Users also have four choices of interruption modes for each piece of information, and consequently, that they can be select the appropriate notification modes that suit their needs.

2. More information, less interruptions. Since interruptions are caused when new information comes in, and the alert of the notification system tries to get out attention, we are forced to leave the current tasks momentarily to take care of interrupting tasks. The goal is to allow users to monitor more information with less interrupting notifications and to reduce any possible negative effects of interruptions.

3. Manage interruption timing. Interruptions are often unpredicted. The goal is to let users have rights to manage when they would like to be interrupted by using McFarlane's (1998) four methods of coordination – immediate interruption, negotiated interruption, mediated interruption, and scheduled interruption.

4. Help users recall. Task resumption is often difficult after interruptions. It is because after responding to the signals of interruptions; people often forget what they were doing before interruptions. The goal for the design is to provide a way for users to recall where and what their tasks were before interruptions.

3.4 IDENTIFY PROCESS CONTROL

3.4.1 USE CASES

The goal of this section is to propose some sample workflows as use cases to demonstrate the interaction between human and computers in different business verticals. The proposed workflows can help to identify where and how interruption could occur.

Use Case 1 - Content/Marketing Communication Manager

Assume Person A is a Content/Marketing Communication Manager at a semiconductor information company. She mainly writes and updates technical manuals. Her job duty is to manage the content flow of the manuals, try to meet the schedule, and redefine strategies and business guidelines. She spends most of her time just updating manuals. Sometimes she wants to make the technical manuals more compelling, so she rewrites major sections of the manuals

She works with about 50 people in her company, and they are in sales, product management, engineering, business development group, and product marketing group.

This is her **workflow** when she writes or updates manuals:

1. Update chapters. Documents are originally in FrameMaker format, and she needs to convert them to Microsoft Word.
2. Distribute documents to the team members.
3. When the documents get back to her, and then she gives them to her manager.
4. She uses the track changes feature on Microsoft Word a lot.
5. Her team members use emails and instant messaging a lot to communicate and distribute documents.

Theses are some **work challenges** and **pain points** she faces:

1. Biggest challenge: Update documents and read comments from others. It takes her a lot of time to consume the information. The original owner of the document, and very often it is the final manager makes the final decision.
2. Keep people going, and make sure they communicate. Sometimes people do not accomplish what they are supposed to do.
3. Pain points: Being caught up with meetings after meetings. Some meetings are not very effective and have no agenda or purpose.

4. She attends a lot of meetings, and has to use phone a lot. She also receives a lot emails everyday. Emails are used to send documents around.

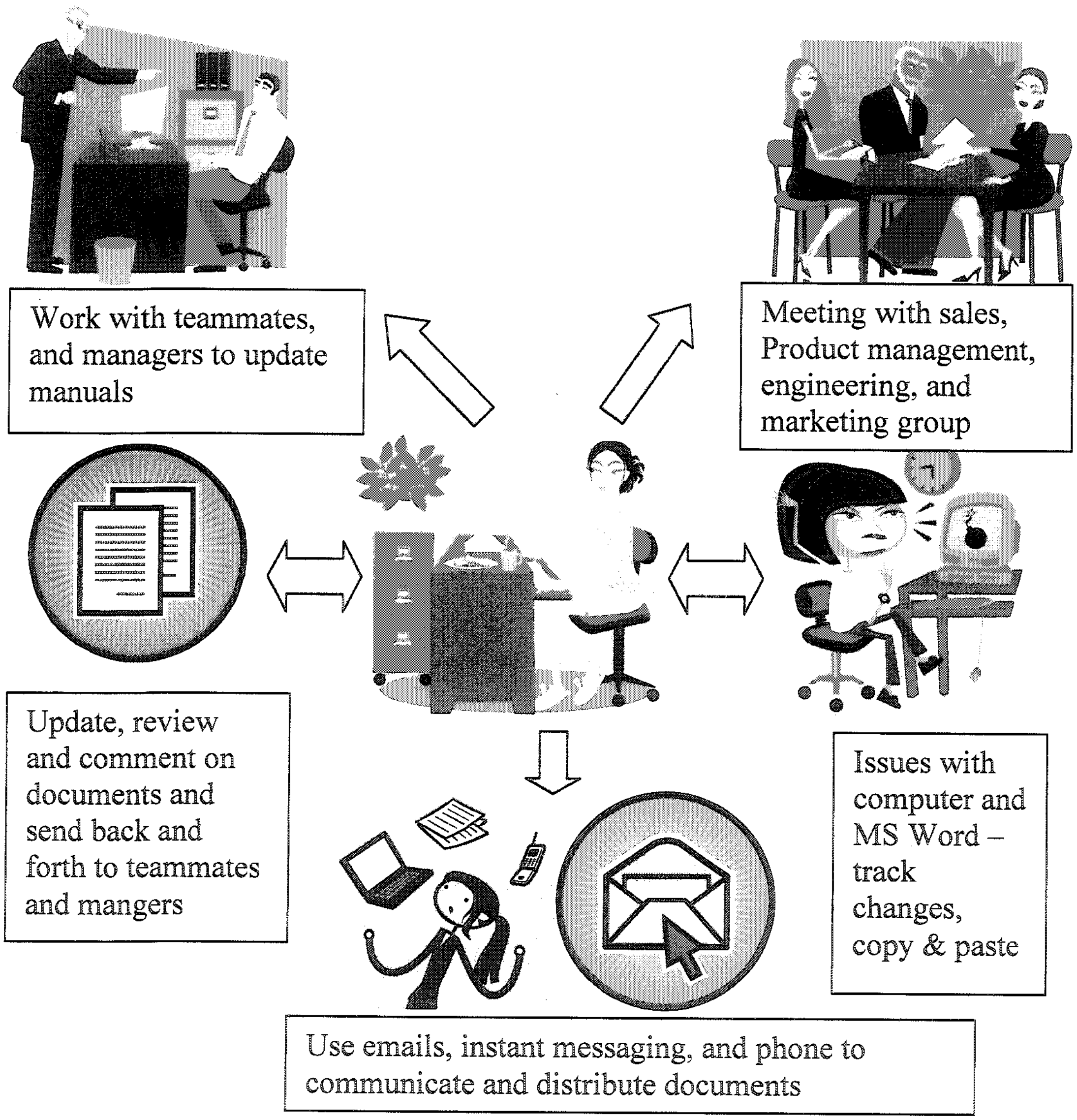

Figure 10: Use Case 1 – Content Manager

Use Case 2 - Portfolio Manager

Assume Person B is a Portfolio Manager at a financial services firm. His company is a mutual firm, and they have different bond groups and equity groups. An example of his work is that if a client wants to build a new museum in San Francisco, the client tells them the amount of the money they need and how much they would like to spend, the his financial company handles finances for the client.

His job involves in managing several equity portfolios. He also spends a lot of time managing other types of financial services.

Here is his **workflow**:

1. When he meets clients, they set up business guidelines, and the guidelines are client-specific. He uses templates for guidelines. Usually clients have certain timelines. For example, if a client would like to build a museum and finish it by 2005. Sometimes timeline gets changed, and then he has to establish communication between clients. He thinks his communication is fine between client and the sales groups as well.
2. He uses the following **software**: PDF, Excel, Word, Excel and Access.
3. He often creates documents on Excel - he calls it stock pages that show economic reviews and curves.
4. He uses two email systems. He uses Bloomberg a lot. Bloomberg is the internal email system he uses for trading because it is very fast. For example, if he wants to sell GM bond and he sends out emails via Bloomberg and everyone in the trade company can see it, and it sells out very fast. He uses Outlook to mail a

document. Traffic of his Outlook account picks on at month end, especially quarter ends.

Here are some of his **work challenges**:

1. Communication is difficult between him and the sales people in his company because the sales people work remotely. Sometime it is hard to communicate over the phone or emails.
2. Financial investment concept is very hard for sales people to understand, because they focus on getting clients, and they are commission based. He sees this could be potential communication problems at his work.
3. He relies on phone and emails a lot. He uses blackberry to keep lists of important and to-do things.

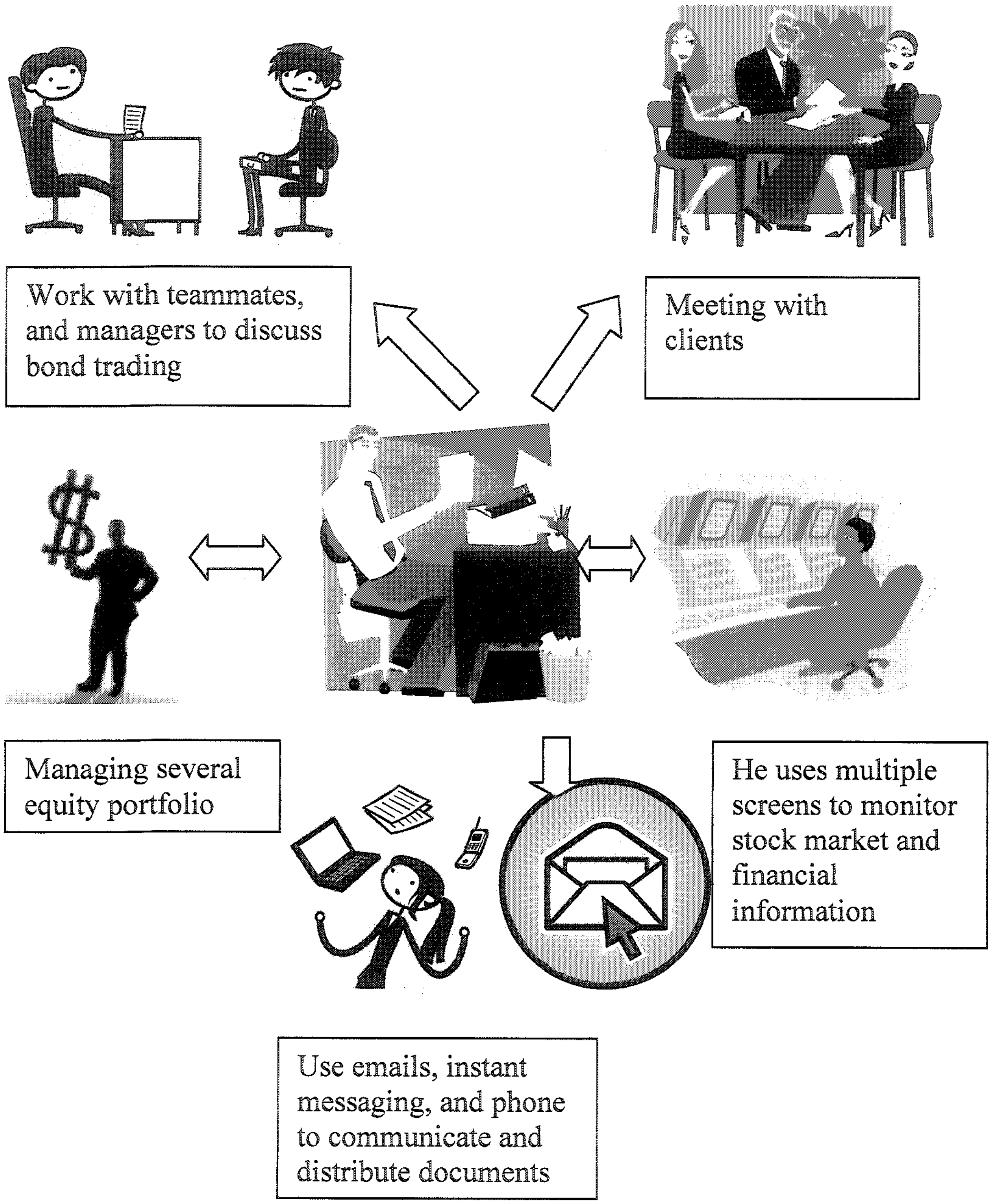

Figure 11: Use Case 2 – Portfolio Manager

Use Case 3 - Senior Industrial Designer

Assume Person C is a Senior Industrial Designer at a design and manufacturing company. As an Industrial designer, he works closely with mechanical engineers and collaborates a lot with other engineers.

Here is his **workflow**:

1. His work involves the following development processes:
2. Phase 0: Propose direction to design and user research. Once the design is approved, execute strategy.
3. Phase 1: Concept phase. Mechanical design involved, manufacturing factors should be considered as well.
4. Phase 2: Pick models and make prototypes.
5. Phase 3: Engineering products.
6. He is involved more in phase 3.
7. Industrial design. This involves with manufacturing a lot.

Here are some of his **work challenges**:

1. Communication between groups is very important. He needs to talk to engineers who are not in his building or not in the US.
2. Accuracy, color, dimensional issues. He needs to translate CAD drawings to other formats, sometimes he needs to use Photoshop to translate. He has software translation problems sometimes.
3. Multiple translations between software are difficult. And very often, he needs to make comments on drawings and send those around.
4. Inaccuracy issues due to problems of software happen a lot. For example, one engineer has something to convey and to output to the screenshot. The screenshot is in tiff format and file size is pretty big, so he has to use Photoshop or Illustrator and convert it PDF.

5. He receive drawings from engineers, and drawings have notes on it all the time
6. If people do not use Photoshop or Illustrator, it becomes a big problem, but it is probably because people might not have knowledge using the software.
7. Manufacturing group is in China, and he relies on electronic communication a lot to communicate with the group.
8. He has problems with long email trail because no one reads them.
9. Using instant messaging is pretty standard now in his company. He does not use instant messaging at work.
10. People use instant messaging a lot at development groups.

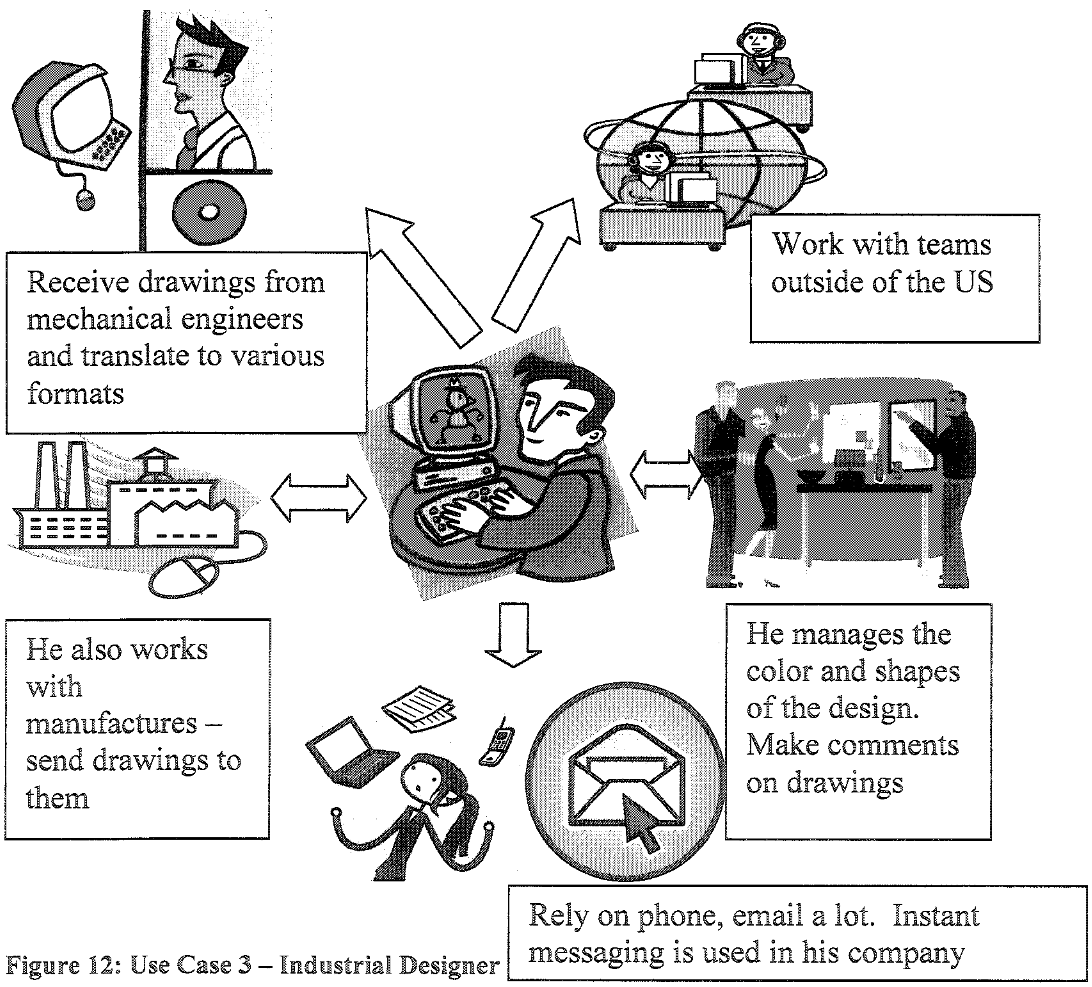

Figure 12: Use Case 3 – Industrial Designer

3.4.2 PAIN POINTS DUE TO INTERRUPTIONS

The use cases show one common problem that people face at work, and the problem is that the workers receive large amount of emails and phone calls everyday. These office workers rely heavily on their computers for communication purposes. They receive and make phone calls when there is an immediate need to communicate and get response with others. Emails are commonly used to send and receive documents. Instant messaging is increasingly adapted in the workspace for both business and personal purposes. The online status in instant messaging helps office workers to identify whether they are in office or not.

However, Jackson et al. (2003) found that forty-three percent of emails at workspace were non-business related, and that means that people spend two weeks per year dealing with non-business related emails. They also found that ninety percent of interruptions are due to personal visits and phone calls, and ten percent are due to emails. And people take about twenty minutes to handle each interruption. Consequently, these tools may facilitate communication between workers, but the tools can also cause potential issues due to frequent interruptions.

3.5 PRELIMINARY DESIGN

3.5.1 DESIGN INITIATIVES

For this thesis, I proposed user interface mockup designs for the Windows desktop environment. The idea was to build a peripheral display – a side bar which appears at the right side of the desktop and that is in users' peripheral view. To personalize the peripheral display, users can decide what information they would like to track, such as emails, instant messaging, stock quotes, or weather information. My approach of the design was to create a centralized area where users can keep and update information in one place. Users can create tickers (small information display) for pieces of information they would like to monitor, and they can dock tickers on the display bar. Please note that any specific software engineering implement for the creation of tickers is not covered in this thesis, because this thesis is aim to focus on solving interruption issues through the user interface design. However, there are sources on the Web that show solutions of tickers creation using JavaScript. Users can also manually change the interruption settings for each ticker, and they can adjust modes according to their preferences. And McFarlane's four interruption coordination methods were taken into consideration for the design of the interruption settings.

Microsoft in 2002 claimed a "task shelf" design, so called SideShow, for their next generation OS, codename Longhorn (Foley, 2002). SideShow allowed users to dock multiple tasks on the shelf, such as email and instant messaging. However, the design of SideShow did not cover issues of interruptions. Although users can view more information and communicate with more people, they are likely to be interrupted more because there is no design solution targeting the interruptions of the software applications. And computer systems do not reason the negative impact of interruptions, thus the user interface design should provide more support for users to handle interruptions.

3.5.2 WHY MY APPROACH IS DIFFERENT

Peripheral Display

My design approach was to integrate information – to centralize and to control information flow. Emails and instant messaging systems nowadays are designed to proactively catch our attention, and interruption cues such as audio and visual pop-ups could possibly interrupt our workflows. Also, visual notifications may pop up in various locations, and which may require more visual attention from cognition, such as searching, task switching, and hand-eye coordination. Moreover, these emails and instant messaging systems are displayed in separate windows on the desktop. This shows several disadvantages. These applications could occupy considerable amount of screen space if all the applications are turned on and the windows are in maximized modes. Even though the windows of these emails and instant messaging applications can be minimized to smaller or hide under task toolbars at the bottom, users have to search and switch between applications if they are using different applications simultaneously. When these applications are in the minimized mode, the ways they notify users are still proactive – visual pop-ups and sometimes with alert sound. The current designs of these communication tools require huge demand in human cognition, and ineffective handling of interruptions such as blocking all the pop-ups or turning off notification modes does not solve the problem. Therefore, this thesis proposed a design which can integrate all information in a single peripheral display. Moreover, in order to reduce the effects of interruptions, the design did not use pop-ups to notify users. Instead, using "flyouts" is the strategy of the notification design for the email systems. To give users more strategies to manage interruptions, users could manually set the interruption modes of how they would like to be notified. To conserve screen space on the desktop, users can remove tickers, or less frequent used task item could be minimized.

Here are some specific examples about how McFarlane's four coordination methods were applied in the design. For example, if users would like to be notified periodically, they should choose the scheduled interruption mode to set the interruption timing. By selecting the scheduled interruption mode, users could set up their email systems to notify every 30 minutes, every hour or other timeframes they prefer. If users were at work, and they would like to be notified when there are important emails coming in, they could set up their email systems to the immediate interruption mode. If users did no specify any interruptions, the default mode is the negotiation interruption mode.

McFarlane (2002) conducted empirical studies on computer tasks to compare these four interruption coordination methods. His studies showed that negotiation is the best method, except the case when interruptions need timely response, but the results only showed small differences. To support his claim, McFarlane also applied theories in natural language and cognitive psychology, and he found that people have a natural ability to negotiate interruptions. And Woods (1995) also suggests that designs for interruption alerts should support and utilize human natural ability. Thus the negotiation interruption method is chosen as the default interruption method for my design.

Moreover, negotiation is a user-controlled method. It notifies users that new information is coming in, and users can decide whether accepting or ignoring the notification. For example, in the call waiting situation, the machine may generate a beeping sound when a new call is coming in, and a person can determine whether listening to the call or not answering it. In the immediate interruption mode, the new call would immediately break into the current call, and the person is forced to listen to the call. Thus users have more control whether accepting interruptions or not in the negotiation method.

Reminders

This thesis also proposed a design that helps users to recover from interruptions – a reminder system. The reminder system is consisted of two parts – a history panel and a reminder button. The history panel displays a list of applications that have been used. Users could track the history of their software usages, and this could help users remember what applications they previously used. The history panel could help users to remember in an application level. To help users retrieve information in a detail level after interruptions, I proposed a design mechanism that shows users where their last active location was in the application. By clicking on the "Where Was I" button, it shifts the cursor and highlights the area of the last active location. I believed using location as a reminding cue could help users remember the content and the task they were working on before interruptions.

3.5.3 ANALYSES

Data collected from user interviews and surveys was entered into tables for analysis. Use cases were extracted from the user interview data. The purpose of the use cases is to understand participants' work challenges from different business verticals.

Examples of their work challenges were analyzed and identified as pain points in the use cases. The results from the surveys were taken consideration into the final design.

3.6 FINAL DESIGN ASSESSMENT

The user interface mockups proposed in this thesis have gone through several iterative design cycles to improve the design. I invited several professional UI designers and user researchers to give me some feedback on my design. Also, Jakob Nielson's ten usability heuristics were used to evaluate the design in each design cycle.

4. RESULTS

4.1 RESULTS OF PRELIMINARY DESIGN

4.1.1 WHAT IS SUPPORTED IN MY DESIGN – PERIPHERAL DISPLAY

The goal for the preliminary design is to allow users to monitor their information with minimum disruption. The target audiences of the design are those who need to attend emails or instant messaging for work-related activities. Since the data showed that the non-business group does not perceive emails or instant messages as part of work challenges, although some of them admit that these tools affect their work efficiency, the goal here is to solve interruptions-related problems for people in business group, and hopefully non-business group users can also benefit from the design. Here are key features that users can access from the peripheral display:

- Users can create personalized information tickers that users can monitor while they are working on other tasks. For example, if users would like to keep track of the performance of the stock market today, they can create tickers for the stock market.
- Users can create many tickers and monitor multiple pieces of information at one time.
- After a ticker is created, it can be docked on the display bar.
- Users can have the email and instant messaging windows placed on the peripheral bar.
- Users can monitor live update information without respectively opening different applications or visiting different websites.

- Users can remove tickers to different locations in the display bar or edit ticker information.

4.1.2 SCREENSHOTS AND WORKFLOW – PERIPHERAL DISPLAY

This is how a user can use tickers on the peripheral display to monitor information:

1. **Create tickers.** Please note that this thesis presents user interface mockups only. Detail software implementations for the user interface design are not included in the scope of the thesis. Users can create tickers for information they would like to keep track with, such as email, traffic or weather information.

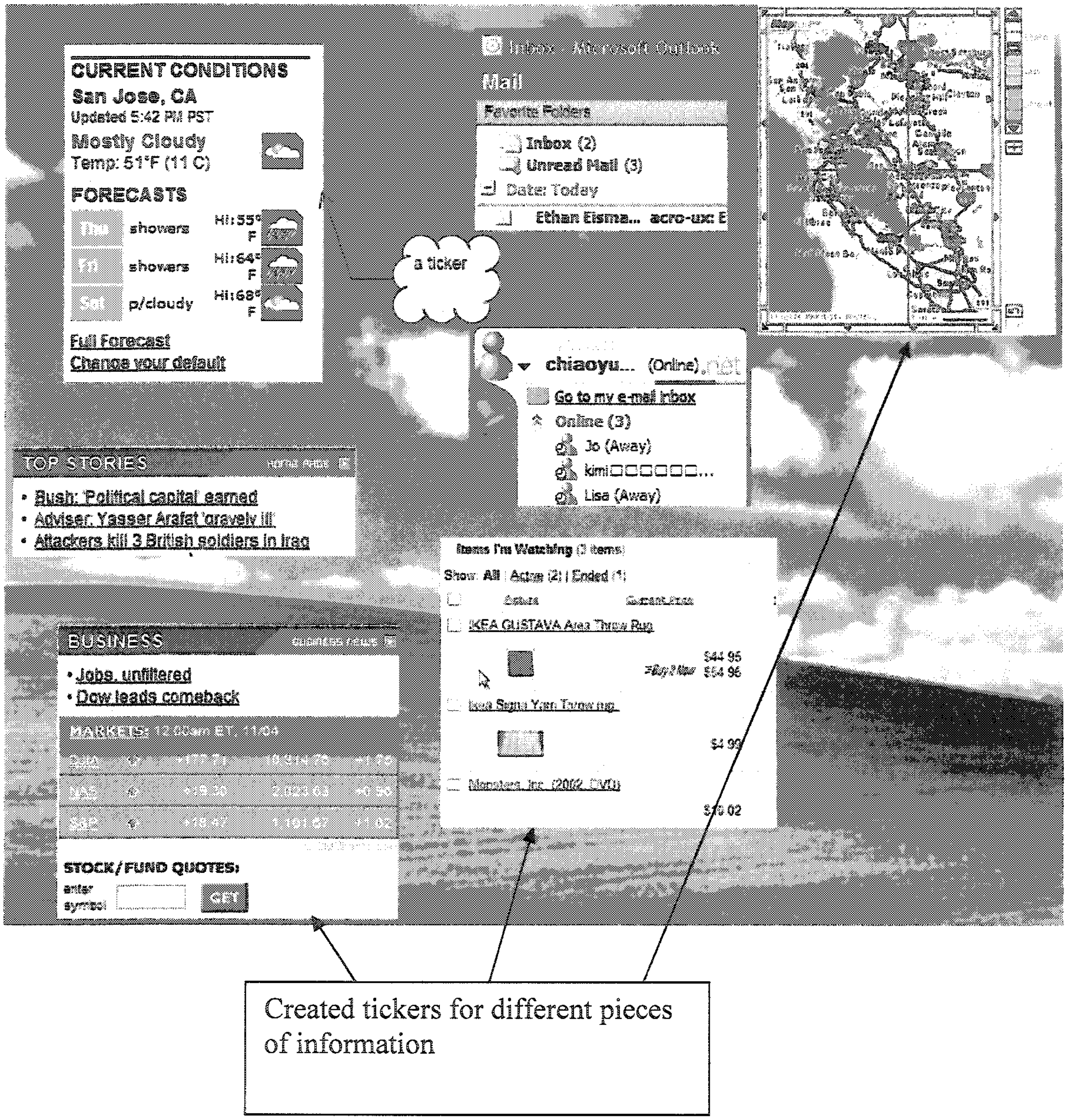

Figure 13: Tickers for Peripheral Display – Preliminary Design

2. **Dock tickers on the display bar.** Users can move the information tickers and dock them on the display bar in any orders they prefer. For example, users might prefer putting email at top because they can view and access it easily.

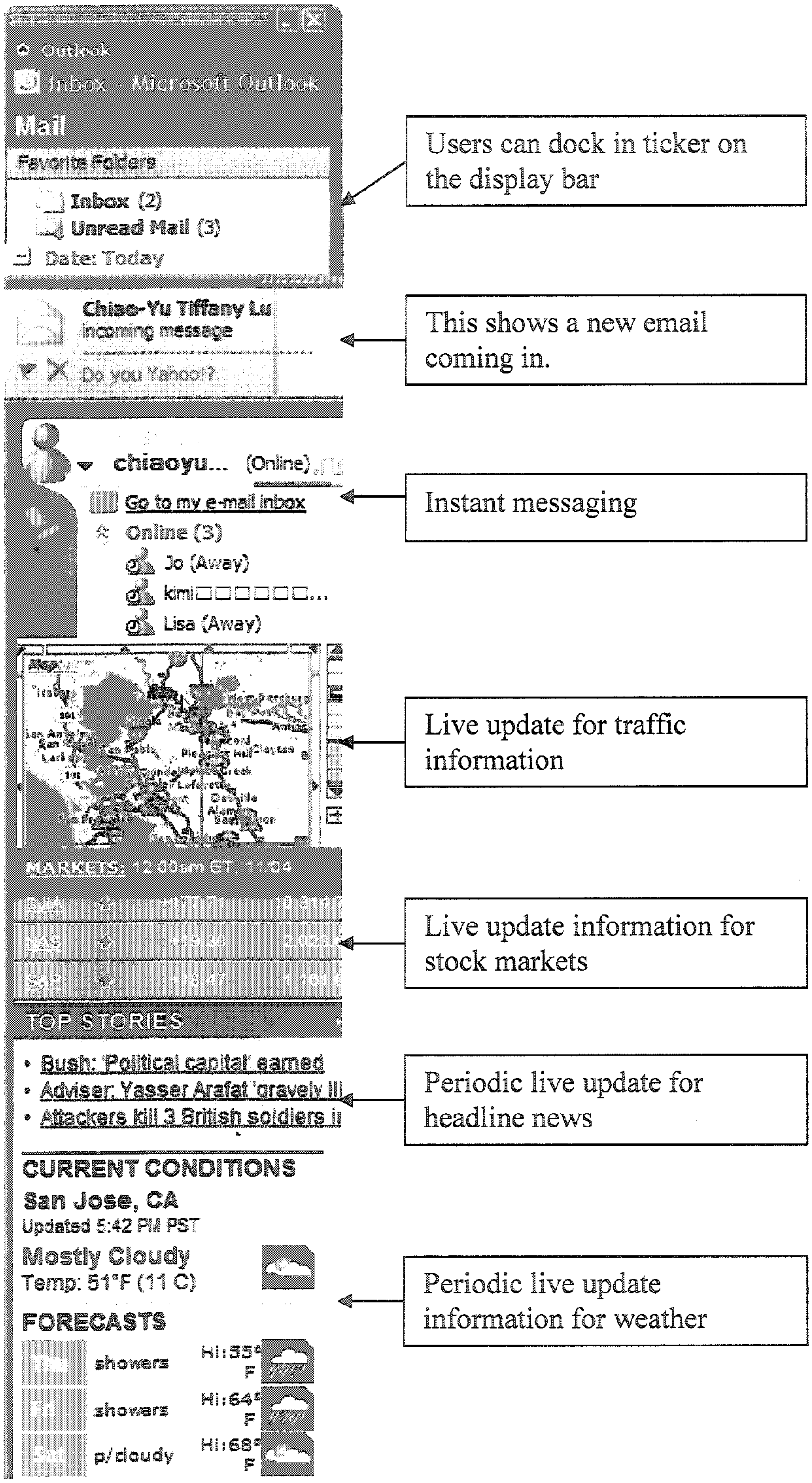

Figure 14: Peripheral Display – Preliminary Design

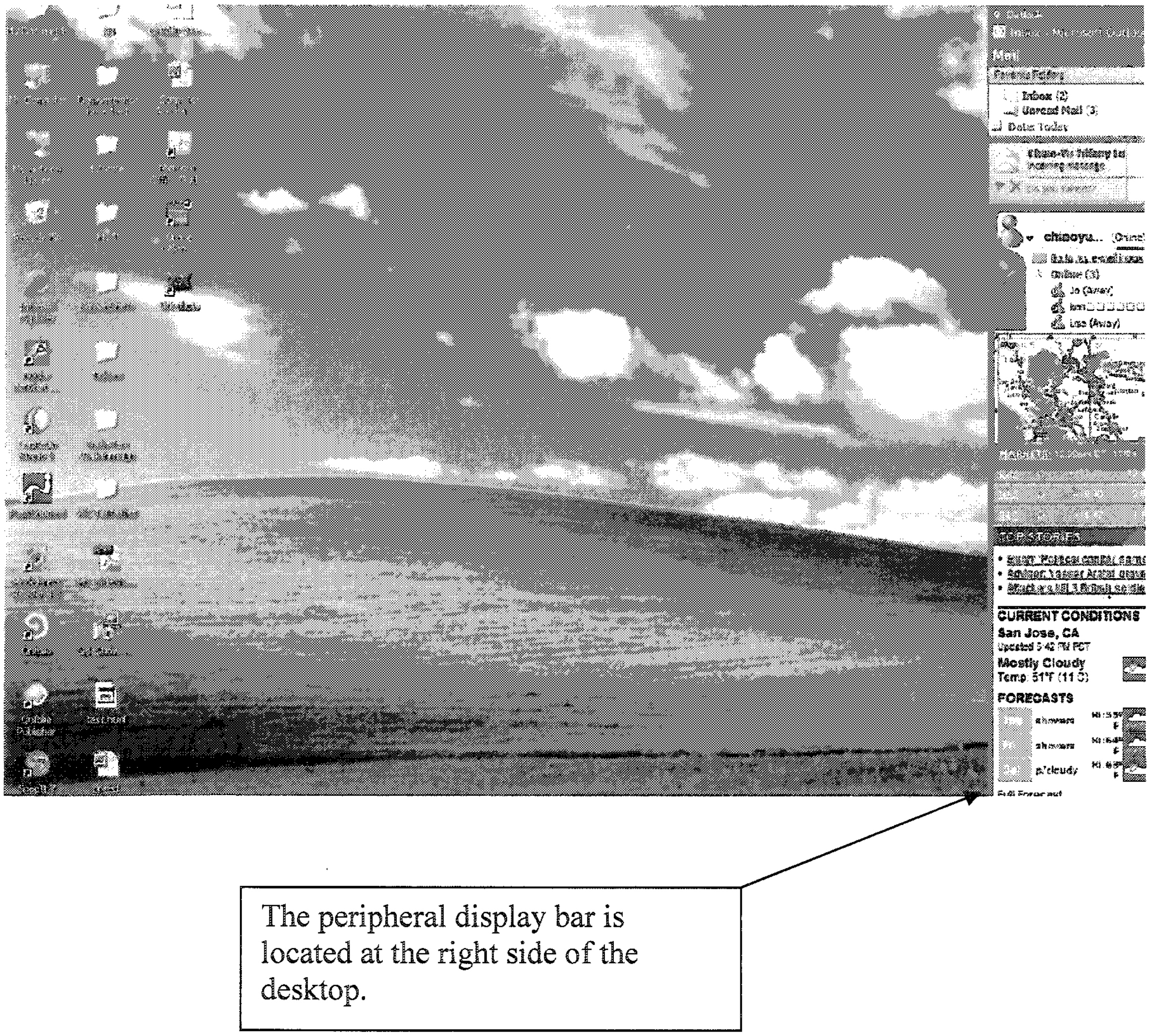

Figure 15: Peripheral Display - Full Screen – Preliminary Design

4.1.3 PRELIMINARY DESIGN ASSESSMENT

After evaluating the preliminary design with design guidelines and usability principles, there were several areas that could be improved. The information tickers presented on the display bar seemed to be overcrowded. It was hard to clarify each piece of ticker. This was because there was no clear frame, border or title bar for each ticker. One of the purposes of the peripheral display is to allow users easily and quickly keep track of information. The display bar could have a problem that users can not efficiently identify the information. Also, there were no controls on the interface for the tickers that tickers can not be minimized or maximized. Thus this confirms the need for a title bar for each ticker to separate tickers and to offer controls of the windows.

4.2 RESULTS OF FINAL DESIGN

4.2.1 IMPROVEMENT – PERIPHERAL DISPLAY

The tickers in final design were improved: each ticker has a title bar. Users can access interruption control through notification preferences. Notification preferences is a dialogue box that offers four notification modes based on McFarlane's four interruption coordination methods. The four notification modes are: (a)Notify immediately, (b) Ask for confirmation before notifying, (c) Check for personal calendar before notifying, and (d) Notify and update in every x (value from 1 to 59) seconds, minutes or hours. Each notification mode is presented as a check box, and users can select the box according to their preferences. The last notification mode is the scheduled interruption method that users can click on the up or down arrow to increase or decrease the amount of time for the notification period. Users can also select from seconds, minutes or hours from the dropdown menu. Every ticker has its own control to notification preferences. Users can right-click on a ticker and select from the option menus to bring up the notification preferences dialogue box.

Another improvement was to change the pop-up behavior of the email display. The original design idea was to pop up email messages whenever there are new emails coming in. To reduce possible visual distraction by the pop-ups, the new designed followed a less proactive way. In the new design, new email messages are shown as "flyouts." A "flyout" is an UI design element that is frequently used for menu design – it shows text menus in a box when a mouse cursor points to. Incoming email messages are shown in a smooth animation transition – fly out and then fade away. Unlike pop-ups, flyout windows show for couple seconds and disappear automatically, and users do not have to take any actions to the flyouts. But pop-up windows often intrude users by showing on the top of other applications and blocking the views, and users have to take actions such as moving the mouse cursor and closing the pop-ups. Thus pop-ups can be disruptive. Incoming email messages are also shown in 50% opacity to give a sense of transparency. The opacity of the window allows users to see through the background and does not block users' view. Also, whenever there is an incoming email, the email message is shown at the left side of the email ticker.

4.2.2 SCREENSHOTS AND WORKFLOW – PERIPHERAL DISPLAY

This is the user interface design for dialogue box for notification preferences. The choices of the preferences are: Notify immediately – immediate interruption method; Ask for confirmation before notifying – negotiation interruption method; Check for personal calendar before notifying – mediated interruption method, and Notify and update in every x second/minutes/hours – scheduled interruption method.

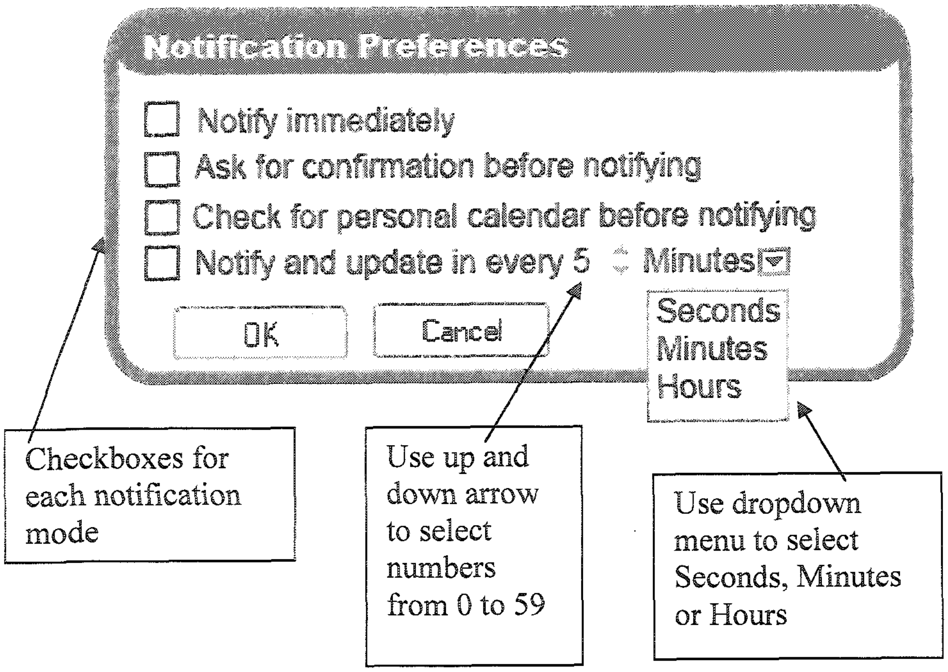

Figure 16: Notification Preferences

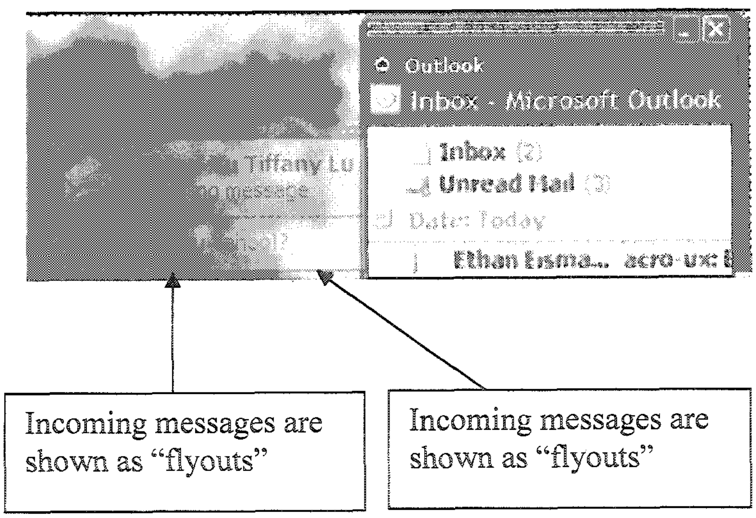

Figure 17: Flyouts – Incoming Messages

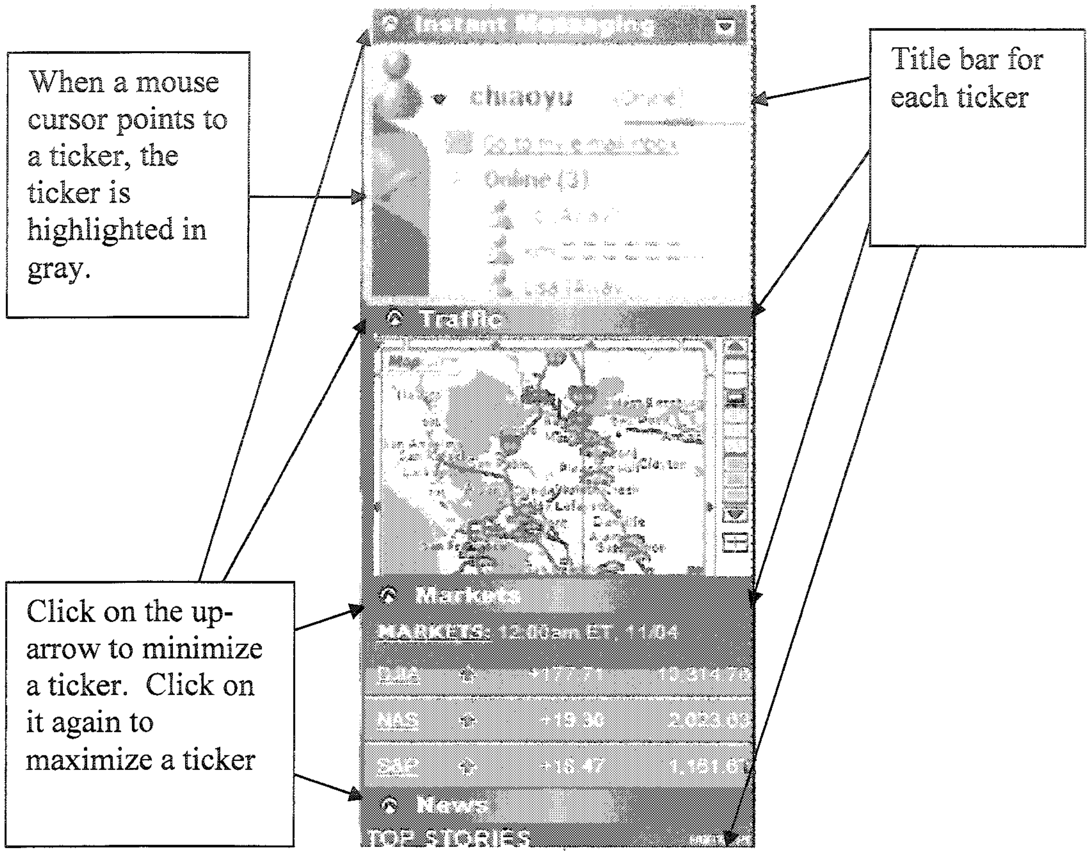

Figure 18: Improved Peripheral Display

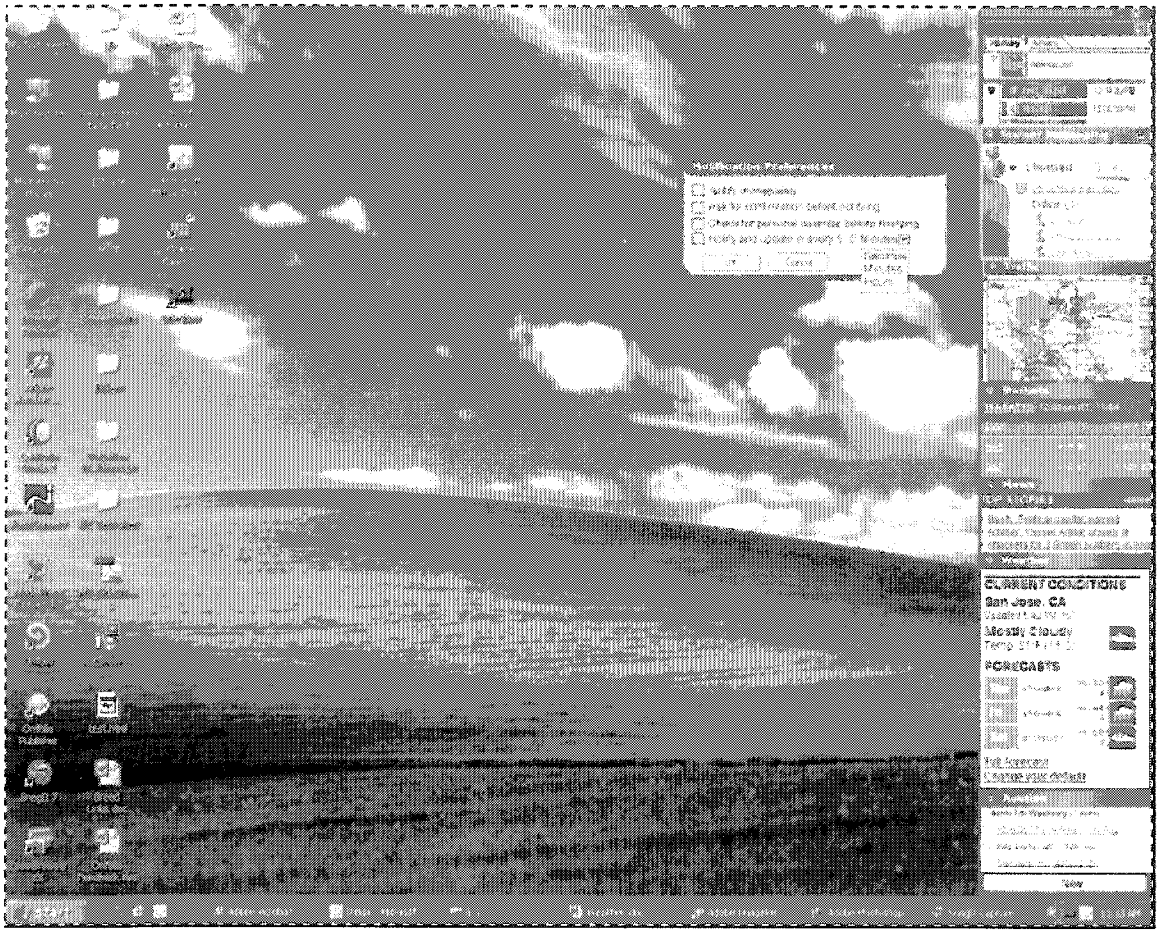

Figure 19: Improved Peripheral Display - Full Screen

4.2.3 UI DESIGN FOR REMINDER SYSTEM

Users can access the following features from the reminder system:

- Users can keep track of a list of application activities from the history pane. The history pane shows the history of all application usages.
- Users can know when the applications are used by looking at the time indicated right next to the application name.
- Users can put flags on applications as reminders for themselves.

- Users can double-click on the name of applications to open up the applications fully.
- To help users remember where exactly they were working on in an application, users can click on "Where Was I?" button to go to the place where their last activity was. The last activity location is tracked by last mouse or keyboard action, such as clicking, highlighting or typing.

4.2.4 SCREENSHOTS AND WORKFLOW FOR REMINDER SYSTEM

Scenario:

A user was working on a Microsoft Word document and a PDF document. The person was reading the PDF document and taking some notes on Word. The person needed some information from some other documents that he was working on last night and this morning. The person was just interrupted to do some house chores. After 3 hours, the person came back and sat in front of his computer.

Workflow:

The person went to the history pane and tried to see a list of applications that was recently used. The person tried to find one document was worked on last night, but the person did not remember the name or the format of the document. The person checked the time indicated right next to the documents and found the one was used last night. The person then put a flag on the document as a reminder.

Screenshots:

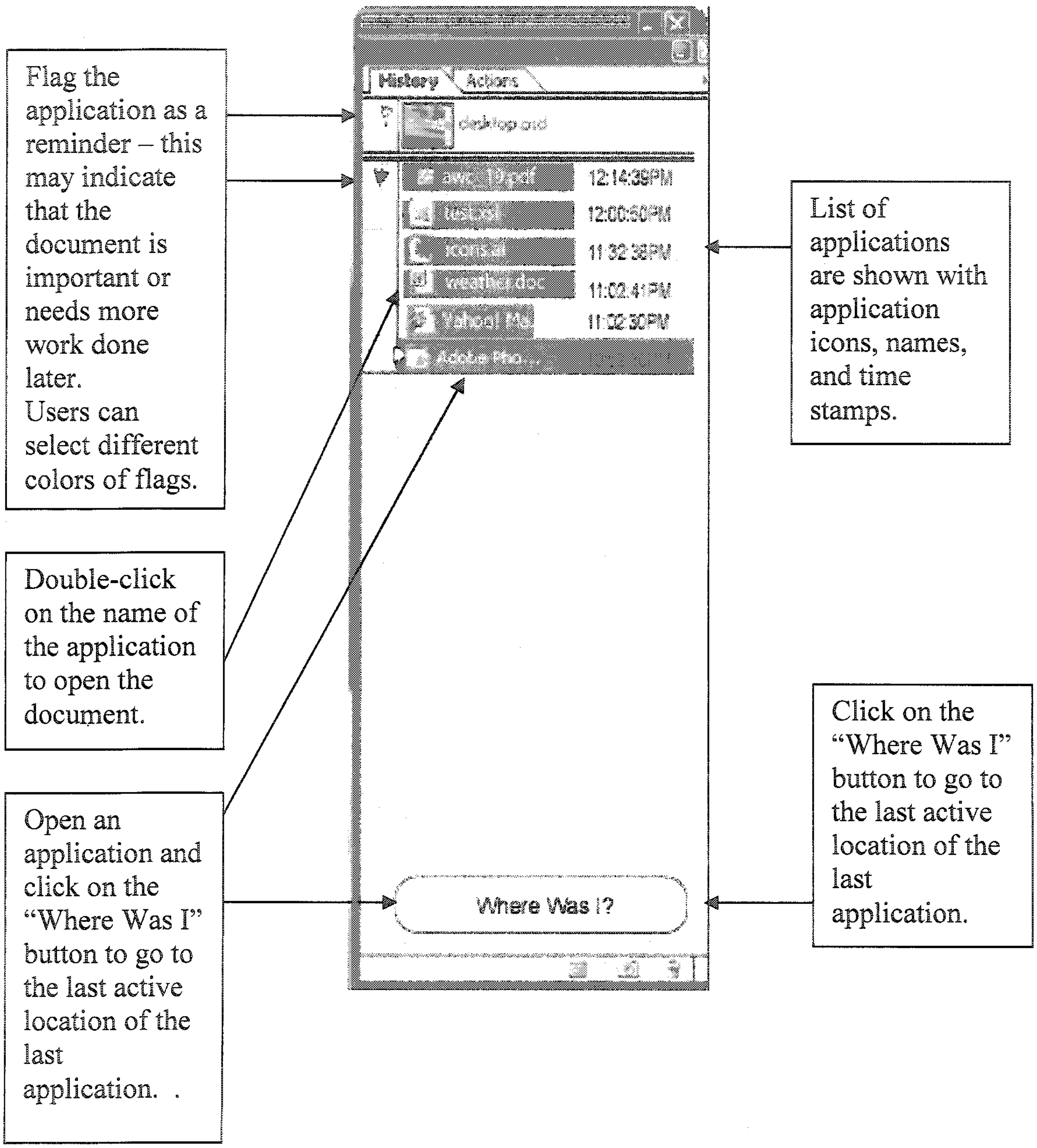

Figure 20: Reminder - History Pane

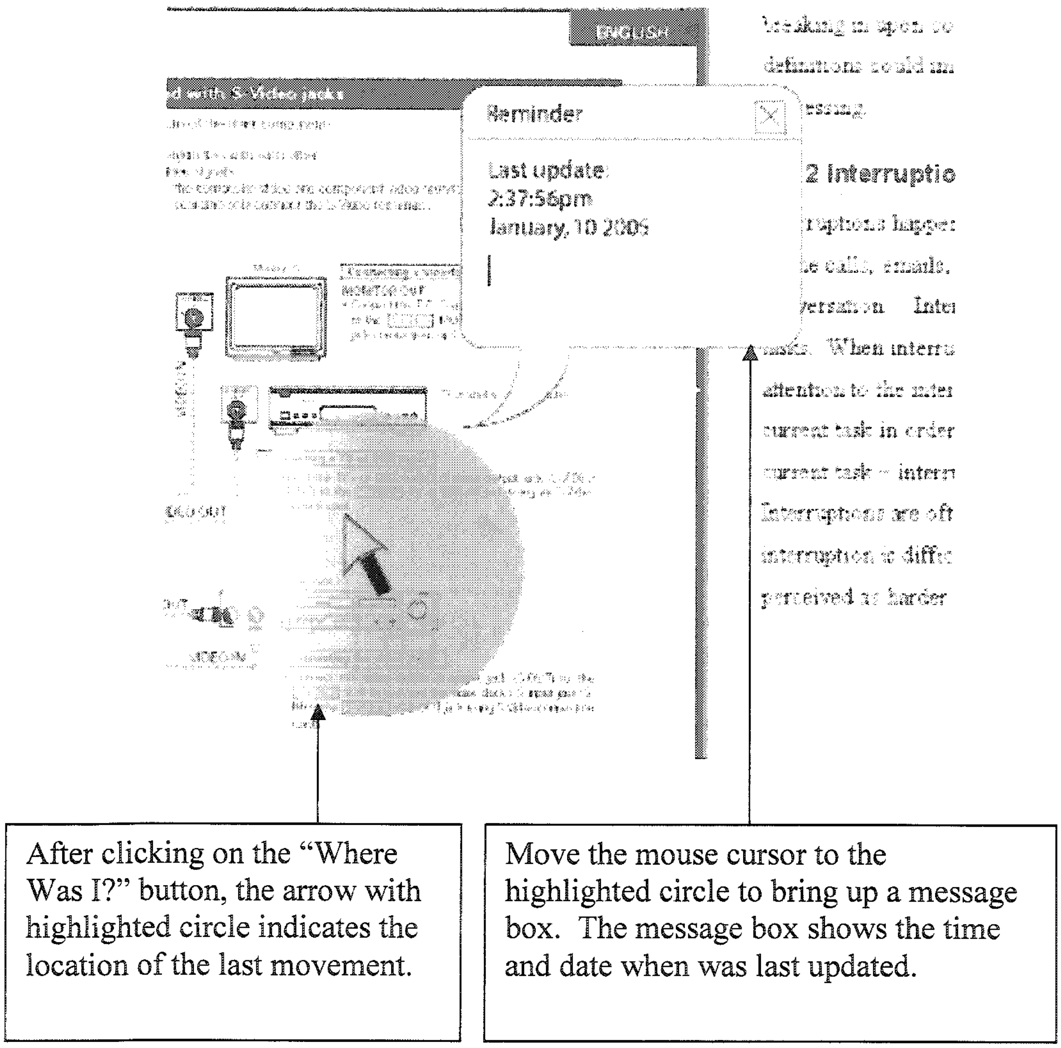

Figure 21: Reminder - Highlight

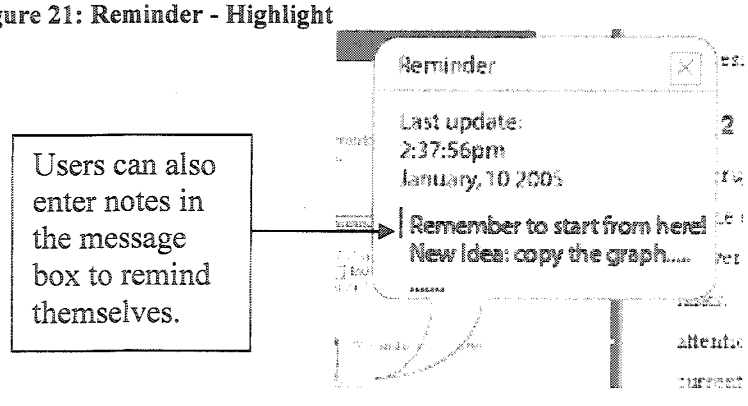

Figure 22: Reminder - Dialogue Box

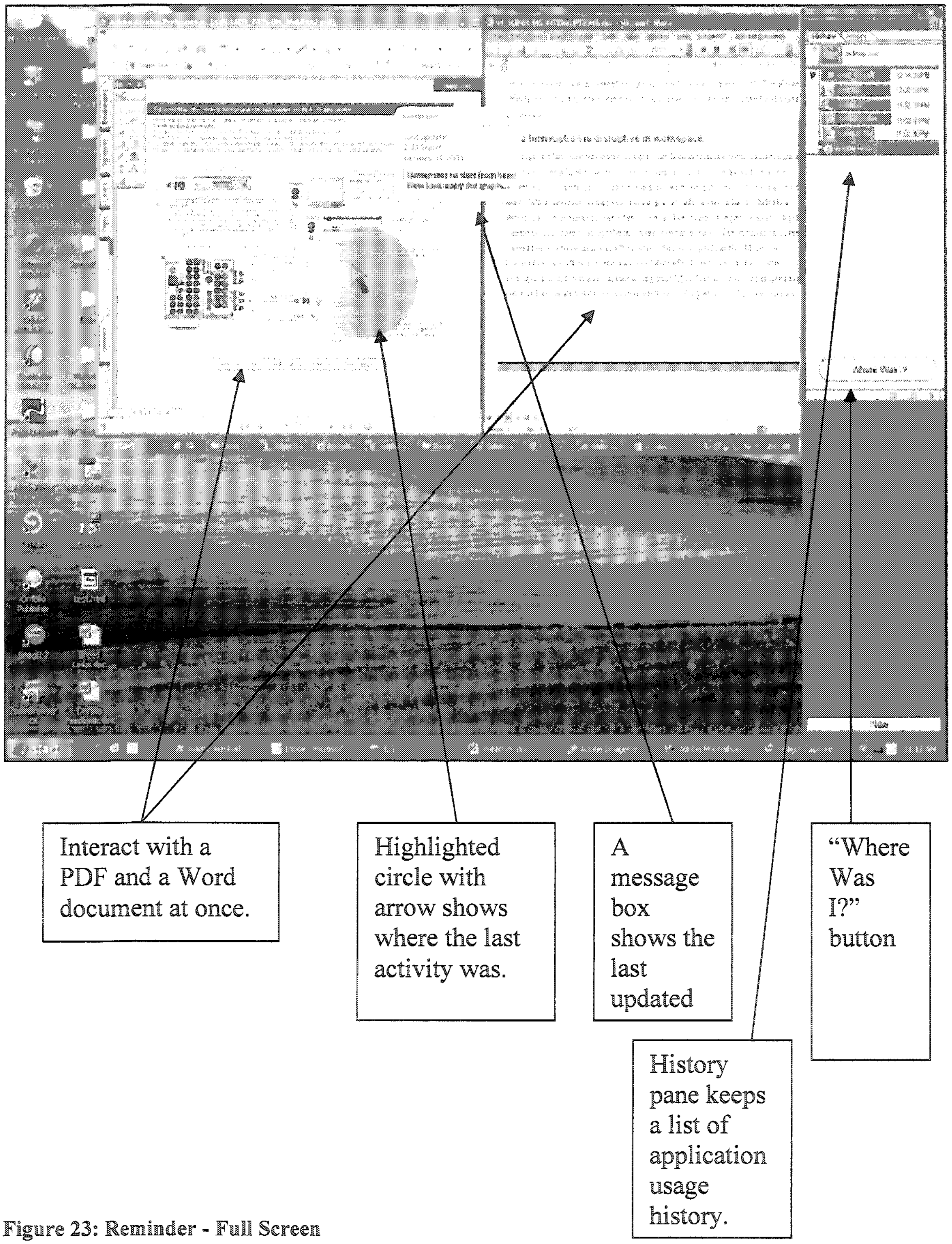

Figure 23: Reminder - Full Screen

4.3 FINAL ASSESSMENT

The final design was shown to several professional UI designers and user researchers. They have positively commented that the final design showed better logic in workflow and looked more plausible. The "Where Was I?" button was originally named as a "Where am I?" button. An user researcher suggested that it is more appropriate to use past tense "Where was I?" rather the present tense "Where am I?" because in common American English expression, people often use the phrase "Where was I?" to refer to what they were talking about during conversation. Also, most of the designers and researchers were impressed and gave positive feedback on the "Where Was I" design.

5. CONCLUSION AND FUTURE RESEARCH

5.1 OVERVIEW

Issues related to interruptions are gradually recognized by Human-Computer Interaction and Human Factor communities. Various research studies have been targeted on cognitive or sociological effects of interruptions. However, there are very few design guidelines or solutions that address the issues of interruptions. And there were very few examples of software applications designed to handle interruptions. This thesis proposed user interface mockups for a peripheral display for users to monitor multiple pieces of information without being interrupted unpredictably by various visual pop-up or audio alerts. Users can also access information quickly without terminating their current task and switching to other applications – this can save some task switching time. Moreover, users can manage and have controls to when and how they would like to be interrupted. Users are able to set notification/interruption modes according to their preferences, and each piece of information they monitor can be set to one of the four interruption modes. In addition, the design of the reminder system allows users to recall where and what applications they last worked on. The reminder system is proposed as a design solution to recover from memory loss after interruptions. The trends in software design nowadays, especially applications that run on computers or mobile devices, tend to cram in large amount of information in very limited screen space. User interface design for such applications becomes extremely critical. Bad user interface design with usability issues may cause low sales of products, and people might be turned away from the applications because of the bad user experience. Moreover, human cognitive, learning, and memory abilities could be limited to handle large amount of information. More information means more notifications, and inappropriate notifications can cause issues in interruptions. Also, interruptions lead to many negative effects, such as work efficiency, stress and cognitive issues. Thus user interface designers and engineers should consider the effect of interruptions in their design.

5.2 REMAINING QUESTIONS

There are several questions raised after the final assessment of the user interface mockups in this thesis. One of the key questions is whether the design of the peripheral display will actually reduce the number of interruptions or not. Since the peripheral display allows users to monitor multiple source of information at once, there are doubts whether people are less interrupted by computers or more interrupted by themselves. Here remain some questions that have not been answered:

- By using the peripheral display, do people feel the numbers of pop-up notification are reduced? Do people feel less interrupted by the notifications?
- When people are able to monitor many more pieces of information at once, do they tend to go back to the display bar more to keep track of the live update information? This means, are people interrupted more by their own thoughts? Are they interrupted more by internal sources of interruptions? This assumes the interruptions from external sources, such as pop-up notifications are less.
- For instance, if a person checks his stock portfolio on E*TRADE twice a day, by using the peripheral display, is the person prompted to trade more everyday?

- Moreover, Woods (1995) claimed that people have natural ability to handle peripheral information. Can people handle and consume the information displayed on the peripheral bar? And what is the effect of interruption caused by the peripheral display? How do people interact with interruptions that come from their peripheral vision?

All of these questions need further investigation and empirical studies to search for evidence. Thus this thesis also suggests some directions for future design and research.

5.3 DIRECTIONS FOR FUTURE WORK

A possible direction for the design of the peripheral display is to conduct empirical researches on interruptions based on the current model. A group of participants will be tested on tasks such as checking emails, looking for weather information and while chatting on instant messaging using some released software applications (Outlook, MSN Messenger, and Internet Explore.) And same group of people will also be tested on the same tasks using the peripheral display. Task performance such as time spent on the tasks can be measured, and work efficiency can be evaluated as well. Also, subjective preference ratings can be collected through surveys to understand their experience with interruptions. The performance results and subjective ratings of the current software model and the proposed design model proposed can be compared.

Another direction for the design is to understand if people are willing to give some screen space on the desktop for the peripheral display. The study can be done by providing different prototypes and let participants pick their preferences. This is to test if users keep the display bar opened or closed, or if users prefer to minimize or maximize the display. The goal for the study will be to understand what will be the tradeoffs that people are willing to give for designs like this.

Another direction for future work is to test the usability and functionally of the reminder system. The goal will be understanding users' workflow with the reminder system. The questions to find out are whether providing cues on locations will help users to remember or not, and if the reminder system effectively helps users recover from interruptions. Furthermore, this design proposed in this thesis can be taken consideration for other user interface design in other applications such as automobile or mobile devices areas.

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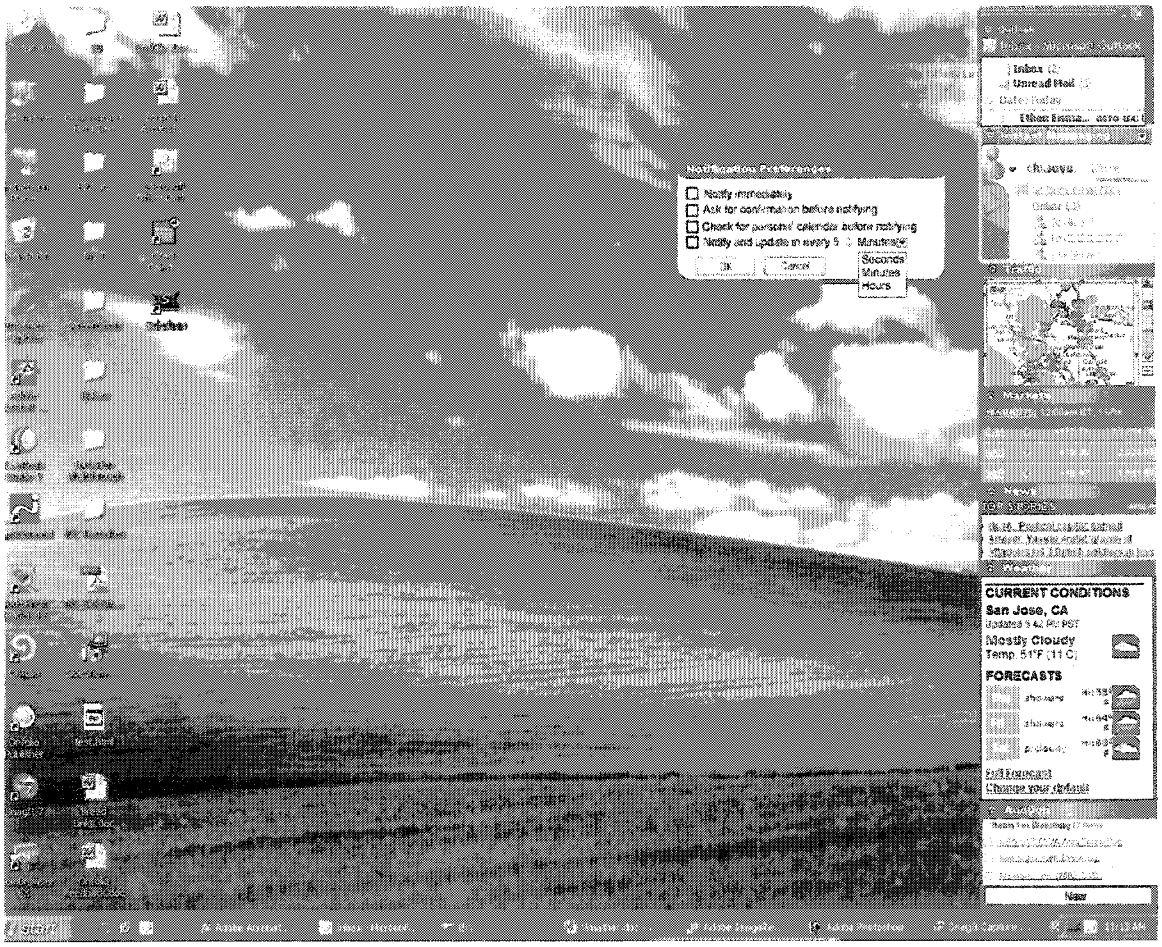
APPENDICIES

APPENDIX A – SCREENSHOTS OF THE PERIPHERAL DISPLAY



APPENDIX B – SCREENSHOTS OF THE REMINDER SYSTEM