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Behavioral performance and visual attention in communication multitasking: A comparison between instant messaging and online voice chat ☆

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A B S T R A C T

Participants carried out a visual pattern-matching task on a computer while communicating with a confederate either via instant messaging (IM) or online voice chat. Communicating with a confederate led to a 50% drop in visual pattern-matching performance in the IM condition and a 30% drop in the voice condition. Visual fixations on pattern-matching were fewer and shorter during the communication task and a greater loss of fixations was found in the IM condition than the voice condition. The results, examined within a threaded cognition framework, suggest that distributing the work between the audio and visual channels reduces performance degradation. Implications for media literacy and distracted-driving are discussed.

1. Introduction

Communication multitasking is becoming a way of life. In a recent national survey, 76% reported using instant messaging (IM) and 80% reported using telephone while working on other computer tasks (Carrier, Cheever, Rosen, Benitez, & Chang, 2009). Defined as using a communication medium or channel to accomplish a goal while simultaneously being engaged in another task with a different goal (Jeong & Fishbein, 2007; Meyer & Kieras, 1997; Ophir, Nass, & Wagner, 2009), communication multitasking has implications on human cognition (Ophir et al., 2009), work performance (Hembrooke & Gay, 2003; Wang & Tchernev, in press), and media campaigns (Voorveld, 2011).

Multitasking through text and voice communication is common while working on a computer (Carrier et al., 2009) and the effects of multitasking in the workplace has received attention. While some studies have examined the interruptive nature of IM (Cameron & Webster, 2005; Renneker & Godwin, 2003), it has been found that IM is perceived to be less disruptive compared to phone (Garrett & Danziger, 2007). Despite the attention on IM, to our knowledge, IM and voice communication have not been directly compared in multitasking situations. Therefore, in this study we examine performance on a visual task when participants are in synchronous communication via IM or online voice chat on a different task. In addition, our choice of IM and voice chat was motivated by theoretical interests on the allocation and management of cognitive resources when two tasks rely heavily on the visual modality in comparison to tasks that are distributed between the visual and auditory modalities (e.g., Basil, 1994; Grimes, 1991; Lang, 2000). In addition to task performance, real-time eye movement data were examined to explore visual attention while communication multitasking.

2. Multitasking theories

The success of multitasking depends on the nature of the tasks and the criteria used to assess performance. For example, texting or talking on the phone when driving has been shown to affect driving performance. On the other hand, playing the guitar and singing can enhance overall performance of a talented musician. In general, however, dual or multiple tasks have been found to impair performance on specific cognitive tasks in laboratory settings, under conditions of explicit or implicit time pressure (e.g., Consiglio, Driscoll, Witte, & Berg, 2003). Two theoretical accounts have been advanced to explain performance deterioration in multitasking—central bottleneck and capacity limitation.

2.1. Central bottleneck theory

The central bottleneck theory (Welford, 1952) posits a pervasive, immutable, "hardware" limitation in human information

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processing and consequently, when two tasks require immediate responses, they have to be placed in a queue. Though central bottleneck has been criticized for being overly rigid, it offers a parsimonious account for a vast array of findings (see Meyer et al., 2002, pp. 102–105), notably the findings from the Psychological Refractory Period (PRP) paradigm. In the typical PRP experiment, two stimuli are presented within a second (100–1000 ms) of each other and the response time to each stimulus is examined. Researchers have found that as the duration between the two stimuli decreases (<330 ms), the time to react to the second stimulus increases and the time to reach to the first stimulus is spared. Furthermore, response time to the second stimulus is not affected by the match or mismatch in modalities between stimulus and response (see Pashler, 1994 for a review). A processing bottleneck or a serial processing mechanism that cannot perform two concurrent tasks is one explanation for the slower response time to the second stimulus. However, when the duration between the tasks increases, say to a half-second or more, the processor is adept at switching between tasks seamlessly and the bottleneck is not noticeable.

2.2. Resource theory and limited capacity

Resource theory, or capacity theory, offers an alternative to the central bottleneck explanation (Kahneman, 1973). According to resource theory, only when the demands of concurrent tasks exceed available resources, a loss in performance is expected. While the central bottleneck relies entirely on a serial processing explanation, resource theory allows for parallel processing together with an executive function or cognitive control mechanism to manage the resources (Meyer et al., 2002). The executive function allocates available resources strategically to different modalities to maximize performance (e.g., Basil, 1994; Lang, 2000). In essence, the executive function serves as a resource manager by allocating resources and initiating routines to accomplish a task and reclaiming resources upon completion of the task.

A variant of resource theory is multiple resources theory (Wickens, 2002). As the name suggests, this theory is premised on multiple resource pools, thus enabling simultaneous or parallel processing of multiple tasks. The extent to which resources can be allocated from one pool without taxing the other is an important area of research and Wickens (2002) has offered a preliminary framework on the limits of multiple resources. In summary, despite the availability of multiple resources for parallel processing, certain tasks create bottlenecks in cognition that limit multitasking performance. An integrated model that accounts for both parallel processing and bottlenecks in multitasking is discussed next.

2.3. Threaded cognition

The key feature of threaded cognition (Salvucci & Taatgen, 2008) is the instantiation of multitasking goals as different goal threads. Each thread has access to different resource pools—perceptual, motor, cognitive-declarative, and cognitive-procedural. In threaded cognition, all resources can operate in parallel with the exception of the cognitive-procedural resource, which manages the other resources, but can process only one task at a time. Though the procedural resource is comparable to the executive function, the authors point out that it is more dispersed and qualitatively different. However, the procedural resource is a bottleneck in threaded cognition and when multiple tasks vie for this resource, they are processed serially.

Perceptual and motor processes, however, can work in parallel to accomplish a sub-goal or sub-task. When one of the resources, for example, the visual perceptual resource, is in use by a thread, that resource is not accessible to other threads. However, the motor resource may be available to perform a mouse-click operation as long that operation does not require the visual perceptual resource. As soon as an operation is completed, the resources used by that operation become available for subsequent operations in the same thread or different threads. If the visual operation in one thread and the mouse-click operation in another thread compete for access to the procedural resource, they can only be processed sequentially because the procedural resource is a serial processor.

Therefore, for the multitasking scenario examined in this study, threaded cognition suggests: (1) multiple goals can be maintained as threads; (2) threads can swap resources as necessary; and (3) while perceptual, motor, and declarative cognitive resources are available for access as separate resources pools, once a thread has accessed a resource, the other threads have to wait for their turn until the resources are released by the previous thread. The model has been used in computational modeling of multitasking behaviors and has been found to offer an adequate account of behavioral data including distracted driving (Salvucci & Taatgen, 2008).

Next, threaded cognition is applied to the two tasks used in the current study. One is a pattern-matching task, which requires encoding and comparing two 3×3 (9-cell) grids and a mouse click to indicate whether the girds are a match or mismatch. The other involves offering directions to a confederate by clicking on hyperlinks and communicating information via IM or online voice chat. The directions task was set up as a split-screen in the bottom half of the window (see Fig. 1). About half of the participants used an IM window to communicate directions to a confederate and the other half used hands-free voice chat to communicate.

Based on the theory of threaded cognition, a hypothetical resource allocation storyboard of the multitasking scenario is shown in Fig. 2. The storyboards are presented from the standpoint of how resources can be allocated optimally while the participant is waiting for the confederate to initiate a request for directions. Comparing the top storyboard (voice chat) to the bottom storyboard (IM chat) in Fig. 2, two critical bottlenecks (shaded gray in Fig. 2) are apparent: (1) early in the cycle when the confederate's request has to be processed, the pattern-matching task can be carried out in parallel in the voice chat condition, but not in the IM condition because visual perceptual resources are in use when reading the text-based request for directions; (2) the other delay is toward the end of the cycle, with a longer waiting period in the IM condition because both the visual and motor resources are tied up during the process of the typing out directions in the form of a text message. Resource constrictions remain longer in the IM condition because both the receiving (encoding the request for directions) and the sending (typing the directions) of information involve visual resources, thus limiting access to these resources required for the pattern-matching thread.

Using threaded cognition as the foundation, two hypotheses were tested in this study. Performance on the pattern-matching task will be better in the absence of a rivaling task that requires allocation and management of visual and procedural resources. Moreover, in the multitasking condition, performance will be better when directions are offered via voice chat than via IM because of less competition for demands on visual resources.

Hypothesis 1 Performance on the visual pattern-matching task will be better in the single-task condition than in the multitasking condition.

Hypothesis 2 When the visual pattern-matching task and the directions task are pursued concurrently, performance on the visual pattern-matching task will be worse in the IM condition than in the voice chat condition.