**Single Versus Multiple Window Design:
Do we hide information or spread it across windows?**

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**A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirement for the degree of
Master's of Arts**

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Carleton University
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Abstract

Two within-subjects experiments compared a single window design that hides information that does not fit in one window to a double window design that spreads the information over two windows. Both experiments tested 8 subjects on single and double window versions of network management applications. The single window design in experiment 1 used tabs and in experiment 2 used scrolling to hide information. The single window designs were compared to the double window designs on domain tasks, in terms of completion time, number of errors made and ease of use. The goal was to determine whether a single window design that tabbed and a single window design that scrolled were superior to a double window design. Few significant differences between the single and double window designs were found in either experiment. A small sample size, due to a limited availability of subjects with network management knowledge, possibly lead to a lack of power. In addition to the within subjects analysis, mixed analyses of variance were conducted and yielded the few significant differences found. Quantitative results suggest a need for further research and discussion revolves around future directions.

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Single Versus Multiple Window Design:

Do we hide information or spread it across windows?

This thesis addresses the question “under what conditions should a designer add additional windows for additional task information, or keep tasks as panels in a single window?” When there is too much information to fit into a single window design two options emerge. Either spread the data across more than one window or hide it within a single window. This thesis involves two experiments. The first investigates whether a difference exists between a single and double window design when the single window version hides information by tabbing. The second experiment investigates whether a difference exists between a single and double window design when the single window version hides information by scrolling.

Since the introduction of window-based systems in the early 1980's, little research has been done on the usability of these systems. There has been research comparing command line interfaces with window systems (Bannon et al., 1983), comparisons of different types of window systems such as tiled versus overlapped (Bly & Rosenberg, 1986), the Rooms model (Card & Henderson, 1986) and Elastic Windows (Kandogan & Shneiderman, 1997a; 1997b). There has been little research looking into the types of user problems that exist in a typical window system besides those comparing different implementations of multiple window systems, such as, tiled versus overlapped.

Window Management

Multiple window systems involve users in window management activities such as, moving, resizing and bringing a window to the top. Tasks often take more time to

complete in a multiple window design because the user has to move and resize windows. This problem intensifies as the number of windows on the screen increases. This is less of a problem when few windows are used since there may be little overlap and few windows to be managed. Bly and Rosenberg (1986) and Tombaugh, Lickorish and Wright (1987) found that novices were slowed due to window manipulation even though people with prior training in such systems found the windows to be helpful. Miah and Alty (2000) suggest that slower performance in window systems may not be due to manipulation of windows but to the task of finding a required window once it is minimized.

There is little debate that as the number of windows on a screen increases performance will decrease due to the necessity to manipulate windows. Does this mean that when two windows are used and window manipulation is minimized, that a single window design is still better? The present research addresses the question of whether a difference exists between single and double window designs. In this situation, issues other than window management must also be considered. One issue that is seldom discussed is that of peripheral visual interference. If two windows are open and only one is used for the task, does the presence of the second window detract from a user's performance? A second issue deals with hiding information. As tasks become more complex and data-intensive, designers can either add more windows or keep information in a single window with information hidden under scrolling or tabbed fields. Hiding information may help by keeping the whole application in one window but it can also lead to time consuming scrolling and users losing their place, thus becoming disoriented. Two types of hiding information are addressed here, hiding information by scrolling and

hiding information by tabbing. A third issue is the notion that a window system may facilitate organization. Information can be classified and separated in different windows providing the user the knowledge of where specific types of information can be found. Alternatively, this classification can be achieved in a single window design with the use of tabs. A fourth issue is global perspective. The phrase global perspective refers to users ability to know, at all times, where they are within the overall application and where they need to go to get other information. If a multiple window design allows for more information to be visible at a single time, does this help the user maintain a global perspective better than in a single window design?

Issue one: Peripheral Visual Interference

The first issue mentioned above is whether having a multiple window system degrades performance due to peripheral distractions. A second window, even if not in use, may distract from performance by being in the user's peripheral viewing area. Mori and Hayashi (1993) conducted research to assess whether windows not being used for the primary task (peripheral windows) interfere, especially from a visual standpoint, with concentration in the primary window (central window). The results of the study were that having only one window resulted in higher accuracy. Performance degraded even more when the peripheral window was dynamic, for example, when changes made in the primary window cause changes in the secondary window. Even when there is no window management requirement, having a second window could be a detriment.

With regard to this thesis, this issue suggests that a single window design, with no secondary window providing visual interference, might result in better performance than a double window design.

Issue Two: Hiding Information

The second issue is hiding information. If a designer chooses to keep all information within a single window, then he must attempt to avoid a cluttered and disorganized interface (Shneiderman, 1997). To do this, the designer will have to hide information since it will not all fit on the screen in a clear manner. The issue of hiding information has several aspects to it.

One problem with hiding information is the reacquisition of one's location when attention is directed elsewhere. For example, with sets of information being viewed in tabs, users often become confused since all cues that were used to represent location are hidden once the user jumps to an alternative tab. The only cue left is the tab title, which can provide some aid but is often an insufficient indicator of what information is enclosed. Tapia and Kurtenbach (1995) felt that hiding information of any kind is a problem and should be avoided at all costs. The authors felt that even pull down and pop-up menus, that break the user's visual focus, hide too much information. As a result, they propose an alternative method of accessing information called marking menus. These are pie charts where each piece of the pie represents a different portion of the overall application. A user can click on a piece of the pie that represents their present location and drag to a piece of pie that represents their desired location. These menus are proposed because they can be implemented in transparent fashion so material can be viewed

through them. Thus, less information needs to be hidden, and therefore, no loss of visual focus. Tapia and Kurtenbach (1995) discuss the loss of visual focus as a problem because the users must spend time re-acquiring their place once the location that was hidden is revealed. The benefit of maintaining visual focus is that the user is not forced to divide visual attention between the content and a user interface widget.

Tapia and Kurtenbach (1995) talk about the issue of losing one's place but they do not talk about the fact that this can happen in several ways that may not be equally problematic. Not knowing where a piece of information is can be caused by moving between tabs, scrolling up and down in a field, and even by an overlapped window. Is there a difference in the ease of reacquiring one's place when the loss is due to the different methods of hiding information? The issue can be even broader. What if two windows are tiled and there is no hidden information? Does the act of moving one's visual attention from one window across to another also require a reacquisition of one's place? Reacquisition of one's place may be required in both a single and multiple window design. The question of which is better, single or multiple window design, is not simple.

Hiding Information by scrolling

One of the most popular ways to hide information is to make lists and fields scroll. A scrolling field allows the user to know what type of information is in the field but he cannot see all of it at once. This can lead to performance degradation and user dissatisfaction since scrolling has been found to be disorienting and more time consuming than simply scanning a page (Arai et al., 1992). Piolat, Roussey and Thunin (1997)

suggest that users spatially encode information while they read, and scrolling information does not provide adequate cues for users to understand where they are in a scrolling set of information. They conducted a study where eight sentences were chosen from a passage for a sentence-locating task. Results were better performance as more location cues were provided. The authors attribute these results to the fact that readers do spatially encode while reading and use the spatial cues to locate information. This study focused on reading text passages and not on task-based applications such as word processing or network management. Nevertheless, the results suggest that hiding information using scrolling provides few cues to help the user locate information, and scrolling may not be a good solution to avoid multiple windows.

With regard to this thesis, the scrolling aspect of the issue dealing with hiding information suggests that a double window design with reduced scrolling might result in better performance than a single window design.

Hiding Information by Tabbing

As mentioned above, tabbing is another method of hiding information. Much like scrolling, tabs allow the designer to save screen space by hiding information that can be re-exposed as needed. Unlike scrolling, tabs have the advantage of titles to indicate what type of information is hidden. Even with this advantage, a single window design which utilizes tabs may not perform better than a multiple window design due to how tabs are used. The main issue with tabs is that there is a need to jump between tabs to collect information. If, for example, there is an application with four tabs, but the task only involves work in each tab in isolation, then there is little problem. Complications arise

when the task requires the user to jump between tabs to collect information or, even worse, when the user has to compare information in different tabs. If the user needs to compare information found in different tabs, the user must commit to memory what was found in one tab while attempting to find the other point of comparison. If the user forgets or needs clarification, then another jump back to the previous point of comparison is required. Besides the requirement of memorizing information for comparison elsewhere, each jump or switch between tabs will require the user to reacquire his place.

Even if the user is not making a direct comparison between tabs, but is collecting information from different tabs, the user is required to show and hide information and thus reacquire his place, as well as remember what was found under each tab.

The issues of memory load and reacquisition of context could be eliminated if information hidden by all tabs were visible at one time. This is the alternative that a multiple window solution can provide. The user would not commit data to memory for comparison purposes because the points of comparison can be viewed at the same time. The issue of reacquisition might still be a factor if the information being compared were laid out at the same time, but in different windows.

With regard to this thesis, the tabbing aspect of the issue dealing with hiding information suggests that a double window design should not result in better performance than a single window design, nor should a single window design result in better performance over a double window design. Titles on tabs should act as cues and should help users avoid some disorientation, but the necessity to reacquire context when jumping

between tabs to collect information should erase any advantages gained by having titles on the tabs.

Issue three: Organization of Content

A third issue when contemplating a single or multiple window design is whether a single window design or multiple window design is better at organizing the content. As reasoned earlier in the discussion of Piolat et al. (1997), users need an organized structure that aids in orientation through the use of landmarks. One could argue that a multiple window design would allow for more window space to facilitate categorization and result in better performance, especially in locating information. Tombaugh et al. (1987) discuss how user's performance on tasks was improved when content was organized in separate windows by category. On the other hand, the method of designing in categories can be achieved in a single window design where each tab represents a separate category. If the number of tabs gets large, this advantage disappears, but one could make the same argument when the number of windows gets too large. Apart from possibly overloading a design, tabs and multiple windows can both be used to help organize content.

With regard to this thesis, the issue of organization of content does not suggest an advantage for either the single or double window design. The double window design can be used to organize content by window but tabs can be used in the same manner.

Issue four: Global Perspective

Global perspective refers to the user's ability to know, at all times, where he is within the overall application and where to go to retrieve other information. Thus far, this discussion has revolved around the idea of giving the user enough information about the

interface so he can find other data that is required. The argument has already been made that hiding information can lead to disorientation. An application that provides an effective global perspective does not guarantee that a user will not become disoriented but it may facilitate the reacquisition of the user's context. This point is demonstrated by Krauss, Middendorf and Willits (1991) who investigated the use of instructional materials that were either online or hardcopy. Users were required to make changes to an application based on instructions and help files given to the users either on paper or online. Users also had the option to call a person for help if they could not fix the problem alone. The online group accessed the help files half as many times as the hardcopy group but called for help 16 times more than the hardcopy group. Krauss et al. (1991) felt that the online group's poorer performance seemed to be the result of an inability to maintain a broad view of their location in the document at any given time. The users became lost and "disoriented," and thus needed to call for outside assistance.

As a result of findings such as those presented in Krauss et al. (1991), several attempts have been made to redesign how users interact with their computing environment to enhance the global perspective. Kandogan and Shneiderman (1997a; 1997b) designed the Elastic Windows system to help provide a greater global perspective. The system is a tiled window system that automatically resizes tiles when another is enlarged or reduced. The idea was that users can organize files related to a topic in a single tile. Multiple tiles can be seen at once and users know at all times where to find files or pieces of information related to any single topic. Unfortunately, this system is not without flaws. As one tile is enlarged for viewing another is automatically

minimized to allow for the extra space. No tile is ever reduced to the point where it cannot be seen. What if there is so much information that only one tile can be viewed at a time and the others are presented as little more than titles, icons or other indicators of content? In this situation, the Elastic windows system seems to be little more than an elaborate tabbing system.

Another design with improved global perspective was developed by Harrison, Ishii, Vicente and Buxton (1995). The authors reported that users claimed that they wanted a greater awareness of one task while they were focused on another. The authors attempted to achieve this by designing with transparent windows. They claim that if an optimal level of transparency can be achieved, then users will have a greater awareness of the workspace but will not be distracted by the background windows. They reported that users had difficulty at first, but requested an increase in transparency over time.

Transparent windows seem to conflict with results by Mori and Hayashi (1993) who reported that performance was worse when even a single additional window was present. The windows used in the Mori and Hayashi (1993) study were completely opaque, yet users had performance degradation. It is not clear whether transparent windows increase awareness or increase distraction from visual noise.

With regard to this thesis, the issue of global perspective does not suggest an advantage for either the single or double window design. This issue is included here to stress the importance of designing applications with the user in mind. It is not enough to simply provide functionality but designers must also consider how to minimize situations where users do not know where to go to collect information or perform tasks.

In summary there are four issues to consider when deciding whether to design an application as a multiple window system or a single window system with hidden information. These issues are summarized in Table 1. First, distraction due to peripheral contents might degrade performance with secondary windows. Second, with a single window scrolling application, information is hidden and performance may suffer due to disorientation, the fact that scrolling has been shown to take longer and the necessity to reacquire context. A single window tabbing application also hides information and performance may suffer due to the necessity to jump between tabs, remember what was in one tab while in another, as well as the need to reacquire context each time the user switches focus between tabs. Third, does the addition of windows enhance the organization of content, or does the use of tabs in a single window design efficiently accomplish this goal? Fourth, does the addition of an extra window increase the user's global perspective of the application, and therefore, reduce disorientation and amount of time spent reacquiring context?

Table 1

Summary of issues and impact on hypotheses

<u>Issue</u>	<u>Advantage for design</u>	<u>Reason</u>
Peripheral visual interference	Single Window	No secondary window providing visual interference
Hiding information by scrolling	Double Window	Reduces scrolling, less chance of disorientation

Hiding information by tabbing	Neither single nor double	Tabbing is more effective than scrolling due to cues such as titles, but tabbing can still be a problem due to the necessity to jump between tabs
Organization of content	Neither single nor double	Separate windows can be used to help organize content but so can separate tabs. As the number of windows and tabs increase, this advantage can be erased
Global perspective	Neither single nor double	Both single and double window versions should be designed to provide users with the knowledge of where in an application they should go to complete a task. Neither version inherently facilitates this.

The present research was conducted to gather information on these tradeoffs. The literature is not adequate to justify one method or the other. Thus, this research hopes to clarify whether a single window design with hidden information is a better alternative to a multiple window design where a task is spread out across two windows. The study was conducted using a conventional windows environment within the context of the network management domain.

Network Management

Network management software is a suite of tools that are used to manage all aspects of a network. Every large network owner or service provider will have trained

professionals who work with software that report and fix faults when a problem affecting service occurs. They monitor performance of the system to avoid degradations, configure the network as in establishing a connection between two points, and keep accounting information for customers.

The present research investigates whether a single or multiple window design is preferable in the context of two network management software applications. The Problem Manager is a fault surveillance application, and the Connection Manager is a configuration application. Both are examples of applications that require hiding of information if a single window design is used. The alternative is to spread the task over two windows. Both applications are tested in the present research to evaluate two different techniques for hiding information. The Problem Manager uses tabs and the Connection Manager uses scrolling to fit necessary information in a single window.

Tabbing and the Problem Manager

The Problem Manager is used to isolate and localize problems in the network. In the network, a loss of service to customers may result in lost revenues for the service provider. Figures 1, 2, and 3 illustrate the application and its three tabs when implemented in a single window design. In Figures 1 - 3, two main panes are used. The top pane, labeled the Problem List, shows all the problems that exist in the network at a given time. The individual who is responsible for surveillance decides which of these problems is the most expensive, shown in column 5, and sends a notice to the appropriate technician once the problem is located. This task is simple unless there are multiple problems with the same cost. In the event that this occurs, the user compares the details

of the problems. For example, a user selects an item from the Problem List pane and information on this problem appears in the Details pane shown in the middle of Figures 1 - 3. They may have to look under three tabs, Service Violations (Figure 1), Alarms (Figure 2) or Performance Degradations (Figure 3), for information on which problem to fix first.

Figure 4 illustrates the task when spread across two windows. The problem list is identical in this implementation but the three tabs are spread across the two windows so contents of all tabs are visible.

This application and task illustrate the issues discussed earlier. First, the multiple window design displayed in Figure 4 illustrates what occurs when a problem is selected from the Problem List and the three details areas appear simultaneously. The user counts the number of unique customers affected, in the Service Violation tab, and may be distracted or slowed down by the changes occurring in the second window. This second peripheral window acts as a dynamic element that can divert a user's attention and hinder completion of the time sensitive task. Second, the single window design displayed in Figures 1-3 fit all the information that is shown in the multiple window design of Figure 4 by displaying the contents of only one tab at a time and hiding the other two. Third, the multiple window design takes advantage of the extra space by spreading the tabs out over the two windows for space and organizational purposes. The first window houses the Problem List and the Service Violations tab used for the first step of the comparison, determining number of unique customers.

Nortel Networks - Problem Manager

Problem List

Problem	Nodes	Alarms	Days Past	Cost	Time
Sonet: experiencing traffic loss, receive traffic not protected	10	9	8	4	1/3/00 14:30:48
Sonet: experiencing traffic loss, transmit traffic not protected	7	5	12	2	1/3/00 14:24:42
FR: subsystem failure, connections are down	14	9	23	3	1/3/00 14:18:31
ATM: logical path communication signal lost	14	8	22	4	1/3/00 14:13:36
Sonet: remote line has failed	6	4	8	1	1/3/00 14:11:34
Switching: trunk connections are down	24	9	11	4	1/3/00 14:15:09
Sonet: remote line has failed	4	8	14	4	1/3/00 14:32:23
ATM: logical path communication signal lost	9	6	10	3	1/3/00 14:44:51
Switching: trunk connections are down	7	4	8	2	1/3/00 14:21:29
ATM: subsystem failure, connections are down	10	9	8	4	1/3/00 14:52:24

Cause and Correction: Locked component on Passport 10222 1009BoFR01 has resulted in a connection being down

Document Reference: 509-4880-257-ubal

Details

Service Violations | Alarms | Performance Degradations

Customer	Cust. Service	Level	Metric	Delivered	Agreed	Penalty/Metric
Bank of Nova	VPN	Gold	Latency	168 msec	< 150 msec	\$80/sec
Boeing Canada	Megaroute	Gold +	Errors	0.95%	< 0.8%	\$100/sec
Campbell Soup	Frame Relay	Silver	Network Availability	95%	> 98.7%	\$500/sec
Canadian Inc	Frame Relay	Silver	Packet Loss	1.5%	< 1.5%	\$100/sec
Clearnet Canada	AMPS Trunk	Gold +	Service Availability	96.3%	> 99.5%	\$500/sec
Microcell Solu'n	AMPS Trunk	Gold +	Network Availability	98%	> 99.9%	\$750/sec
National Post	Frame Relay	Gold +	Packet Loss	1.75%	< 0.7%	\$150/sec
Sears Canada	Frame Relay	Gold	Packet Loss	1.75%	< 1%	\$50/sec
Sympatico	IP VPN	Gold	MTBF	2 days	> 5 days	\$500/sec

8 SLA(s) total at last refresh: 02/02/00 14:35:22

Metric Agreed Penalty

Mean Time to Repair (MTTR):

Mean Time Between Failures (MTBF):

Network Availability:

Service Availability:

Metric Agreed Penalty

Dial-Port Availability:

End-to-End Latency:

Packet Loss:

Discards:

Contact Information:

[View Contract](#)

Figure 1: Single window tabbing application. The single window version of the Problem Manager is displayed with the first tab "Service Violations" selected.

Nortel Networks - Problem Manager

Problem List

Problem	Total	Alarms	Degraded	Cost	Time
Sonet: experiencing traffic loss, receive traffic not protected	10	9	8	4	1/3/00 14:39:48
Sonet: experiencing traffic loss, transmit traffic not protected	7	5	12	2	1/3/00 14:24:42
FR: subsystem failure, connections are down	14	9	23	3	1/3/00 14:16:31
ATM: logical path communication signal lost	14	8	22	4	1/3/00 14:13:36
Sonet: remote line has failed	6	4	8	1	1/3/00 14:11:34
Switching: trunk connections are down	24	9	11	4	1/3/00 14:15:09
Sonet: remote line has failed	4	8	14	4	1/3/00 14:32:23
ATM: logical path communication signal lost	9	6	10	3	1/3/00 14:44:51
Switching: trunk connections are down	7	4	8	2	1/3/00 14:21:29
ATM: subsystem failure, connections are down	10	9	8	4	1/3/00 14:52:24

Cause and Correction: Receive Traffic is not protected on NE 291 OC12 G1. The far-end optical card detected a problem on its received optical signal.

Document Reference: 468-6588-156-15uc

Details

Service Violations | Alarms | Performance Degradations

NE Name	Type	Unit	Reason	Severity	Time
291 DalaiTN01	Fac	OC12 G1s	LOS	CRITICAL SA	1/3/00 14:13:04
1010 JesseATM01	Com	Cell	LCD	CRITICAL SA	1/3/00 14:29:58
1010 JesseATM01	Com	Path	signalLabelMismatch	CRITICAL SA	1/3/00 14:30:01
1010 JesseATM01	Com	Communi	RX RFI	CRITICAL SA	1/3/00 14:30:01
1010 JesseATM01	Com	Near Path	degradedSignal	minor nsa	1/3/00 14:30:07
291 DalaiTN01	Fac	OC12 G1	Line RFI	CRITICAL SA	1/3/00 14:30:00
1010 JesseATM01	Com	Far Path	degradedSignal	minor nsa	1/3/00 14:30:07
1010 JesseATM01	Com	Communi	commSubsystemFailure	MAJOR SA	1/3/00 14:30:18
800 WonderTN03	Fac	STS G3 1	Rx AIS	warning nsa	1/3/00 14:14:22
800 WonderTN03	Fac	STS G2 2	Rx AIS	warning nsa	1/3/00 14:14:22
1002 LexATM01	Com	Cell	LCD	CRITICAL SA	1/3/00 14:32:20
1002 LexATM01	Com	Communi	Rx AIS	CRITICAL SA	1/3/00 14:32:23
1002 LexATM01	Com	Near Path	degradedSignal	minor nsa	1/3/00 14:32:29
1002 LexATM01	Com	Communi...	commSubsystemFailure	MAJOR SA	1/3/00 14:32:46

14 Alarm(s) total at last refresh: 02/02/00 14:35:22 Refresh Now

Location: _____ Acknowledged by: _____ Reason:

Shelf Position: _____ Display:

Slot: _____ Hostname: _____

CLFI: _____ Time: _____

Figure 2: Single window tabbing application. The single window version of the Problem Manager is displayed with the second tab "Alarms" selected.

Figure 3: Single window tabbing application. The single window version of the Problem Manager is displayed with the third tab "Performance Degradations" selected.

Figure 4: Multiple window tabbing application. The three tabs illustrated in Figures 1, 2 and 3 are spread out on two windows.

The two windows are effectively used to categorize the information in the tabs and to organize the tabs in an order that reflects the task flow. Fourth, the single window version of the Problem Manager utilizes tabs to fit all the information into one window. This allows for an investigation into whether tabs affect performance negatively due to the necessity to jump between tabs to access hidden information. If there is a need to compare information found in different tabs, a heavy cognitive load is placed on the user and a reacquisition of context is required. If no comparison is required across multiple tabs then the cognitive load, which increased when comparing information in one tab to information in another tab that cannot be seen, can be reduced. However, there is still a need to reacquire ones context each time a new tab is revealed. This can occur in the single window design when the user collects information from the three tabs. Fifth, the comparison of the single and multiple window designs allows for the investigation into whether seeing all the tab contents at once, as shown in Figure 4, provides a better global perspective than the single window design which hides information under tabs.

Scrolling and the Connection Manager

Unlike the Problem Manager, which hides information under tabs, the Connection Manager hides information by scrolling. The inclusion of both applications in this research allows for comparison of single and multiple window designs when the single window design hides information through the use of tabs and the use of scrolling.

The Connection Manager is used to establish communication circuits that connect a user from one location to another. For example, a customer may request a phone connection between offices in New York and Los Angeles. As can be seen in Figure 5,

the Connection Manager has three panes: Retrieval Criteria at the top, Connection Inventory in the middle and Connection Details at the bottom. The top pane is used to search for information such as all connections for customer X and the middle pane displays the results of the search. By selecting any of the listed results in the middle pane, details are displayed in the bottom pane. The connection is a link of network elements that pass data along the chain from one endpoint, across intermediate network elements to the other endpoint.

The user will typically search for a customer's connection, as can be seen in the top pane in Figure 5, and all connections dealing with this customer will appear in a list in the middle pane. The user will search the list, which might involve scrolling. Figure 6 shows a two-window version of the Connection Manager. There is much more room in the Connection Inventory area, and much more room to show the connections. The two windows may require the user to split attention between two windows and thus possibly lose focus and require extra time for reacquisition. This is especially serious if a user is selecting from the Connection Inventory and looking at the graphic window repeatedly in an effort to compare several connections. However, by moving the graphic display area to a second window the graphic size can be greatly increased. The amount of scrolling, both vertical and horizontal, is much greater in the single window design than the multiple window design.

Figure 5: Single window scrolling application. Single window version of the Connection Manager is displayed. Illustrated are the Retrieval Criteria, Connection Inventory and Connection Details panes in a single window design.

Figure 6: Multiple window scrolling application. Graphical viewing area is placed in the second window. Notice the reduction in scrolling in both the list area (Connection Inventory) in window 1 and the graphic area in window 2.

It is hypothesized that performance with the single and multiple window design will depend on the type of application. The second window will be preferred in a scrolling (Connection Manager) application but not in the tabbing (Problem Manager) application. In the scrolling Connection Manager, it is hypothesized that the multiple window design will facilitate the viewing of the search results list and the connection graphic by allowing for more space and reducing the amount of scrolling. Thus, in the Connection Manager, time, number of errors and rated ease of use, will be better for the multiple window design than the single window design.

For the tabbed Problem Manager, it is hypothesized that the multiple window design will not be preferred over the single window design, and performance will not be better. This hypothesis is made largely due to the contention that tabbing is a more effective method of hiding information than scrolling. Users will be able to maintain a stronger global perspective and context due to the use of tabs than is possible when scrolling hides information.

Experiment 1: A Tabbing Application (Problem Manager)

Method

Participants

Eight individuals who have knowledge of network management applications dealing with surveillance or fault detection participated. The participants had to either be presently working with network management software systems or have a proven knowledge of the domain. Participants were recruited by the author from a large networking firm and were told that a gift would be provided for participation. A gift certificate for \$50 was given after participation was complete.

Apparatus

All experimental testing was performed on a Dell Optiplex Gxa, 200 MHz computer with 64 megabytes of RAM. Single and double window versions of the Problem Manager were designed using Metacard (Metacard Corp, 1998). They were displayed on a 21 inch Apple monitor with resolution set at 1280 x 1024 with 16 bit color. Metacard was the sole software requirement. All testing was conducted in the same testing lab.

Procedure

In the present study the multiple window designs consist of only two windows. Some of the problems discussed earlier are made worse as the number of windows increase and therefore, the two-window comparison is seen as a best-case scenario for the multiple window design. If the double window design is shown to be an improvement

over the single window versions then future research will have to address the question of how many windows can be added before the benefits are reduced.

Half of the subjects were tested on the single window design followed by the double window design and half were tested on the double window version followed by the single window design.

Testing sessions began with an explanation that the purpose of the study was to evaluate two implementations of a next-generation network surveillance tool. The tool was to be utilized in a future network management suite of tools for the company that employed the participants. Then training included a discussion of previous versions of the application and how it had changed. Training continued with a description of the interface and an explanation of what was expected of the user. The interface description that was performed as part of the training was conducted with the application on the screen. All materials used for training can be seen in Appendix A.

On the wall was a large poster explaining the high-level goals that the user had to achieve. The contents of the poster can be seen in Appendix B. This information was visible throughout the testing session. The poster served as a reminder of what was the next appropriate step while performing experimental tasks. The goal of the poster was to bring the users, who were familiar with a previous version of the interface, as close to expert status with the prototype as possible.

Once training was complete, six questions, shown in Appendix C, were posed to determine if the user had the basic knowledge required to use the interface. If the participant could not answer all questions, then the participant was excused. This

criterion prevented the possibility of poor performance due to a lack of task knowledge affecting overall results. All recruits achieved the criterion.

Three tasks, which all had the same format, were conducted in each version of the interface. Table 2 illustrates the task flow conducted in all three tasks. Tasks required the user to search for information in lists found under the three tabs described earlier and illustrated in Figures 1, 2, and 3. The goal was to narrow a list of problems down to the problem that should be addressed first. The criterion for reducing the list was to fix the most expensive problem first. The participant had to scan a list of problems and decide, based on a cost indicator, which was the most expensive. If there were multiple problems of equal cost, then the participant had to identify which was the problem affecting the most customers. This required counting the number of unique customers affected by each problem. This activity was conducted in the first tab (Service Violations) as seen in Figure 1. If there were still multiple problems of equal cost and number of unique customers affected, the user had to count the number of unique network services (ATM, IP, VoIP, etc.) affected by the problem. This was done in the third tab (Performance Degradations) as seen in Figure 3. If there were still multiple problems with equal cost, number of customers and network services affected, the user had to fix the oldest problem first. The “fix” required the participant to point out the Root Cause of the problem to the experimenter. The Root Cause is a fault in the network that is the cause of the problem found in the Problem Lists of Figures 1-3. This was found under either the second (Alarms) tab, as seen in Figure 2 or the third (Performance Degradation) tab, as seen in Figure 3.

Table 2

Task flow for all tasks in experiment 1

<u>Step</u>	<u>Question</u>	<u>Action</u>	<u>Answer</u>
1	Is there a single problem that is costing the most?	Scan the cost column of the problem list and assess whether a single problem is rated the highest.	<ul style="list-style-type: none"> - If yes, locate and acknowledge the root cause of the problem found under the Alarm tab or Performance Degradation tab. - If no, go to second step
2	Is there a single problem that is affecting the largest number of customers?	Count the number of unique customers found under the Service Violations tab.	<ul style="list-style-type: none"> - If yes, locate and acknowledge the root cause. - If no, go to third step
3	Is there a single problem that is affecting the largest number of network services?	Count the number of unique network services found under the Performance Degradation tab.	<ul style="list-style-type: none"> - If yes, locate and acknowledge the root cause. - If no, go to fourth step.
4	Which problem is the oldest?	Compare the time of occurrence of the root cause for each problem	<ul style="list-style-type: none"> - Address the problem that is the oldest

The only difference in the three tasks was the volume of information. The first task was conducted with a very small amount of data to allow users an opportunity to feel comfortable performing the task. Little scrolling was required in any of the fields and the user did not have to compare multiple problems since only one problem was involved. Since scrolling was controlled by having the scrollable fields the same size in both the

single and double window designs the volume of information played little role. Tasks 2 and 3 had large volumes of information, as would be the case for a real problem, and comparisons of the details of different problems had to be conducted. This type of task is the major function of the target end-user. Appendix D contains the tasks performed.

All tasks were timed manually with a stopwatch and errors were recorded manually. If the participants were talking out loud, the stopwatch was not stopped. If the participant stopped working on the task and turned to address the administrator of the test, then the stopwatch was stopped and started once the user turned back to the task. An error was recorded only when a user gave an incorrect answer. After each task, the user was asked to rate the task on ease of use from 1 (very easy) to 6 (very difficult).

Participants had a pad of paper to help organize what they were counting. This was provided since the user encountered situations that required him to count the number of unique customers and network services.

The tasks and procedure for the single and double window versions of the application were identical except for the names of customers and other data, which were changed to minimize learning effects. The volume of information and size of scrollable fields, in each question, were identical in both versions of the interface.

After all three tasks were complete in the single and the double window versions of the application, the user was asked to rate which implementation they preferred on a scale of 1 (much prefer single window design) to six (much prefer double window design). After rating, there was discussion on why one version was better than the other. The sessions were completed in approximately 1 to 1.5 hours.

Results

It was hypothesized that neither the double window design nor the single window design when tabbing (Problem Manager) is used for hiding information would be more efficient (faster completion times), less error prone or rated as easier to use. This hypothesis is based on the contention that tabbing is a more effective method of hiding information than scrolling but tabbing can lead to disorientation when required to jump between tabs to collect information.

Completely within subjects comparisons of single and double window designs on three dependent variables, task completion time, number of errors made and rated ease of use were conducted. Analyses for experiment 1 were done on three tasks and totals. Analyses were conducted one task at a time, and task was not treated as an additional independent variable because the data in the tasks were not commensurate. Few differences were found so mixed analyses of variance were conducted with the addition of a between subjects independent variable of order of presentation (single – double vs. double – single).

A large number of analyses were conducted on the data collected as part of this experiment and all analyses were conducted at the alpha level of 0.05. It is recognized that a corrected alpha could have been used to reflect the large number of analyses. An attempt was made to maximize the chances of finding significant results since few differences were found, and the study suffers from small sample sizes with possibly lack of power. All F 's, even non-significant, are reported to illustrate the diversity and lack of consistency of results.

Subjects performed three tasks to evaluate each of the two window designs. All tasks required subjects to answer questions based on material presented in lists, but differed in the type and amount of data presented. The tasks required users to decide which problem required attention first. Table 2 shown above outlines the task flow of all tasks.

Time in seconds was measured from when the user started a task until the correct completion. An error was recorded when the participant gave a response that was incorrect. Participants made ease of use ratings using a scale from one to six where one was “very easy” and six was “very difficult”. Tables 3-5 show results for the three dependent variables, task completion time, number of errors made and rated ease of use, respectively.

Tables 3-5 all have the same form. Columns are tasks 1 – 3 and a total over all three tasks. The first row shows means and standard deviations for the single window condition on the dependent variables. In addition, a total across all three tasks is shown: total time, total number of errors and mean ease of use rating. The second row shows the same information for the double window display condition. Rows 3 and 5 show F tests on the dependent variables in the table for single vs. double window display. The third row shows Fs obtained with 1 and 7 degrees of freedom for analyses where the only independent variable was the within-subject manipulation of display condition (single vs.

double)¹. The fifth row shows Fs obtained with 1 and 6 degrees of freedom for analyses where the within-subject manipulation of display condition (single vs. double) was combined with a between subjects manipulation of order of testing (all tasks under single display condition first, or all tasks under the double display conditions first). Rows 4 and 6 show eta squares, the proportions of variance in the dependent variables that can be accounted for by the single vs. double window manipulation, for these analyses.

Tables 3-5 show that differences between the single and double window designs are small and inconsistent. The single window design resulted in faster completion times, less errors and higher rated ease of use in some tasks and the double window design was better in other tasks.

None of the tests of differences shown in Tables 3-5 were significant. Seventeen of the 24 Fs were well below 1 with small Eta squares suggesting that non-significance was not due to small sample sizes. However, five of the analyses had Eta squares above 0.20 suggesting that these analyses suffered due to the small sample sizes and a possible lack of power, and therefore, a larger sample size might have resulted in significant differences.

¹ Multivariate analyses were not conducted because of small sample sizes. Cohen (1988, p.472) states that multivariate analyses with small sample sizes may yield large proportions of variance that are misleading and cannot be interpreted.

Table 3

Results for time to perform tasks (in seconds) as a function of single versus double window design.

	<u>Task - 1</u>		<u>Task - 2</u>		<u>Task - 3</u>		<u>Total Time</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
Single	70.57	55.32	225.10	42.65	184.38	56.99	480.05	113.47
Double	66.71	63.86	228.50	85.87	207.63	46.06	502.85	154.74
F(1,7)*	0.02		0.30		1.54		0.26	
η^2	0.01		0.01		0.18		0.04	
F(1,6) **	0.03		0.03		1.76		0.29	
η^2	0.01		0.01		0.23		0.05	

* F-Obtained for the within-subjects comparison of single vs. double window designs as the only independent variable.

**F-Obtained for the within-subjects comparison of single vs. double window designs in a mixed factorial design that also included the between subjects manipulation of order of presentation.

Table 4

Results for number of errors as a function of single versus double window design.

	<u>Task - 1</u>		<u>Task - 2</u>		<u>Task - 3</u>		<u>Total Errors</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
Single	1.00	1.07	1.00	1.07	0.62	0.74	2.62	2.88
Double	0.87	1.13	1.25	1.03	0.75	1.03	2.82	3.19
F (1,7)*	0.05		0.20		0.08		0.06	
η^2	0.01		0.20		0.08		0.06	
F(1,6) **	0.06		0.19		0.07		0.09	
η^2	0.01		0.03		0.01		0.01	

* F-Obtained for the within-subjects comparison of single vs. double window designs as the only independent variable.

**F-Obtained for the within-subjects comparison of single vs. double window designs in a mixed factorial design that also included the between subjects manipulation of order of presentation.

Table 5

Results for ease of use ratings as a function of single versus double window design (1 = very ease, 6 = very hard).

	<u>Task - 1</u>		<u>Task - 2</u>		<u>Task - 3</u>		<u>Mean Ease Ratings</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
Single	1.84	0.94	2.53	1.28	2.31	1.23	2.23	1.11
Double	1.66	0.98	2.09	1.37	2.22	1.40	1.99	1.19
F(1,7) *	0.78		1.72		0.30		1.37	
η^2	0.10		0.20		0.04		0.16	
F(1,6) **	1.25		1.96		0.43		2.16	
η^2	0.17		0.25		0.07		0.26	

* F-Obtained for the within-subjects comparison of single vs. double window designs as the only independent variable.

**F-Obtained for the within-subjects comparison of single vs. double window designs in a mixed factorial design that also included the between subjects manipulation of order of presentation.

Analyses involving order of presentation

To counterbalance the order of presentation of the two designs, half of the participants were tested on the single window design first and half were tested on the double window design first. The between subjects independent variable of order of presentation (two orders) was analyzed in a mixed analysis of variance with the within subjects independent variable of window design (single vs. double windows). Due to the lack of significant differences found in the completely within subjects analyses coupled with the expectation of large differences, mixed analyses of variance were conducted between the within subjects variable of window design and the between subjects variable of order of presentation. These analyses were conducted to increase the chances of finding differences between single and double window designs. Table 6 illustrates the experimental design.

Table 6

Experimental design for the mixed analysis of variance between window design and order of presentation

Order 1 (s-d) $n_1 = 4$	Single	Double →
Order 2 (d-s) $n_2 = 4$	←	

Main effect of order of presentation

Appendix I shows tables comparable to Tables 3-5, but for order of presentation. Of the 12 mixed factorial analyses of variance (3 dependent variables x 4 scenarios – 3 tasks plus total), only one main effect of order of presentation was significant. The significant main effect of the between subjects manipulation of order of presentation was found in the analysis on task 2 when the dependent variable was number of errors made, $F(1,6) = 8.72$, $p < .05$, $\eta^2 = .59$. When the designs were presented in the order of single first and double second an average of 1.62 errors were made by users. When the designs were presented in the order of double first and single second the average number of errors made by the users dropped to 0.62.

Interaction of order of presentation and window display type

Of the 12 mixed factorial analyses, there were no significant interactions between window design and order of presentation. Table 7 displays the obtained Fs for all the interactions on the dependent variables time, errors, and ease of use ratings as functions of window design and order of presentation. Appendix J shows graphs of the interactions for all 12 combinations of dependent variables and tasks. No clear pattern of results exists in these graphs of the interactions.

Table 7

Obtained Fs for all interactions between window design and order of presentation on all dependent variables

<u>Dependent variable</u>	<u>Task - 1</u>	<u>Task - 2</u>	<u>Task - 3</u>	<u>Combined Scores</u>
Time	3.92	0.53	2.01	1.81
Errors	2.88	0.77	0.07	3.04
Ease of Use	5.02	1.96	3.86	5.00

Preferences

In addition to rating each task on ease of use the participants were asked to rate which implementation of the Problem Manager they preferred. After all tasks were completed, the participants were asked to give a rating on a scale from 1 (much prefer Single Window Design) to 6 (much prefer Double Window Design). As can be seen in Table 8, the participant's ratings were split between the two implementations and no clear preference was evident. A single sample t-test was conducted to test the mean preference rating against the null hypothesis that there was no preference for the single or double window designs. The mean preference rating of 4.25 was compared against the neutral value of 3.5. No significant preference for the single window design or the double window design was found, $t(7) = 0.97$, $p > .10$. A binomial test on the same data showed that the probability of getting five subjects who preferred one display type and three who preferred the other was 0.73.

Of interest here is the polarity of the ratings. There is no clear preference for the single or double window design, but there is strong preference for one or the other. Table

8 displays the frequency of the ratings of preference for the two designs. No one used the moderate categories of 3 and 4. If all the ratings were in the middle of the scale, then the lack of preference could be due to indifference. On the six-point scale, only the most extreme categories were used. There seem to be strong preferences, which differ from participant to participant.

Table 8

Frequency of ratings of preference for single or double window design in Problem Manager (tabbing)

	Prefer Single				Prefer Double	
Preference	1	2	3	4	5	6
# of responses	1	2	0	0	1	4

Comments

At the conclusion of each testing session, time was allotted for discussion of why the users made the preference that they indicated in Table 8. Table 9 displays the comments made and their frequency. Comments made by the subjects illustrate the issues discussed in the introduction and show the polarity of opinion. For example, comments 1 and 2 illustrate a number of user's preference for having all information visible at all times as in the double window design, but comments 6 and 7 illustrate the opinion that the double window design leads to increases in noise and refocusing of attention.

Table 9

Comments and frequency regarding preference for the single or double designs

<u>Comment</u>	<u>Frequency</u>
1) - User felt that the double window design allowed them to see everything that was involved in the interface and there was no fear that something required was hidden. Several of these users referred to this ability to see everything at once as having a "global perspective." - "I have a stronger visual understanding of the problem with double windows."	5/8
2) - User felt that the double window design was faster because there was no guessing where a piece of information was. - "I like to see it all at once."	5/8
3) -User felt that the screen management and refocusing of attention required in the double window design was not a problem. User felt that they had been working with window systems for a long time and are quite comfortable with these issues.	3/8
4) - "In the single window design I had to go back to memory for comparison. The double window version is cued and less memory of details is required."	2/8
5) - User felt that more than one window in an application requires jumping between windows and this was tedious.	2/8
6) - User felt that the double window design required a refocus of attention each time he had to look to another window. The single window design was preferred because he could focus on one location and simply flip the tabs.	2/8
7) - User felt that the double window design produced too much visual noise. He felt that having all the information visible on the screen at one time was too much to handle. He felt that his attention was easily drawn elsewhere and the single window design facilitated focusing on the task.	2/8
8) - User felt that mouse management of tabs is a bigger problem compared to the refocusing of attention required when switching between windows.	2/8
9) - User felt that the task flowed better in the single window design	1/8
10) - User felt that the double window design removed the problem of not remembering what was in the other tabs. NOTE: Even though there was no need to compare between tabs this problem surfaced. If direct comparison of tabs were required then this problem would likely have been more frequent.	1/8

Experiment 2: A Scrolling Application (Connection Manager)

Method

Participants

Eight individuals who have knowledge of network management applications dealing with the connection of virtual circuits participated. The participants had to either be presently working with network management software systems or have a proven knowledge of the domain. Subjects participated in Experiment 1 or Experiment 2, but not both. Participants were recruited by the author from a large networking firm and were told that a gift would be granted for participation. A gift certificate for \$50 was given after participation was complete.

Apparatus

The same equipment was used in Experiment 1 and 2.

Procedure

The procedure was the same as in Experiment 1. Half the subjects were tested on the single window design first and half were tested on the double window version first.

Testing sessions began with an explanation that the purpose of the study was to evaluate two implementations of a next-generation network management tool for establishing virtual circuit connections. The tool was to be utilized in a future network management suite of tools for the company the participants were employed at. The session continued with training that included a discussion of previous versions of the application and how it had been changed. Training continued with a description of the interface and what was expected of the user. The interface description that was performed

as part of the training was conducted with the application on the screen. All materials used for training can be seen in Appendix E.

On the wall was a large poster highlighting the key application changes that the user would not be aware of based on their knowledge of previous versions of the application. The contents of the poster are provided in Appendix F. The poster remained visible throughout the testing session. The poster did not directly help with execution but rather served as a reminder of changes from what they were used to. The goal of the poster was to bring the users, who were familiar with a previous version of the interface, as close to expert status, with the prototype, as possible.

Once training was complete, five questions, shown in Appendix G, were posed to determine if the subjects had the basic knowledge required to use the interface. If a participant could not answer all the questions, then the participant's data was not admissible in the analysis. This was a guard against the possibility of poor performance due to lack of domain knowledge affecting the overall results. All recruits achieved the criterion.

Seven tasks were run to evaluate whether hiding information by scrolling was more efficient, less error prone and easier to use than a double window implementation. These tasks can be viewed in Appendix H. An overview of all tasks can be seen in Table 10 below. All seven tasks required the user to find a piece of information in the interface. Two types of information were searched for (a) information in a scrolling list, (b) information in a scrolling graphic (network view). Task analysis revealed that the target end users would have a written list of information to be dealt with so users in this study

were also provided with a written list. For example, a company name to be searched for was given on paper for reference as opposed to having the searchable information committed to memory.

Table 10

Overview of tasks performed in experiment 2

<u>Task</u>	<u>Description</u>	<u>Volume of information</u>	<u>Target</u>
1	Search for customer's connection in a list (Connection Inventory)	20 list items	Alphabetical
2	Search for customer's connection in a list (Connection Inventory)	40 list items	Alphabetical
3	Search for start point of customer's connection in a list (Connection Inventory)	40 list items	Numerical
4	Search for start point of customer's connection in a list (Connection Inventory)	20 list items	Numerical
5	Determine if customer's connection passes through a specific node in graphical representation of connection	short connection	Graphical
6	Search for 2 customer names in a list (Connection Inventory)	40 list items	Alphabetical
7	Determine if customer's connections pass through specific nodes in graphical representation of connection	large connection	Graphical

In Table 10, Task 1 required the user to search for a customer's connection between two network elements with a specific network service. The search would return

approximately 20 list items (little scrolling), the user had to find the correct connection in the Connection Inventory (as seen in Figures 5 and 6), and make a minor change to the connection's details. If the user changed the details of the incorrect connection this was noted as an error.

Task 2 was similar to task 1 but the search resulted in 40 returned list items that required a larger amount of scrolling. The same task with small and larger amounts of scrolling were conducted to see if there was a performance difference in the two implementations when the volume of information was varied.

Task 3 utilized the same list of information that was used in task 2 but required the participant to search the list for a numerical piece of data, as opposed to alphabetical, as in tasks 1 and 2. Each virtual circuit is defined by the physical location of the circuit. For example, a connection may start on a network-switch in city A on shelf 1, sub-shelf 2, slot 2, port 12. As can be seen in both Figures 5 and 6, this connection definition (shelf, sub-shelf, slot, port) was displayed in the list as a numeric string such as 1-2 2 12, and the participant was asked to locate a specific numeric connection definition.

Task 4 was similar to task 3 but the search resulted in only 20 returned list items. This task was conducted to compare numerical information retrieval from a larger amount of data and small amount of data.

Task 5 was also an information retrieval task, but the information was retrieved from a scrolling graphic not a scrolling text list as in the previous tasks. The Connection Manager supplied the user with an end-to-end view of a virtual connection in the details area of the application. The details area can be found in the bottom pane of the single

window version, illustrated in Figure 5 and in the second window of the double window version, illustrated in Figure 6. This included the two endpoint network elements and all intermediate connections. Task 5 required the user to determine whether the selected connection passed through a specific network element. The user had to read labels on the scrolling graphic (small amounts of information) to determine if the network element in question was involved.

Task 6 was, once again, an information retrieval task from a scrolling list (40 connections), but this time required the user to search for two pieces of information as opposed to previous tasks which required the user to locate a single target piece of information.

Task 7, like task 5, required the user to locate a specific network element in a scrolling graphic, which represented the end-to-end connection. This task differed in that the graphic was larger than that in task 5. This required the user to spend more time scrolling, both horizontally and vertically, than in task 5. An overview of the seven tasks performed is provided above in Table 10.

After all tasks were completed in the single and double window versions of the application, the user was asked to rate which implementation they preferred on a scale of 1 (much prefer single window design) to six (much prefer double window design). After rating, there was discussion on why one version was better than the other. The sessions were completed in approximately 1 to 1.5 hours.

Results

It was hypothesized that the double window design would be more efficient (faster task completion times), less error prone and rated as easier to use compared to a single window design that hides information by scrolling.

Completely within subjects comparisons of single and double window designs on three dependent variables, task completion time, number of errors made and rated ease of use were conducted. Analyses for experiment 2 were done on seven tasks and totals across tasks. Analyses were conducted separately and task was not treated as an additional independent variable because the data in the tasks were not commensurate. Few differences were found so mixed analyses of variance were conducted with the between subjects independent variable of order of presentation (single – double vs. double – single).

All analyses were conducted at the alpha level of 0.05. As in experiment 1, it is recognized that a corrected alpha could have been used to reflect the large number of analyses but an attempt was made to improve the chances of finding significant results since few differences were found, and the study suffers from small sample sizes and possibly a lack of power. All F's, even non-significant, are reported to illustrate the diversity and lack of consistency of results.

Time in seconds was measured from when the user started a task until the correct completion. An error was recorded when the participant gave a response that was incorrect. Ease of use ratings were made on a scale from one to six where one was "very easy" and six was "very difficult. Tables 11-13 show results for the three dependent

variables, task completion time, number of errors made and rated ease of use, respectively.

All three tables have the same form. Columns are tasks 1 – 7 and a total over all seven tasks. The first row shows means and standard deviations for the single window condition on the dependent variables on each task. In addition, a total across all seven tasks is shown: total time, total number of errors, and mean ease of use rating. The second row shows the same information for the double window display. Rows 3 and 5 show F tests on the dependent variables in the table for single vs. double window display. The third row show Fs obtained with 1 and 7 degrees of freedom for analyses where the only independent variable was the within-subject manipulation of display condition (single vs. double). The fifth row shows Fs obtained with 1 and 6 degrees of freedom for analyses where the within-subject manipulation of display condition (single vs. double) was combined with a between subjects manipulation of order of testing (all tasks under single display condition first, or all tasks under the double display conditions first). Rows 4 and 6 show eta squares, the proportions of variance in the dependent variables that can be accounted for by the single vs. double window manipulation, for these analyses.

Tables 11-13 illustrate that the differences between the single and double window designs are unsystematic. Some places the single window design had longer completion times, more errors made and lower rated ease of use, and some places the double window design resulted in longer completion times, more errors and lower rated ease of use.

Only four of the 48 tests of differences shown in Tables 11-13 were significant. All four were found in task 5, between the single and double window design when the

dependent variable is time, and when the dependent variable is ease of use rating. These differences were significant when the between subjects independent variable, order of presentation, was included and when it was not included. The first significant difference between the single window design ($\underline{M} = 16.40$) and the double window design ($\underline{M} = 7.50$) was found on the dependent variable time in task 5 when the between subjects independent variable, order of presentation, was included (Row 5) $\underline{F}(1,6) = 32.01$, $p < .05$, $\eta^2 = .84$ and when it was not included (Row 3) $\underline{F}(1,7) = 28.86$, $p < .05$, $\eta^2 = .80$. The second significant difference between the single window design ($\underline{M} = 1.62$) and the double window design ($\underline{M} = 1.12$) was found on the dependent variable ease of use rating in task 5 when the between subjects independent variable, order of presentation, was included (Row 5) $\underline{F}(1,6) = 6.00$, $p < .05$, $\eta^2 = .50$ and when it was not included (Row 3) $\underline{F}(1,7) = 7.00$, $p < .05$, $\eta^2 = .50$. Of the remaining 38 differences displayed in Tables 11-13, 24 of the Fs were below 1 with small Eta squares. However, 10 of the analyses had Eta squares above .20 suggesting that these analyses suffer from a small sample size and a possible lack of power. A larger sample size might have resulted in significant differences.

Table 11

Results for time to perform tasks (in seconds) as a function of single versus double window design.

	<u>Task - 1</u>		<u>Task - 2</u>		<u>Task - 3</u>		<u>Task - 4</u>		<u>Task - 5</u>		<u>Task - 6</u>		<u>Task - 7</u>		<u>Total Time</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
Single	91.75	61.79	108.31	46.28	38.71	38.51	18.08	10.92	16.40	6.81	52.81	22.74	103.99	31.07	430.06	170.46
Double	83.35	49.79	111.70	60.04	16.13	7.62	16.22	13.42	7.50	3.80	69.06	33.18	103.01	35.46	406.98	145.87
F(1,7)*	0.08		0.02		3.26		0.18		28.86		1.97		0.01		0.15	
η^2	0.01		0.01		0.32		0.02		0.80		0.22		0.01		0.02	
F(1,6)**	0.20		0.01		3.83		0.15		32.01		1.85		0.01		0.43	
η^2	0.03		0.01		0.39		0.25		0.84		0.24		0.01		0.07	

* F-Obtained for the comparison of the single and double window designs.

**F-Obtained for the mixed comparison of the single and double window designs with the between subjects manipulation of order of presentation.

Table 12

Results for number of errors as a function of single versus double window design.

	<u>Task - 1</u>		<u>Task - 2</u>		<u>Task - 3</u>		<u>Task - 4</u>		<u>Task - 5</u>		<u>Task - 6</u>		<u>Task - 7</u>		<u>Total Errors</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
Single	0.13	0.35	0.87	0.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.35	1.12	1.25
Double	0.25	0.46	0.37	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.35	0.12	0.35	0.87	0.99
F(1,7)*	0.30		3.50		***		-		-		1.00		0.00		0.47	
η^2	0.04		0.33		-		-		-		0.12		0.00		0.06	
F(1,6)**	0.27		3.43		-		-		-		1.00		0.00		0.43	
η^2	0.04		0.36		-		-		-		0.12		0.00		0.07	

* F-Obtained for the comparison of the single and double window designs.

**F-Obtained for the mixed comparison of the single and double window designs with the between subjects manipulation of order of presentation.

***Indicates that the analysis could not be conducted since zero errors were made while performing the task.

Table 13

Results for ease of use ratings as a function of single versus double window design (1 = Very Ease, 6 = Very Hard).

	<u>Task - 1</u>		<u>Task - 2</u>		<u>Task - 3</u>		<u>Task - 4</u>		<u>Task - 5</u>		<u>Task - 6</u>		<u>Task - 7</u>		<u>Total Ease</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
Single	2.25	1.03	2.50	1.07	1.87	1.36	1.50	1.07	1.62	0.74	1.75	0.71	2.75	0.89	2.04	0.55
Double	2.50	0.76	2.37	1.30	1.87	0.64	1.62	0.52	1.12	0.35	2.25	0.89	2.37	0.75	2.02	0.47
F(1,7)*	0.37		0.05		0.00		0.10		7.00		1.75		1.34		0.01	
η^2	0.05		0.01		0.00		0.01		0.50		0.20		0.16		0.01	
F(1,6)**	2.00		0.04		0.00		0.13		6.00		1.50		1.17		0.01	
η^2	0.25		0.01		0.00		0.02		0.50		0.20		0.16		0.01	

* F-Obtained for the comparison of the single and double window designs.

**F-Obtained for the mixed comparison of the single and double window designs with the between subjects manipulation of order of presentation.

Analyses involving order of presentation

To counterbalance the order of presentation of the two designs, half of the participants were tested on the single window design first and half were tested on the double window design first. The between subjects independent variable of order of presentation (two orders) was analyzed in a mixed analysis of variance with the within subjects independent variable of window design (single vs. double windows).

Due to the lack of significant differences found in the completely within subjects analyses coupled with the expectation of large differences, mixed analyses of variance were conducted between the within subjects variable of window design and the between subjects variable of order of presentation. These were conducted to maximize the

probability of finding the expected differences. Table 14 illustrates the experimental design.

Table 14

Experimental design for the mixed analysis of variance between window design and order of presentation

	Single	Double
Order 1 (s-d) $n_1 = 4$
Order 2 (d-s) $n_2 = 4$

Main effect of order of presentation

Appendix K shows tables comparable to Tables 11-13, but for order of presentation. Of the 24 mixed factorial analyses of variance (3 dependent variables x 8 scenarios – 7 tasks plus total), no significant main effects of the between subjects manipulation of order of presentation were found.

Interaction of order of presentation and window display type

Of the 24 mixed factorial analyses, there were four significant interactions between the within subjects variable of window design and the between subjects variable order of presentation. Two of the significant interactions were found in the analyses for

task 1, one was found in the analyses for task 3 and the final significant interaction was found on the analysis of time scores when the results of all tasks were combined. Table 15 displays the obtained Fs for all the interactions on mixed analyses. Appendix L shows graphs for all 24 combinations of dependent variables and tasks.

Table 15

Obtained Fs for all interactions between window design and order of presentation on all dependent variables

	<u>Task - 1</u>	<u>Task - 2</u>	<u>Task - 3</u>	<u>Task - 4</u>	<u>Task - 5</u>	<u>Task - 6</u>	<u>Task - 7</u>	<u>Combined Scores</u>
Time	11.62	0.12	2.72	0.00	1.76	0.59	4.58	14.47
Errors	0.27	0.86	*	-	-	1.00	0.00	0.43
Ease of Use	32.00	0.04	8.00	3.26	0.00	0.00	0.13	4.53

* Indicates that the analysis could not be conducted since zero errors were made while performing the task.

The first significant interaction involving the within subjects variable of window design and the between subjects variable of order of presentation was found for the dependent variable time in task 1, $F(1,6) = 11.62$, $p < .05$, $\eta^2 = .66$.

This interaction is illustrated in Figure 7. A significant difference was found between the single window design ($M = 136.28$) when presented as the first condition and the single window design ($M = 47.22$) when presented as the second condition, $F(1,6) = 8.76$, $p < .05$. A significant difference was also found between the single window design presented first ($M = 136.28$) and the double window design presented second ($M = 63.85$), $F(1,6) = 7.44$, $p < .05$. All other simple effects were not significant.

Figure 7: Interaction of window design (single or double window) and order of presentation for task 1 on dependent variable time.

The second significant interaction involving the within subjects variable of window design and the between subjects variable of order of presentation was found for the dependent variable of ease of use rating in task 1, $F(1,6) = 32.00$, $p < .05$, $\eta^2 = .84$.

This interaction is illustrated in Figure 8. A significant difference was found between the single window design presented first ($M = 3.00$) and the double window design presented second ($M = 2.25$), $F(1,6) = 9.00$, $p < .05$. A significant difference was also found between the single window design presented second ($M = 1.5$) and the double window design when presented first ($M = 2.75$), $F(1,6) = 25.00$, $p < .01$. Finally, a significant difference was found between the single window design when presented as the first condition ($M = 3.00$) and the single window design when presented as the second condition ($M = 1.5$). The users rated the single window design as significantly easier to use when they had the double window design presented first $F(1,6) = 9.00$, $p < .05$. The double window design ease of use ratings did not differ significantly depending on order of presentation.

The third significant interaction involving the within subjects variable of window design and the between subjects variable of order of presentation was found for the dependent variable ease of use ratings in task 3, $F(1,6) = 8.00$, $p < .05$, $\eta^2 = .57$.

This interaction is illustrated in Figure 9. None of the simple effects were significant. The largest F found was for the simple effect of order of presentation at the single level of the independent variable of window design, $F(1,6) = 5.44$, $p > .05$.

Figure 8: Interaction of window design (single or double window) and order of presentation for task 1 on the dependent variable ease of use ratings.

Figure 9: Interaction of window design (single or double window) and order of presentation for task 3 on the dependent variable ease of use ratings.

The fourth significant interaction involving the within subjects variable of window design and the between subjects variable of order of presentation was found for the dependent variable total time, $F(1,6) = 14.70$, $p < .05$, $\eta^2 = .70$.

This interaction is illustrated in Figure 10. A significant difference was found between the single window design ($M = 552.63$) when it is presented as the first condition and the double window design ($M = 395.49$) when presented as the second condition, $F(1,6) = 9.94$, $p < .05$. A significant difference was also found between the single window design when presented as the first condition ($M = 552.63$) and the single window design when presented as the second condition ($M = 307.48$), $F(1,6) = 8.67$, $p < .05$. Significant differences were not found between the double window design when presented first and when presented second.

A similar relationship is found in this interaction as the other three. The single window design takes longer and is rated as harder to use when in the first condition but in the second condition, the users are faster with the single window design and rate it as easier to use.

Preferences

In addition to rating each task on ease of use, participants were asked to rate which implementation of the Connection Manager they preferred. After all seven tasks were completed the participants were asked to give a rating on a scale from 1 (much prefer Single Window Design) to 6 (much prefer Double Window Design). As can be

Figure 10: Interaction of window design (single or double) and order of presentation for all tasks combined on dependent variable total time.

seen in Table 16 the participant's ratings were split between the two implementations with a slight edge in favor of the double window design. A single sample t-test was conducted to test the mean preference rating against the null hypothesis that there was no preference for the single or double window designs. The mean preference rating of 4.5 was compared against the neutral value of 3.5. No significant preference for the single window design or the double window design was found, $t(7) = 1.76$, $p > .10$. A binomial test of the same data showed that the probability of getting six subjects who preferred one display type and two who preferred the other was 0.29.

Of interest here is the polarity of the ratings. There is no clear preference for the single or double window design but there is strong preference for one or the other. No one used the moderate categories of 3 and 4. If all the ratings were in the middle of the scale, then the lack of preference could be due to indifference. On the six-point scale, only the most extreme categories were used. There seem to be strong preferences, which differ from participant to participant.

Table 16

Frequency of ratings of preference for Single or Double Window Design in Connection Manager (Scrolling)

	Prefer Single				Prefer Double	
Preference	1	2	3	4	5	6
# of responses	0	2	0	0	4	2

Comments

At the conclusion of each testing session, time was allotted for discussion of why the users preferred one design or the other. Table 17 displays the comments made and their frequency. Comments made by the subjects illustrate the issues discussed in the introduction and show the polarity of opinion. For example, comment 1 and 4 illustrate how some users like the double window design due to having a large scrolling list and other users disliked the double window version because of the larger scrolling list.

Table 17

Comments and frequency regarding preference for the single or double designs

<u>Comment</u>	<u>Frequency</u>
1) - User preferred the double window version due to the decreased amount of scrolling that was required in the list and graphic. The user felt it was tedious and easy to lose one's place. - "I want more and more real estate for what I am presently working on." - "Scrolling leads to losing track."	5/8
2) - User does not mind the window management or the refocusing of attention that is required in a double window version. - "I would rather the whole screen be used to show the graphic. It could even cover everything else and I would close it each time to go to the next."	4/8
3) - User preferred the single window version because there was no need to jump between windows.	2/8
4) - User felt that the long textual list provided in the double window version lead to information overload. The user felt that the long list was too much to look at and scan at one time.	2/8
5) - User liked the double window version because all information that was included in the interface can be seen and used at one time, even with the overlap. This facilitated double comparisons.	2/8
6) - User felt that the task flowed better in the single window design.	1/8

Discussion

It was hypothesized that performance with the single and double window design would depend on the type of application. A double window design would result in better performance and be preferred in an application that hides information by scrolling (Connection Manager), but a double window design would not result in better performance and would not be preferred in an application that hides information by tabbing (Problem Manager). No conclusive evidence was found to suggest that either the single or double window designs in either the scrolling or tabbing applications was superior.

Issue one: Peripheral Visual Interference

One issue that contributed to the hypothesis was that a double window design would likely result in poor performance because of interference from a second window when working in a primary window (Mori and Hayashi, 1993). Harrison, Ishii, Vicente and Buxton (1995) provided research that suggested that user's performance improved when a transparent window was used to remove overlapping windows. A transparent window should increase the amount of interference from the underlying window and yet, the subjects' performance improved. This disagreement of results between the two studies was not resolved in the present research. Anecdotally, users did not mind the second window from an interference perspective. In the comments made by subjects involved in the tabbing application, only two of eight subjects commented that the second window was a distraction. In the case of the scrolling application, no comments were

made regarding interference from one window or the other. A future study could investigate the effect of peripheral visual interference in a single tiled window.

Issue two: Hiding Information

A second issue that contributed to the hypotheses was that a single window design might result in poor performance because of the necessity to hide information by using tabs or scrolling. The hiding of information can cause users to lose their place. In the present study the users may have avoided getting lost because they were trained to perform the tasks and the task was posted on the wall. This might have been one cause for the lack of significant differences between the single and double window design. For example, the decision was made that the users should be informed of which tab housed specific information. The users knew that the customer information was found under the first tab, Service Violations. The goal of the research was to test whether tabbing slowed users or caused more errors than a double window design. The experiment was attempting to test the user's interaction with tabs versus two windows and thus attempted to train the users so that domain problems would be minimized and only the interaction methods would be evaluated.

Hiding Information by scrolling

In the case of the scrolling application, the double window design was hypothesized to perform better because less scrolling would be required and thus less chance of disorientation (Arai et al., 1992). Of the two experiments, only one task yielded a significant difference between the single and double window designs. Task 5 of the scrolling application required users to locate a specific network element in a scrolling

graphic representation of a network that was small. The task was significantly shorter and significantly rated as easier when using the double window design. This seems to support the contention that when scrolling is used to hide information, a double window design is preferable. On the other hand, no significant differences were found between the two designs in task 7 which was the same as task 5 except more scrolling was required. If the double window design was truly responsible for the differences found in task 5, then an even greater difference between the two should have been found in task 7. It is difficult to see why there was a difference on task 5 but not task 7. The significant effects on task 5 may be due to sampling fluctuation.

Observing differences in how the users scrolled through a list, such as the Connection Inventory of the scrolling application, demonstrated how individual differences might have contributed to the lack of differences between the two designs. Users employed four distinct search methods. No count of how many subjects used each method was taken since the diversity was not expected. The first method employed by users was to scroll the list line by line. The second method employed by users was to scroll the list a page at a time. The users accomplished this by clicking in the area between the two vertical scroll arrows. This method will be referred to as paging. The third method employed by the users was to scroll line by line but these subjects highlighted the first line and scrolled using the arrow buttons on the keyboard rather than the mouse on the scroll bar. This allowed the users to read the highlighted line and avoid losing their place. A fourth search method used by subjects was to highlight the last visible line in the list and then scroll line by line using the vertical arrows on the scroll

bar. When the highlighted line reached the top of the list the user would once again highlight the last visible line in the list. This method allowed the user to know which lines have already been searched and help avoid disorientation.

It was clear from observing the users that a better method was required for accessing information from a list. Those subjects who used the highlighting methods seemed to have fewer problems with disorientation but they had to slowly scroll line by line. Those users who paged multiple lines were susceptible to becoming disoriented since this method leaves three or four lines which have already been read at the top of the list in what appears to be an attempt to help users find their place. If the list would consistently page to the first line that was previously not viewable, then the users could continue reading the data without pause. However, a novice user may not be confident that lines were not missed. Regardless of how users scrolled, it was clear that the methods of interacting with scrolling fields are inadequate and the users in the study were employing different techniques to help improve performance at varying speeds and competence.

Leading mouse manufacturers such as Logitech have attempted to help users with scrolling lists by offering a variety of scrolling techniques that are included with the mouse drivers. For example, Universal Scrolling from Logitech allows users to press on a middle mouse button to provide both horizontal and vertical scrolling, without breaking visual focus, by moving the mouse. These tools need to be provided to users who frequently work with scrolling lists of information such as those in the network management domain.

In addition to providing input devices that facilitate scrolling, such as Logitech's Universal Scrolling, improved design could have helped. Bednall (1992) conducted research comparing different methods of presenting list data. The research showed that when a blank line was inserted between filled lines the subjects were able to find information in the list faster than when the blank lines were not provided. A second experiment showed that when the lines in a list were presented in alternating format the subjects were able to find information faster. An example of alternating format could have been to use slightly altered background color every second line, Bednall (1992) alternated between dashes and dots to fill blank space between information across rows in the list. Alternating line format could improve task completion in scrolling applications.

Hiding Information by tabbing

Tabs can be seen as both an asset and a detriment. Tabs do provide titles to indicate what category of information is under the tab. However, tabs could also be a detriment depending on how they are used. A user has to change focus when collecting information from different tabs and this can lead to disorientation. Also, when comparing information, the user has to commit to memory information from one tab, while comparing it to information in a second tab. The extra cognitive load can lead to disorientation and errors. In the present tabbing application, the tasks did not require comparisons to be made across tabs. Most time was spent collecting information from separate tabs in isolation.

There was some evidence of the problems that can occur when working in a tabbing application. Although the steps required for completing the task were posted on

the wall, two users chose to commit the steps to memory as opposed to using the poster. These two users knew they wanted to count the number of unique customers affected by a problem, but could not remember which tab this information was under. They looked in the three tabs, but did not notice that the first tab had customer information. Having not found the information, they abandoned the systematic searching of the tabs and started selecting tabs in no particular order.

If the tasks conducted in the tabbing application had required more detailed comparisons of information found under the tabs, an advantage to the double window designs might have been found.

Issue three: Organization of content

It was suggested that the organization of the interface's content might affect performance of the tasks with the single and double window designs. Piolat et al. (1997) and Tombaugh et al. (1987) both suggest that if the content is organized by category and includes aids such as landmarks, then an application could provide for optimum performance. Both the single and double window versions were designed to reflect the users' task flow and were organized for performance. As well, neither design added too many windows or tabs that would negatively affect performance. Regardless of whether designing a single or double window application, care must be taken to organize content into categories and place them in the application in a way that reflects the user's task flow.

Issue four: Global Perspective

A high-quality global perspective can not only help avoid situations where the user gets lost or help when the user needs to reacquire his place, but also help in providing a more efficient design. A good global perspective should allow the user to know at all times where they are within the application but also know where they have to go to find information being sought. No evidence was found as to whether a double window design was more effective at providing a global perspective than a single window design using tabbing or scrolling. Anecdotally, five of eight users tested in the tabbing application felt that the double window design allowed them to see everything that was involved in the interface. This removed the fear that something required was hidden out of sight. One user expressed the opinion, "I have a stronger visual understanding of the problem with double windows." Two of eight of the subjects in the scrolling application felt the same way. Yet, no significant differences were found between the two designs. Therefore, this study did not provide a clear indication whether the double window versions provided a better global perspective over the single window versions.

Quantitative Results

Statistically, these experiments suffer from two contradictory problems. First, there are small sample sizes with possible lack of power. Second, there is a possibility of excessive Type I errors because of a large number of analyses, all conducted with an alpha of .05.

Clearly there is potential for a lack of power when only eight subjects are used in a statistical procedure, even when the main tests of concern are within-subjects comparisons. The small sample sizes were unavoidable due to the lack of availability of sufficient expert subjects.

Conflicting with the small sample sizes, leading to potential Type II errors, is the fact that a large number of analyses, at the .05 alpha level, would increase the chances of Type I errors. Because the study suffers from small sample sizes and few significant differences, many different analyses on many dependent variables were performed to increase chances of finding differences between the single and double window designs. A total of 72 analyses were conducted comparing the single and double window tabbing and scrolling designs. A corrected alpha could have been used, but this would have resulted in even less chance of finding differences. The final result is an indeterminate mixture of possible low power because of small sample sizes and possible high power because of an alpha level that is too high.

One place where significant results were found was when the order of presentation was analyzed as a between-subjects variable in a mixed analysis of variance with the within-subjects independent variable of window design. Of the 36 separate interactions analyzed in the two experiments, only four interactions were significant. All four were found in the experiment analyzing the scrolling applications. As can be seen in Figures 7-10, all four interactions have similar form. Performance with the single window design when presented first is slowest and rated as most difficult to use. Yet, when tested second, the single window design results in fastest performance and highest rated ease of

use. It appears as though a single window scrolling design is the hardest to learn at first attempt, but is a more efficient tool once the user gets used to the tasks involved and learns the interface. This might have implications for design. If a designer is creating an application that caters to users who have never seen it before, then a double window design may be preferable. If this application is one where the target users will have training time and repeated use, then a single window design may be the better choice. An example of the former may be an information kiosk in a mall, and an example of the latter may be a network management tool that would be supplied with training.

The question remains of why only four of 36 order by window design interactions were significant. If the single window design did result in the slowest completion times when presented first and fastest when presented last, then we would expect to see more significant interactions. As can be seen in Appendix L, the non-significant interactions have a variety of forms that do not follow the pattern found in the four significant interactions. The interactions may not be due to the explanation provided above. There it was stated that performance on the single window design was best and worst depending on whether it was presented first or second. In reality, the interaction may be nothing more than sampling fluctuation.

Qualitative Results

Combining the two experiment's preference scales, there are 11 subjects rating the double window design as preferable and five rating the single window design as preferable. Not one of these ratings fell in the middle of the six-point scale at either three or four. If non-significant differences in preferences were because subjects were

indifferent, then designers could take this to mean that users will accept either the single or the double window design. This was not the case. Rather, subjects were not indifferent. If a developer designed an application as a single window design, he would be alienating all the people who prefer the double window design. The opposite is true as well. The polarity of preference ratings suggests a customizable design with both options. An example of a customizable design might start as a single window with specific panes that can be pulled off as second windows. The user could decide whether he wants to keep the application as a single window or go to a double window.

Future Research

Future investigations into differences between the single and double window tabbing and scrolling applications should be conducted outside of the network management domain. As well, a replication of the present study should be conducted within the network management domain but with completely task-naïve and system-naïve subjects. The present study attempted to test future application concepts on expert users. Subjects never saw the concepts prior to the testing day so training was conducted to bring the users up to the point where they might perform at a high level. This may have had a negative effect in that the users knew where they had to look for pieces of information and the differences between tabbing and windowing may not have surfaced. Another problem with using domain experts and trying to bring them to the level of application experts is that they seemed to have a difficult time suppressing prior experience and expectations.

It is possible that subjects who have never seen either application could be trained longer or over more practice sessions and tested even though they have no network management domain knowledge. The extra time training may have been a worthwhile investment if the result was expert subjects who were not distracted by transfer from past experience.

An important addition to any of the suggested replications is the inclusion of time pressure. In the present study the subjects were timed but they were allowed to have as much time as required to complete each task. The subjects were instructed to work at the speed they normally do but may not have since they were cognizant of the fact that they were only in a testing situation involving a prototype. Performance differences between the two designs may have been exposed if the subjects were pressured by time. Future replications should allow a time limit on each task and the limit should be short enough to make the subjects work at a speed similar to their real world scenarios. It may be possible that performance is better in the single or double window designs when the user is working at a fast pace or is rushed.

Another variation to the present study that should be conducted is the inclusion of design scalability as an issue. If the results of the present study had showed conclusive evidence that a double window design resulted in faster completion times, could we then assume that a design consisting of four windows would outperform a single window design with six tabs? Obviously, we cannot come to this conclusion without conducting the experiment.

In addition to design scalability, an investigation of task scalability is required. Research should investigate at what point a new window should be added to an application. For example, the scrolling Connection Manager defined a short scrolling list as 20 lines and a long scrolling list as 40 lines. It may be possible that a list of 200 lines would have demonstrated an advantage of the double window design.

A final improvement for future studies is to add rating scales for each design separately. Both of the present experiments concluded with the subjects rating their preference for the single or the double window design on a bi-polar scale. Two additional scales should be included, one that rates the single window design on a numeric scale such as, “Likes a lot” to “dislikes a lot,” and one for the double window design. Separate rating scales may yield different ratings of the two designs since they are not forced to rate each design based on how much better or worse it was from the other design.

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Appendix A: Training materials for the tabbing application, Problem Manager

The Interface

- a one-stop tool for revenue maximization through penalty minimization.
- interface has a list of problems that exist in the network
 - clicking on a problem displays...
 - a list of correlated alarms
 - a list of correlated performance degradations
 - a list of correlated service level agreements

Information included in the interface:

- list of problems
- cost indicator
 - 1 - least costly
 - 5 - most costly
- count of SLA violations, alarms and performance degradations associated with each problem.
- time of root cause detection

Service Level Agreement information:

- list of customer's whose SLAs have been violated due to selected problem
- customer service provided (e.g. email, http)
- level of service guaranteed (Gold, Silver, Bronze)
- violated service metric (latency, Mean Time to Repair etc)
- penalty for violation of agreement
 - e.g. 5K/hour
- more detailed information for each SLA violation.

Alarm information:

- list of correlated alarms
 - sorted by name of node
- type of individual alarm (comm, fac etc)
- unit (OC12 GIs, cell, path, near path, far path etc)
- alarm reason
- alarm severity
- time of alarm
- root cause
 - indicated in purple

Performance Degradation information :

- list of correlated performance degradations
 - sorted by name of node
- unit (OC12 Gls, cell, path, near path, far path etc)
- metric (marginal call rate, Line Rx ES)
 - actual level and threshold surpassed
- network services affected (e.g. ATM, Frame Relay, Optical)
- time of threshold crossing
- root cause
 - indicated in purple

Appendix B: Wall poster for the tabbing application, Problem Manager

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Priorities:

- 1) Problem that is costing the most! (1= low, 5 = high)
- 2) Problem that is affecting the largest number of unique customers (SLA information)
- 3) Problem that is affecting the largest number of unique types of Network Services. (Performance Degradation info.)
- 4) Fix the problem that is the oldest.
- 5) I.D. the Root Cause and acknowledge. (Perf. Degradation OR Alarm info.)

Appendix C: Knowledge assessment questions for the tabbing application, Problem Manager

- 1) What information do you expect to see when you select a problem?

Ans: the set of alarms and performance degradations

- 2) How is the cost of a problem indicated?

Ans: levels 1 - 5 where 5 is most expensive

b) What is costing the company more money?

Problem A with a cost level of 4
or
Problem B with a cost level of 3

- 3) There are two problems in the problem list that have a cost level of 5. How would you decide which to fix first?

Ans: The one with the most unique customers affected

- b) Of the three types of information correlated to each problem (SLA, alarm, performance degradation) which would indicate the number of unique customers affected by the problem?

Ans: SLA information

- 4) You have found five problems with a cost level of 4 (and none more expensive). Three of these have 12 unique customers and one has 8. Of the three left over how would you decide which to fix first?

Ans: The one with the most unique network services affected.

- b) Of the three types of information correlated to each problem (SLA, alarm, performance degradation) where would you find the number of unique network services affected by the problem?

Ans: Performance Degradations

- 5) You have gone through your list of problems and found four that have the same number of unique customers and unique network services affected by the problem. What criteria would you use to decide which to fix first?

Ans: oldest!

- 6) Where is the root cause indicated?

Ans: Alarm or performance degradation information.

Appendix D: Tasks used to test the single and double window versions of the tabbing application, Problem Manager

Experimental Questions for the Unified Problem Manager (single)

This study is being conducted to evaluate two possible future designs of a Unified Problem Manager. I will be asking you to complete a series of tasks in both interfaces. I want you to know that I will be timing each task but this is not a race, work at the speed you normally do. It is important to realize that I am not testing you. I am testing the interface. I know it is not perfect and I want to make it better. After each task you will get a chance to rate it and you can tell me what you liked and disliked and how I can improve it. The details of the questions are on that paper and you can refer back to them. All information included in the questions must be used. As well, no keyboard shortcuts are provided in the prototype so use the mouse for all navigation between fields and for button pressing. This is an early prototype, undoubtedly there are some bugs Any questions?

1A) Tell me which problem is the least expensive?
5th problem

1B) For the same problem, tell me how many **unique** customers had their Service Level Agreements violated
4

1C) For the same problem, please tell me how many different types of network services are affected.
3

1D) Tell me how you would acknowledge the root cause of the problem.

5th PM

2A) Please tell me which problem or problems are the most expensive?

(1, 4, 6, 7, 10)..

2B) Of these five problems, which problem(s) have the most unique customers?

#6 and #10 each have 9 unique customers affected.

2C) Of these problems, which problem(s) have the most unique Network Service types?

both problems have 7 unique services affected.

2D) Please decide which problem should be fixed and acknowledge which node holds the root cause of the problem.

(#6) should be fixed first, acknowledging that the 22nd PM is the root cause. (364 StevensTN)

3A) In this next scenario you are still the Network Operator for Fault management but now you are specifically concerned with the following companies: Acura Canada, Air Canada, Boeing Canada, Campbell Soup and Clearnet Canada. So, when you are looking at the number of unique customers you are to focus on these. I want to point out that the data set may look similar but it is not!

Please tell me which problem or problems are the most expensive?

(2, 4, 5, 8, 9).

3B) Of these five problems, which problem(s) have the most unique customers?

#4 and #8 each have an equal number of key customers..

3C) Of these problems, which problem(s) have the most unique Network Service types?

#4 – 7

#8 - 6.

3D) Please decide which problem should be fixed and acknowledge which node holds the root cause of the problem.

(#4) should be fixed first, acknowledging that the 8th PM is the root cause. (1011 CleoATM)

Experimental Questions for the Unified Problem Manager (Double)

This study is being conducted to evaluate two possible future designs of a Unified Problem Manager. I will be asking you to complete a series of tasks in both interfaces. I want you to know that I will be timing each task but this is not a race, work at the speed you normally do. It is important to realize that I am not testing you. I am testing the interface. I know it is not perfect and I want to make it better. After each task you will get a chance to rate it and you can tell me what you liked and disliked and how I can improve it. The details of the questions are on that paper and you can refer back to them. All information included in the questions must be used. As well, no keyboard shortcuts are provided in the prototype so use the mouse for all navigation between fields and for button pressing. This is an early prototype, undoubtedly there are some bugs Any questions?

1A) Tell me which problem is the least expensive?

9th problem

1B) For the same problem, tell me how many **unique** customers had their Service Level Agreements violated

4

1C) For the same problem, please tell me how many different types of network services are affected.

3

1D) Tell me how you would acknowledge the root cause of the problem.

4th PM 364Steele

2A) Please tell me which problem or problems are the most expensive?

(2, 6, 8, 10)..

2B) Of these five problems, which problem(s) have the most unique customers?

#6 and #10 each have 9 unique customers affected.

2C) Of these problems, which problem(s) have the most unique Network Service types?

#6 – 7

#10 - 6

2D) Please decide which problem should be fixed and acknowledge which node holds the root cause of the problem.

(#6) should be fixed first, acknowledging that the 24nd PM is the root cause. (134 BaxterzRTR)

3A) In this next scenario you are still the Network Operator for Fault management but now you are specifically concerned with the following companies: Gifford Assoc, Hitachi, KPMG, Maytag and Nesbitt Burns. So, when you are looking at the number of unique customers you are to focus on these. I want to point out that the data set may look similar but it is not!

Please tell me which problem or problems are the most expensive?

(1, 3, 6, 7, 109).

3B) Of these five problems, which problem(s) have the most unique customers?

#6 and #10 each have an equal number of key customers..

3C) Of these problems, which problem(s) have the most unique Network Service types?

#6 – 7

#10 - 7.

3D) Please decide which problem should be fixed and acknowledge which node holds the root cause of the problem.

(#6) should be fixed first, because it is older acknowledging that the 22nd PM is the root cause. (364 Stevens)

Appendix E: Training materials for the scrolling application, Connection Manager

Connection Manager

- This application is a next-generation concept for connection management.
- This application will be used to establish connections for all service types; ATM, Optical, Frame Relay, Transport, Voice, and Internet Protocol.
- functionality will be tested for only two of the service types.
E.g. frame relay and transport

Features

1) Graphical view of end-to-end connection

- see the connection from the start node to the end node with all intermediary node.
- details such as whether a connections passes through specific nodes can be seen with this feature.
- Details such as Shelf, sub-shelf, slot and port are provisioned in the graphical area. Click on the endpoint node to add these details

2) Connection syntax

Form: #_FirstNode-LastNode_service type
Example: 2345_westminster-baxter_videoFac

3) Endpoint Definition

- the definition of a connection has been reduced to the shelf, sub-shelf, slot and port.
- e.g.

1-2 2 3

4) AutoRoute

- Clicking on the Auto Route button results in an automatic “draw” of the connection based on criteria set under an option menu
 - Assume they are preset for our purposes e.g. least hops.
- no need for manual “draw” of connection or route advisor. They have been integrated in the application in a single function.

Tasks

- Three major tasks involved:

1) new connections -

- name of connection
- name of customer
- endpoint details (within the graphic)
(e.g.) shelf, sub-shelf, slot and port for start and end nodes (done separately)
- AutoRoute

II) Edit existing connections -

- retrieve an existing connection from the database
- edit the parameters (e.g.) changing the name of the connection
- Apply (write) to the database
-

III) Read existing connections -

- retrieve an existing connection from the database
- collect connection details without making changes
(e.g.) Does a customer's connection goes through a specific node of interest.

Appendix F: Wall poster for the scrolling application, Connection Manager

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Features Reminder:

I) AutoRouter

II) Connection syntax

#_FirstNode-LastNode_service type
2345_westminster-baxter_videoFac

III) Simplified Connection Definition

shelf, sub-shelf, slot, port
1-2 2 11

IV) Click on endpoint node to provision (details)

Appendix G: Knowledge assessment questions for the scrolling application, Connection Manager

- 1) Could you please tell me what each part of the following connection name is indicating? 2673_George-Patrick_videoFac
*Ans: 2673 - connection number
George - start node
Patrick - end node
videoFac - service type*
- 2) What is the benefit of being able to view a connection from end to end?
Ans: allows for increased analysis of details such as whether a connection runs through a specific node.
- 3) What does the following indicate?
1-2 3 11
Ans: Shelf 1, sub-shelf 2, slot 3 and port 11
- 4) What is the autoroute function used for?
Ans: Drawing connections!
- b) When would it be used?
Ans: When creating a new connection
- 5) What are the steps that need to be taken to create a new connection?
Ans: Specify the connection name, specify the customer name, specify endpoint details (shelf, sub-shelf etc), autoroute.

Appendix H: Tasks used to test the single and double window versions of the tabbing application, Connection Manager

Experimental Questions for the Unified Connection Manager (single)

This study is being conducted to evaluate two possible future designs of a Unified Problem Manager. I will be asking you to complete a series of tasks in both interfaces. I want you to know that I will be timing each task but this is not a race, work at the speed you normally do. It is important to realize that I am not testing you. I am testing the interface. I know it is not perfect and I want to make it better After each task you will get a chance to rate it and you can tell me what you liked and disliked and how I can improve it. The details of the questions are on that paper and you can refer back to them. All information included in the questions must be used. As well, no keyboard shortcuts are provided in the prototype so use the mouse for all navigation between fields and for button pressing. This is an early prototype, undoubtedly there are some bugs Any questions?

- 1) Retrieve the connection for Sears Canada between NE WestATM02 and NE TownATM02.

*There are a few connections for Sears between these two nodes with different service types. Please find the Sears connection b/w these two nodes with the service type "videoRoute" and change the priority of the connection from 1 to 3.
(Note: Little Scrolling)*

- 2) Retrieve the connection for Bank of Montreal between NE BankTN03 and NE CanalTN01.

*There are a few connections for BoM between these two nodes with different service types. Please find the Sears connection b/w these two nodes with the service type "Backbone" and change the priority of the connection from 1 to 4.
(Note: Lots of Scrolling)*

- 3) What connection starts on shelf 1, sub shelf 2, slot 3, port 2
Kernel-Pon_localPath

- 4) What connection starts on shelf 1, sub shelf 2, slot 2, and port1 (1-2-2-1)
(Note: Little Scrolling)
4287_Park-By_dataRoute

- 5) Does the connection go through node "BartonTN03"
yes

- 6) Node HarrisonATM21 is being taken offline for testing! Please find all customers on this node and assess whether your two largest customers Air Canada and Toyota are affected.
(Note: Lots of Scrolling)
Yes, Toyota

- 7) There is a problem that may be affecting service between nodes "WellingtonTN01" and "DalTN31". It is thought that the problem resides on node "LarsonTN01". Our most important customer, "General Motors" may have connections between the nodes and their traffic must be protected. Assess whether their connections run through node "LarsonTN01"?
2 and 4

Experimental Questions for the Unified Connection Manager (Double)

This study is being conducted to evaluate two possible future designs of a Unified Problem Manager. I will be asking you to complete a series of tasks in both interfaces. I want you to know that I will be timing each task but this is not a race, work at the speed you normally do. It is important to realize that I am not testing you. I am testing the interface. I know it is not perfect and I want to make it better. After each task you will get a chance to rate it and you can tell me what you liked and disliked and how I can improve it. The details of the questions are on that paper and you can refer back to them. All information included in the questions must be used. As well, no keyboard shortcuts are provided in the prototype so use the mouse for all navigation between fields and for button pressing. This is an early prototype, undoubtedly there are some bugs. Any questions?

1) Retrieve the connection for Esso between NE EastATM04 and NE LakeATM12. *There are a few connections for Esso between these two nodes with different service types. Please find the Esso connection b/w these two nodes with the service type "videoPath" and change the priority of the connection from 1 to 4.*
(Note: Little Scrolling)

2) Retrieve the connection for Holt Renfrew between NE MountainTN11 and NE ViewTN31. *There are a few connections for Holt Renfrew between these two nodes with different service types. Please find the Holt Renfrew connection b/w these two nodes with the service type "dataFac" and change the priority of the connection from 1 to 5.*
(Note: Lots of Scrolling)

3) Which connection is on 2-1 2 1 1

stein-welty_tarriFFac

4) What connection starts on shelf 2, sub shelf 1, slot 2, and port2 (2-1 2 2)

(Note: Little Scrolling)

Microcel Solutions

5) Does the connection go through node "CandyTN05"

yes

6) Node FrancoATM32 is being taken offline for testing! Please find all customers on this node and assess whether your two largest customers Starbuck's and Hudson's Bay are affected.

(Note: Lots of Scrolling)

Yes, Starbucks

7) There is a problem that may be affecting service between nodes "CarsonTN23" and "FrontTN14". It is thought that the problem resides on node "GateTN17". Our most important customer, "Time-Warner" may have connections between the nodes and their traffic must be protected. Assess whether their connections run through node "GateTN17"?

2 and 4

Appendix I: Order of presentation tables for the tabbing application, Problem Manager

Table 1

First order (single-double) versus second order (double-single) results for time to perform tasks.

	<u>Task - 1</u>		<u>Task - 2</u>		<u>Task - 3</u>		<u>Total Time</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
First	78.80	45.75	239.43	76.56	201.58	69.16	519.82	147.65
Second	58.47	63.70	214.17	57.62	190.42	30.51	463.08	120.78
F(1,6) *	0.37		0.29		0.11		0.41	
η^2	0.06		0.05		0.02		0.06	

*F-Obtained for the between-subjects comparison of first order vs. second order in a mixed factorial design that also included the within subjects manipulation of window design.

Table 2

First order (single-double) versus second order (double-single) results for number of errors.

	<u>Task - 1</u>		<u>Task - 2</u>		<u>Task - 3</u>		<u>Total Errors</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
First	1.25	0.96	1.62	1.12	1.00	1.11	3.87	1.98
Second	0.62	0.95	0.62	0.66	0.37	0.54	1.62	1.70
F(1,6) *	1.60		8.73		2.14		5.12	
η^2	0.21		0.59		0.26		0.46	

*F-Obtained for the between-subjects comparison of first order vs. second order in a mixed factorial design that also included the within subjects manipulation of window design.

Table 3

First order (single-double) versus second order (double-single) results for ease of use ratings.

	<u>Task - 1</u>		<u>Task - 2</u>		<u>Task - 3</u>		<u>Mean Ease Ratings</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
First	2.22	1.08	2.87	2.40	2.68	1.64	2.59	1.39
Second	1.28	0.28	1.75	0.81	1.84	0.87	1.62	0.62
F(1,6) *	3.02		1.85		0.83		1.64	
η^2	0.33		0.23		0.12		0.21	

*F-Obtained for the between-subjects comparison of first order vs. second order in a mixed factorial design that also included the within subjects manipulation of window design.

Appendix J: Interaction graphs of window design and order of presentation for the tabbing application, Problem Manager

Figure 1: Interaction of window design (single or double window) and order of presentation for task 1 on the dependent variable time.

Figure 2: Interaction of window design (single or double window) and order of presentation for task 2 on the dependent variable time.

Figure 3: Interaction of window design (single or double window) and order of presentation for task 3 on the dependent variable time

Figure 4: Interaction of window design (single or double window) and order of presentation for all tasks on the dependent variable total time.

Figure 5: Interaction of window design (single or double window) and order of presentation for task 1 on the dependent variable errors made.

Figure 6: Interaction of window design (single or double window) and order of presentation for task 2 on the dependent variable errors made.

Figure 7: Interaction of window design (single or double window) and order of presentation for task 3 on the dependent variable errors made.

Figure 8: Interaction of window design (single or double window) and order of presentation for all tasks on the dependent variable total errors made.

Figure 9: Interaction of window design (single or double window) and order of presentation for task 1 on the dependent variable ease of use ratings.

Figure 10: Interaction of window design (single or double window) and order of presentation for task 2 on the dependent variable ease of use ratings.

Figure 11: Interaction of window design (single or double window) and order of presentation for task 3 on the dependent variable ease of use ratings.

Figure 12: Interaction of window design (single or double window) and order of presentation for all tasks on the dependent variable total ease of use ratings.

Appendix K: Order of presentation tables for the scrolling application, Connection Manager

Table 1

First order (single-double) versus second order (double-single) results for time to perform tasks.

	Task - 1		Task - 2		Task - 3		Task - 4		Task - 5		Task - 6		Task - 7		Total Time	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
First	100.06	45.44	128.76	67.64	38.10	29.86	15.54	11.13	14.86	5.84	69.70	19.66	107.26	25.74	474.05	162.49
Second	75.03	35.93	91.24	25.26	16.98	6.28	18.76	14.18	9.03	2.87	52.16	24.27	99.74	34.28	362.97	105.65
F*	0.90		2.57		2.33		0.16		3.81		1.16		0.19		1.47	
η^2	0.13		0.30		0.28		0.03		0.39		0.16		0.03		0.19	

*F-Obtained for the between-subjects comparison of first order vs. second order in a mixed factorial design that also included the within subjects manipulation of window design.

Table 2

First order (single-double) versus second order (double-single) results for number of errors.

	Task - 1		Task - 2		Task - 3		Task - 4		Task - 5		Task - 6		Task - 7		Total Errors	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
First	0.12	0.25	0.37	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.79
Second	0.25	0.50	0.87	0.92	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.25	0.25	0.25	1.50	1.23
F*	0.43		1.04		-		-		-		1.00		3.00		2.40	
η^2	0.07		0.15		-		-		-		0.14		0.33		0.29	

*F-Obtained for the between-subjects comparison of first order vs. second order in a mixed factorial design that also included the within subjects manipulation of window design.

Table 3

First order (single-double) versus second order (double-single) results for ease of use ratings.

	<u>Task - 1</u>		<u>Task - 2</u>		<u>Task - 3</u>		<u>Task - 4</u>		<u>Task - 5</u>		<u>Task - 6</u>		<u>Task - 7</u>		<u>Total Ease</u>	
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>
First	2.62	0.89	2.75	1.11	2.25	1.00	1.75	0.99	1.50	0.73	2.00	0.96	2.37	0.77	2.17	0.61
Second	2.12	0.54	2.12	1.33	1.50	0.41	1.37	0.25	1.25	0.29	2.00	0.73	2.75	0.86	1.87	0.29
F*	1.04		1.06		2.08		0.69		0.43		0.00		0.57		0.99	
η^2	0.15		0.15		0.26		0.10		0.07		0.00		0.09		0.14	

*F-Obtained for the between-subjects comparison of first order vs. second order in a mixed factorial design that also included the within subjects manipulation of window design.

Appendix L: Interaction graphs of window design and order of presentation for the scrolling application, Connection Manager

Figure 1: Interaction of window design (single or double window) and order of presentation for task 1 on dependent variable time.

Figure 2: Interaction of window design (single or double window) and order of presentation for task 2 on dependent variable time.

Figure 3: Interaction of window design (single or double window) and order of presentation for task 3 on dependent variable time.

Figure 4: Interaction of window design (single or double window) and order of presentation for task 4 on dependent variable time.

Figure 5: Interaction of window design (single or double window) and order of presentation for task 5 on dependent variable time.

Figure 6: Interaction of window design (single or double window) and order of presentation for task 6 on dependent variable time.

Figure 7: Interaction of window design (single or double window) and order of presentation for task 7 on dependent variable time.

Figure 8: Interaction of window design (single or double window) and order of presentation for all tasks combined on dependent variable total time.

Figure 9: Interaction of window design (single or double window) and order of presentation for task 1 on the dependent variable errors made.

Figure 10: Interaction of window design (single or double window) and order of presentation for task 2 on the dependent variable errors made.

Figure 11: Interaction of window design (single or double window) and order of presentation for task 3 on the dependent variable errors made.

Figure 12: Interaction of window design (single or double window) and order of presentation for task 4 on the dependent variable errors made.

Figure 13: Interaction of window design (single or double window) and order of presentation for task 5 on the dependent variable errors made.

Figure 14: Interaction of window design (single or double window) and order of presentation for task 6 on the dependent variable errors made.

Figure 15: Interaction of window design (single or double window) and order of presentation for task 7 on the dependent variable errors made.

Figure 16: Interaction of window design (single or double window) and order of presentation for all tasks on the dependent variable total errors made.

Figure 17: Interaction of window design (single or double window) and order of presentation for task 1 on the dependent variable ease of use ratings.

Figure 18: Interaction of window design (single or double window) and order of presentation for task 2 on the dependent variable ease of use ratings.

Figure 19: Interaction of window design (single or double window) and order of presentation for task 3 on the dependent variable ease of use ratings.

Figure 20: Interaction of window design (single or double window) and order of presentation for task 4 on the dependent variable ease of use ratings.

Figure 21: Interaction of window design (single or double window) and order of presentation for task 5 on the dependent variable ease of use ratings.

Figure 22: Interaction of window design (single or double window) and order of presentation for task 6 on the dependent variable ease of use ratings.

Figure 23: Interaction of window design (single or double window) and order of presentation for task 7 on the dependent variable ease of use ratings.

Figure 24: Interaction of window design (single or double window) and order of presentation for all tasks on the dependent variable total ease of use ratings.