Designing and Evaluating Glanceable Peripheral Displays

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ABSTRACT
Peripheral displays are an important class of applications that improve our ability to multitask. Increased knowledge on how to design and evaluate glanceable peripheral displays can lead to better support for multitasking. We will contribute a set of guidelines for designing glanceable peripheral displays, using the wealth of abstraction techniques (*e.g.,* change detection, feature extraction), design variables (*e.g.,* color, shape), and design characteristics (*e.g.,* dimensionality, symbolism) available. We will contribute an evaluation framework that clearly defines peripheral displays, metrics for evaluating their success, and guidelines for selecting evaluation methods. These contributions will improve peripheral displays that enable users to manage multiple tasks through low-effort monitoring.

Keywords: Peripheral displays, information visualization, glanceability, abstraction, multitasking, interface design

ACM Classification Keywords: H5.2 *User Interfaces*– Graphical user interfaces. H5.m *Miscellaneous*.

INTRODUCTION
Peripheral displays are an important class of applications that improve our ability to multitask. Information workers often balance many interruptions and tasks. A recent study found that information workers kept an average of 10 "working spheres," or basic units of work, active at once, spent as little as 3 minutes (on average) on a task before switching, and were interrupted at least once per task [1]. Because peripheral displays convey information in a low-attention way outside of a focal task, they can be used to show secondary task information. Figure 1 shows examples. In a lab study of these designs, we show that task-relevant information can be highly valuable to multitasking performance since its allows users to monitor tasks that have temporarily been set aside, to determine the most appropriate time to switch tasks, and to aid in the reacquisition of paused tasks [2]. Further, designs like those in Figure 1a perform best because they make the most relevant task information visible and easier to understand. The goal of this thesis is to inform the design of displays like the task management application in Figure 1. We believe that improving the glanceability of these displays will enable more efficient multitasking.

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However, existing literature on peripheral displays suffers from a lack of consistent terminology that has slowed design and evaluation progress. This proposed thesis presents a common terminology and meaning for peripheral displays derived from an Activity Theory analysis. This common ground enables us to derive design goals and evaluation guidelines for peripheral displays.

With this foundation, we propose a series of studies to inform the design of glanceable peripheral displays. First, we interview designers to explore the glanceability of design variables (derived from a literature survey). Next, we explore three abstraction techniques in the lab, determining which technique most improves multitasking performance. Finally, we are planning two studies to empirically measure the glanceability of abstract representations with different design characteristics. Psychology literature on signal detection suggests that distinctness is key to absolute judgment of stimuli, but there are limits (roughly, 7 plus or minus 2, according to classic work by Miller [4]). We hypothesize that as numbers of information mappings increase, symbolic representations will become more important. Expected results include finding a sweet spot between symbolic and simple representations that enables both easy interpretation and perception. Our goal is to design studies that increase knowledge of glanceable design.

PROPOSED THESIS SCOPE
In existing literature, *peripheral display* has been used to describe a variety of different applications. In this proposed thesis we study a subset of peripheral displays that are visual and graphical (*i.e.,* we are not specifically targeting auditory, tangible, or olfactory applications).

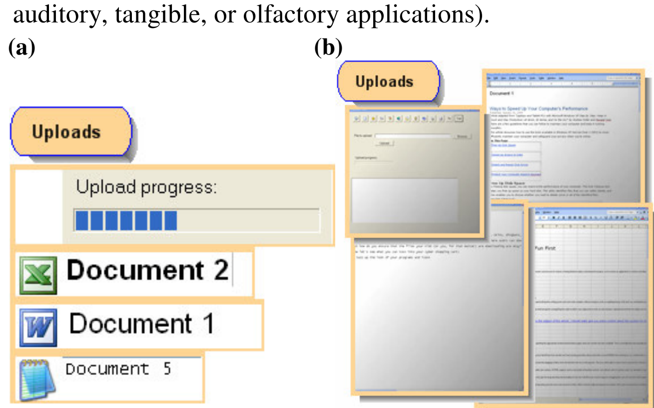

Figure 1: An example of different task cluster designs for the Scalable Fabric task management system [2]: (a) clippings of task-relevant information; (b) scaled versions of task windows.

Our exploration of glanceability does not include issues of interruption or attention capture. Glanceability refers to the perception and interpretation of information *after* the user is paying attention to the interface. Attention capture refers to the process of attracting the user's attention away from their focal task (*e.g.,* using techniques like abrupt onset, flashing, and other motion). Thus glanceability and attention capture are issues that can be studied largely independently.

Finally, we will study *glancing*, not *peripheral vision*. Though users may be able to interpret some of our representations with peripheral vision, optimizing for this is not our goal. Rather, we focus on optimizing for *glancing* at non-primary displays with focal vision.

INTERVIEWING PERIPHERAL DISPLAY CREATORS

The major challenges in creating peripheral displays lie in their design and evaluation, a fact emphasized in interviews with ten peripheral display creators that we conducted as a basis for this thesis. Interview participants were from 8 institutions, including 3 designers, 3 implementers, and 4 who were both. Interviewees highlighted the interdependent issues of needing increased design knowledge and better early stage evaluation to select from many design options:

> "I think it's frustrating because there are so many options for designing the information. Literally in some instances, there are millions of options and you're never going to be able to systematically test all of those."

The studies presented in this proposed thesis begin to solve these problems by investigating glanceable design: comparing abstraction techniques and empirically measuring the glanceability of design variables.

ACTIVITY THEORY ANALYSIS OF PERIPHERAL USE

Hindering our ability to discuss peripheral display design is the inconsistent terminology involved in existing literature. Inconsistencies were evident in interviews with peripheral display creators, who disagreed whether they should or should not interrupt users. One said, "I would argue a peripheral display should be for peripheral information. If there is something that needs to be seen… it should be on [a different] display that is used to get your attention." Another contradicted: "That was what [peripheral] displays were doing in general; they were alerting people… When data arrives they bring themselves to the forefront."

Our Activity Theory analysis of peripheral displays explores their use, leading to a definition: peripheral displays are *tools* used primarily at the *operation* level (*i.e.,* their usage requires relatively low cognitive cost) [3]. We then derive a framework for evaluating peripheral displays, including metrics, design characteristics that effect evaluations, and guidelines for selecting methods.

Our analysis leads to core design goals: that the display is glanceable and non-interruptive. Glanceability is particularly important because it can improve our ability use a display operationally (*i.e.,* with little cognitive effort). We explore how to design glanceable displays in the following studies.

INTERVIEWING DESIGNERS ABOUT GLANCEABILITY

To begin to answer the question, how do we design glanceable peripheral displays, we interviewed experienced designers, discussing a taxonomy of design variables we derived from a literature survey. The designers revealed qualities of glanceable displays: they use abstraction, are distinct, match user expectations, and maintain consistency. However, it is still unknown what abstraction methods (*i.e.,* methods of reducing information and/or transforming it to a representative form) and design characteristics lead to the best glanceability, questions addressed in the next studies.

IMPROVING MULTITASKING EFFICIENCY WITH DESIGN

A major application of peripheral displays is to support users as they monitor non-primary tasks and switch between tasks. Many studies have investigated how people balance multiple tasks [1]. Several core concepts from multitasking literature can be supported by peripheral displays: maintaining primary task *flow*, monitoring secondary tasks to determine when to *resume* or switch back to tasks, and *reacquiring* tasks upon switching to them.

In order to determine what abstraction methods will improve multitasking performance for information workers (if any), we conducted an empirical study of three abstraction methods: showing task-relevant information (Figure 1a), change detection, and scaling (Figure 1b) [2]. Results show that task-relevant information gives the most benefit and that task-relevant information plus change detection adds slightly more benefit. The study also shows that peripheral displays can positively impact task flow, resumption, and reacquisition.

EMPIRICALLY MEASURING GLANCEABILITY

To address the research question, what design characteristics lead to the best glanceability, we plan to conduct two empirical studies to measure the glanceability of peripheral email displays with different characteristics. The characteristics of information representations we study are *symbolism* (*i.e.,* ability to convey meaning), *dimensionality* (*i.e.,* the number of visual variables used; or visual complexity), and the *entity* shown to convey meaning (*e.g.,* situations/ideas, objects, or people). Our studies are designed to gather information about several qualities of these characteristics: perceptibility (*i.e.,* the ease in which a visual is recognized), interpretability (*i.e.,* the ease in which the visual's meaning is identified), memorability (*i.e.,* how well the visual enables recall of its meaning), and aesthetics (*i.e.,* the attractiveness of the visual).

The first study compares the speed and ease of user *interpretation* of abstract representations (and text) they have never seen. The expected result is that symbolic representations will lead to faster and easier interpretation. Results will enable us to determine what dimensionalities and entities lead to more interpretable representations.

The second study compares the speed and ease of user *perception* and *interpretation* of representations (and text) they have been trained to identify. We will vary the number of information items mapped to representations (3, 6, 9) to test when users switch from using perceptive capabilities to using cognitive capabilities, and what representations lead to the fastest item identification.

We hypothesize that symbolic representations will be critical to glanceability as the number of abstract mappings increases. For fewer abstract mappings, simplicity of representations will be most important, reducing the need for symbolism. We also hypothesize that memory for abstract representations with few dimensions will be lower in multitasking situations than in single-task situations (for which Miller provides a rough limit of 7 ± 2 [4] – rough because it depends on stimulus, memory abilities, time of day, stress, and so on). For abstract representations with many dimensions, we hypothesize that users will interpret them as a Gestalt (*i.e.,* a single stimulus) and the precise number of dimensions will be less relevant to their glanceability than the use of those dimensions to create a meaningful, discriminable visualization.

In short, we hypothesize that there is a sweet spot between symbolism and dimensionality. Conveying lots of meaning with complex visuals may not be as effective as conveying *just enough* meaning in a *simple way*. With results of our combined experiments, we will be able to discuss the conflict between the need to convey meaning and to maintain simple visuals for glanceability, and make recommendations for designers.

CONTRIBUTION, STATUS, AND FUTURE WORK

We will contribute a clear foundation for discussing peripheral displays and set of guidelines for designing and evaluating glanceable peripheral displays. Our design guidelines will help designers use the wealth of abstraction techniques (*e.g.,* change detection, extracting relevant information, scaling), design variables (*e.g.,* color, shape), and design characteristics (*e.g.,* dimensionality, symbolism, entities shown) available. Our evaluation framework will include a clear definition of peripheral displays, metrics for evaluating their success, and guidelines for selecting evaluation methods.

The work proposed here is complete except the last two empirical studies measuring interpretation and perception of representations with different design characteristics, which are in planning phases. The initial research points to future work, including studying glanceability in the field (*i.e.,* replicating results in a natural usage environment); gathering design knowledge about creating *non-interruptive,* dynamic displays that maintain multitasking productivity; and applying design knowledge gathered in this work to different peripheral display applications.

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