GRADED AND MULTIMODAL INTERRUPTION CUEING IN SUPPORT OF PREATTENTIVE REFERENCE AND ATTENTION MANAGEMENT

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A decade ago, attention management was considered by some "the least explored frontier in cognitive science and human-machine cooperation" (Woods et al., 1994). Today, at least one aspect of attention management – interruption handling – still poses a major challenge for the design of human-machine systems and computer-supported collaborative work. Successful interruption management requires that both unintentional dismissals and preemptive integrations of interruption signals are avoided (Latorella, 1999). One means of achieving this goal is to support preattentive reference, i.e., the processing of interruption signals that occurs before attentional selection. Operators need to be provided with at least partial information about the nature and cognitive requirements of a potential interruption, and this information should be presented in a way that allows for peripheral access. This paper will discuss and illustrate how currently underutilized graded and multimodal information presentation could help accomplish this goal and support various stages of the overall interruption management process.

INTRODUCTION

A decade ago, attention management, i.e., “the dynamic prioritization and allocation of attentional resources to several parallel threads of activity” (Woods, 1995), was considered by many "the least explored frontier in cognitive science and human-machine cooperation" (e.g., Woods et al., 1994). Today, at least one aspect of attention management – interruption handling – still poses a major challenge for the design of human-machine systems and computer-supported collaborative work. Operators in complex event-driven domains still struggle with prioritizing and scheduling tasks and associated competing attentional demands. Their efforts result in various forms of interruption management behavior that were laid out by Latorella (1998, 1999) in her interruption management stage model (IMSM): a) oblivious dismissal (interruption not detected), b) unintentional dismissal (significance of interruption signal not interpreted correctly), c) preemptive integration (interruption task immediately started and completed, thus intruding on ongoing task), d) intentional dismissal (interruption correctly interpreted; deliberate decision not to perform interruption task), and e) intentional integration (interruption and ongoing task considered as set and integrated by operator).

The first three behaviors – oblivious and unintentional dismissals as well as preemptive integration - are symptoms of a breakdown in task and interruption management whereas intentional dismissals and intentional integration are desirable responses that should be - but rarely are - supported through information and interface design. This paper will discuss, and give examples of, the use of graded and/or multimodal interruption signals for supporting preattentive reference and attention management.

THE PROCESS OF INTERRUPTION MANAGEMENT

Figure 1 lays out the various steps involved in handling an interruption. It illustrates that interruption management can break down for a variety of reasons at various stages of this process. For example, an interruption signal may co-occur in parallel with another cue of greater importance or higher salience and may therefore be missed altogether. Even if the signal is being perceived, it is not necessarily informative and does not, by itself, support the critical step of judging the relative importance and feasibility of handling the interruption immediately, in parallel with current tasks, or in a delayed fashion. Uninformative signals thus create a paradox: they force users to interrupt ongoing tasks, orient their attentional focus towards the interruption to gather more information about its nature and requirements, only to decide whether they should have interrupted the ongoing task in the first place (Woods, 1995).

To overcome this problem, more informative interruption cues are needed that can be processed preattentively to learn about relevant aspects of the interruption, such as its source, urgency or modality. The need for supporting preattentive reference has been acknowledged by many researchers; yet, surprisingly few efforts have been made to develop effective means of achieving this goal and thus avoid unintentional dismissals as well as preemptive integration. Instead, the focus has often been on identifying and counteracting the negative consequences of these two forms of breakdown in interruption management.

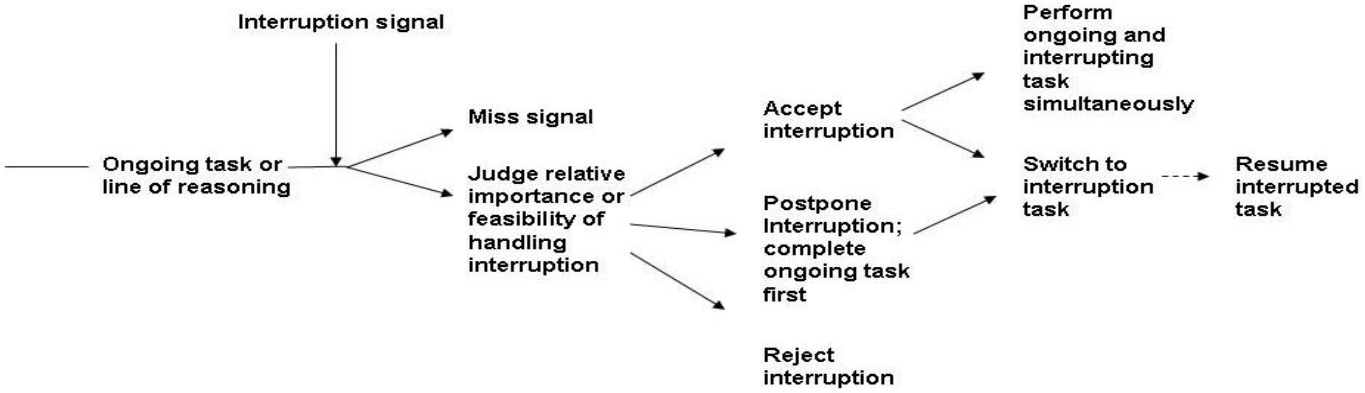

Figure 1. The Process of Interruption Management

INFORMATIVE INTERRUPTION CUEING AND PREATTENTIVE REFERENCE

A recent study in our laboratory has examined the benefits of informative interruption cueing (Ho et al., 2003, 2004). In this study, 48 participants who performed a visually demanding air traffic control task were randomly assigned to three experimental groups that differed with respect to the availability of information (not available, available upon request, available automatically) about the urgency and modality of pending interruption tasks. The modality, frequency, and priority of these tasks varied within subjects. The findings from this study show that information about the nature of pending tasks was highly valued and quickly accessed and processed by participants in the "available upon request" condition. All participants delayed visual interruption tasks the longest in order to avoid intramodal interference and scanning costs associated with performing the visual task concurrently with their ATC tasks. The group that automatically received task-related information showed better ATC performance and thus a net performance gain.

One shortcoming of the approach taken in Ho et al.'s work is that, in all cases, information on the nature of the pending task was presented in visual form, thus requiring at least a brief re-orientation of attention away from the ongoing visual air traffic control task. A more appropriate approach would be to distribute information across sensory channels and thus allow for peripheral access and support preattentive reference, i.e., the preattentive evaluation of an interruption signal. The term 'preattentive processing' was first used in the visual attention literature where it refers to the automatic processing of the entire visual field with the goal to detect basic features of objects, such as colors, contrast, or size (Treisman, 1986) and determine which objects should undergo further processing (Broadbent, 1977; Neisser, 1976).

Applying this concept to attention management in the context of human-machine interaction, Woods (1995) outlined the following criteria for preattentive reference: attention-directing signals need to a) be picked up in parallel with ongoing tasks and activities, b) provide information on the significance and meaning of the interruption, and c) allow for evaluation that does not require focal attention. Supporting preattentive reference is critical for achieving a high level of flexibility in the scheduling of tasks (e.g., Hess and Detweiler, 1994; Lee, 1992) and for giving operators ultimate control over when to handle interruptions (Obermayer and Nugent, 2001). Yet, few effective means of supporting preattentive reference have been developed and/or tested to date. Three promising candidates – 1) the use of non-traditional information channels (such as touch), 2)

graded information presentation, and 3) the design of ambient displays – will be discussed in the following section.

MULTIMODAL AND GRADED INFORMATION PRESENTATION IN SUPPORT OF PREATTENTIVE REFERENCE

Earlier research (for example Latorella, 1999; Wickens and Horrey as part of this symposium) has acknowledged the importance of modality information and effective modality usage as part of a successful interruption management interface. For example, Latorella's (1998, 1999) work on interruption management on commercial flight decks investigated the influence of the modality (visual versus auditory) of interrupting and interrupted tasks on pilot performance and strategies. Her results confirm the expected performance benefits of cross-modality conditions (e.g., a visual task should be easier to perform concurrently with an auditory task than with another visual task), the more compelling nature of auditory interruptions, and the high level of resistance to interruptions of ongoing auditory tasks.

Most research in the area of interruption management to date has focused on the visual and auditory channel. Other modalities, such as touch, have received little attention. One of the few studies to examine the usefulness of the underutilized tactile modality for coordinating attentional demands was recently conducted by Ho and Sarter (2005). These authors investigated multimodal computer-supported collaborative work in the context of simulated battlefield operations. Participants in this research were allowed to employ the visual, auditory, and tactile modalities based on their needs and preferences. The authors observed that participants preferred to use tactile patterns (in the form of vibrotactile cues that were presented to participants' wrists) for indicating critical events that required a reliable and immediate response or action (e.g., NBC alerts or the initialization of an ambush).

One reported reason for this preference was that these rarely employed cues were the least likely to be missed due to intra- or crossmodal interference and could be picked up in parallel with ongoing tasks and activities. Other media, such as written messages, were reserved primarily for items that could be attended in a delayed fashion.

This study also explored the use of graded notifications, i.e., notifications that consist of signals that are proportional to the degree of urgency of an interruption and/or vary over time in terms of their intensity. For example, participants in this study commented that varying the numbers of tactile "buzzes" (in this case, 2 versus 4 buzzes) and the amplitude of tactile cues were effective ways of indicating the urgency of a message.

Another earlier study on the use of graded feedback proposed the use of so-called likelihood alarm displays (Sorkin, Kantowitz, and Kantowitz, 1988). With this display, the likelihood of an event is computed by an automated monitoring system and encoded in an alerting signal. For example, an operator may be informed that a system failure is possible, probable, or certain. Under high workload conditions, this information is more effective than traditional binary alarm signals in helping operators decide whether and when to interrupt ongoing tasks to attend to the problem without imposing undue attentional demands.

The use of graded feedback is useful not only when first notifying the user of a pending task or interruption. It is also a powerful means of updating the user in a data-driven fashion on changes in the urgency of a delayed interruption. This potential benefit was examined in a recent study on the design of warning systems by Lee et al. (2004). The authors presented graded collision warning signals to participants in the context of a driving simulation. The results from this study show that graded warnings provided a greater safety margin. Graded warnings did not lead to habituation. They induced fewer inappropriate responses to nuisance alarms, drivers trusted the graded warnings more, and there was no indication of increased annoyance associated with the greater number of alerts produced by this notification strategy.

Finally, preattentive reference can be supported through the design of so-called ambient displays. Ambient displays present information through subtle changes in light, sound, movement, and other dimensions, which are assumed to be processed without conscious awareness. This information is usually presented somewhere in the space surrounding the user, rather than trying to integrate it with already limited traditional visual display space. Ambient displays serve to inform the user about background events and activities, such as the presence of others or the dynamic changes in the processing level of a system, without requiring focused attention.

CONCLUDING REMARKS

In many domains, the increasing need for interacting and collaborating with a growing number of human and machine agents is likely to create challenges for attention and interruption management. One prerequisite for addressing these challenges is to develop informative interruption cues and support preattentive reference. In this paper, we argue that multimodal and

graded interruption cues are a promising but underutilized means of achieving this goal. The paper will present recent research findings that support this claim and propose further candidates for this approach.

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