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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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ABSTRACT

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.

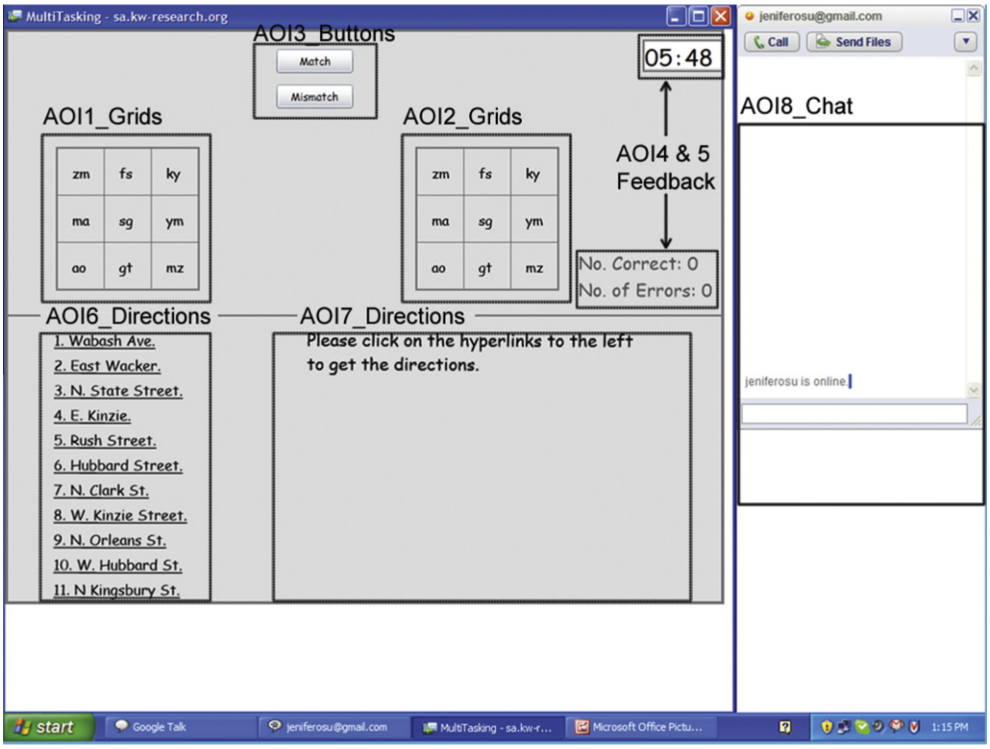

Fig. 1. Screenshot of the task interface and the eight Areas of Interest (AOIs). Note: AOIs 1–5 were of interest during both the single-task and multitasking phases. AOIs 6–8 were of interest only during the multitasking phase. During the single-task phase, areas of 6–8 were a blank screen.

As explained above, the performance on the pattern-matching task depends mainly on visual resources and to a small extent on motor resources for a mouse click. Further, we have argued that competition for visual resources is the reason for the deteriorated performance in the IM condition in Hypothesis 2. To test overt visual attention to the tasks in our study, real-time eye fixation was used as the key outcome (Duchowski, 2007; Rayner, 1998; Wickens & McCarley, 2008).

Hypothesis 3 Less visual attention (indicated by eye fixations) will be allocated to the pattern-matching task because of competition from the directions task.

Hypothesis 4 When the visual pattern-matching task and the directions task are pursued concurrently, less visual attention (indicated by eye fixations) will be allocated to the pattern-matching task in the IM condition than in the voice chat condition.

3. Method

3.1. Experimental design, procedures, and participants

A 2 (Task: Single, Multi) $\times$ 2 (Communication mode: IM, Voice) mixed design was used, with task as a within-individual factor and communication mode as a between-individual factor. Thirty-two students from a large Midwestern university participated in the study for course extra-credit and monetary bonus. They were between 20 and 26 years of age ($M = 21.72$, $SD = 1.57$) and 62.5% were female. On average, participants took between 30 and 40 min to complete the experiment.

Upon arrival at the lab, informed consent was sought and the participant was assigned randomly to one of the two communication modes: IM (using Google Chat) or voice chat (using Google Talk with headphones and an attached microphone). Then the participant filled out a pre-test questionnaire on a computer, which was administered through MediaLab (Jarvis, 2008). The questionnaire included measures on preference for multitasking, the Extraversion personality scale, familiarity with communication technologies like IM and online voice chat, and demographics. After the pre-test, the participant moved to an adjacent room with ASL Eye-Trac 6 data acquiring system coupled with the ASL D6 desk-mounted optics. During the single-task phase, the participant completed the visual pattern-matching for 2 min. Immediately after this, the participant began a 6-min multitasking phase, which involved working on the pattern-matching task and at the same time offering directions to a confederate via IM or voice. Eye movement data were acquired during the single-task and the multitasking phases. Finally, a post-test questionnaire with self-assessments of performance and a recognition memory test on details of the conversation with the confederate was administrated using MediaLab software.

3.2. Manipulation and materials

3.2.1. The visual pattern-matching task

Each trial brought up a pair of 3 $\times$ 3 grids and each cell in the grid was populated with a 2-digit number or a 2-letter string. Participants were asked to compare the corresponding cell entries between the two grids and judge whether these two grids were a "Match" or "Mismatch" by clicking a button on the screen with a computer mouse. The two grids were judged as a match when all cells were exactly the same in both grids. In the mismatched grids, only one of the nine cells was different. Further, in half of the trials, the cell entries were numbers; in the other half, they were letters. The letter and number entries for each cell were randomly generated by a customized computer program and whether a particular trial involved numbers or letters also was determined randomly.

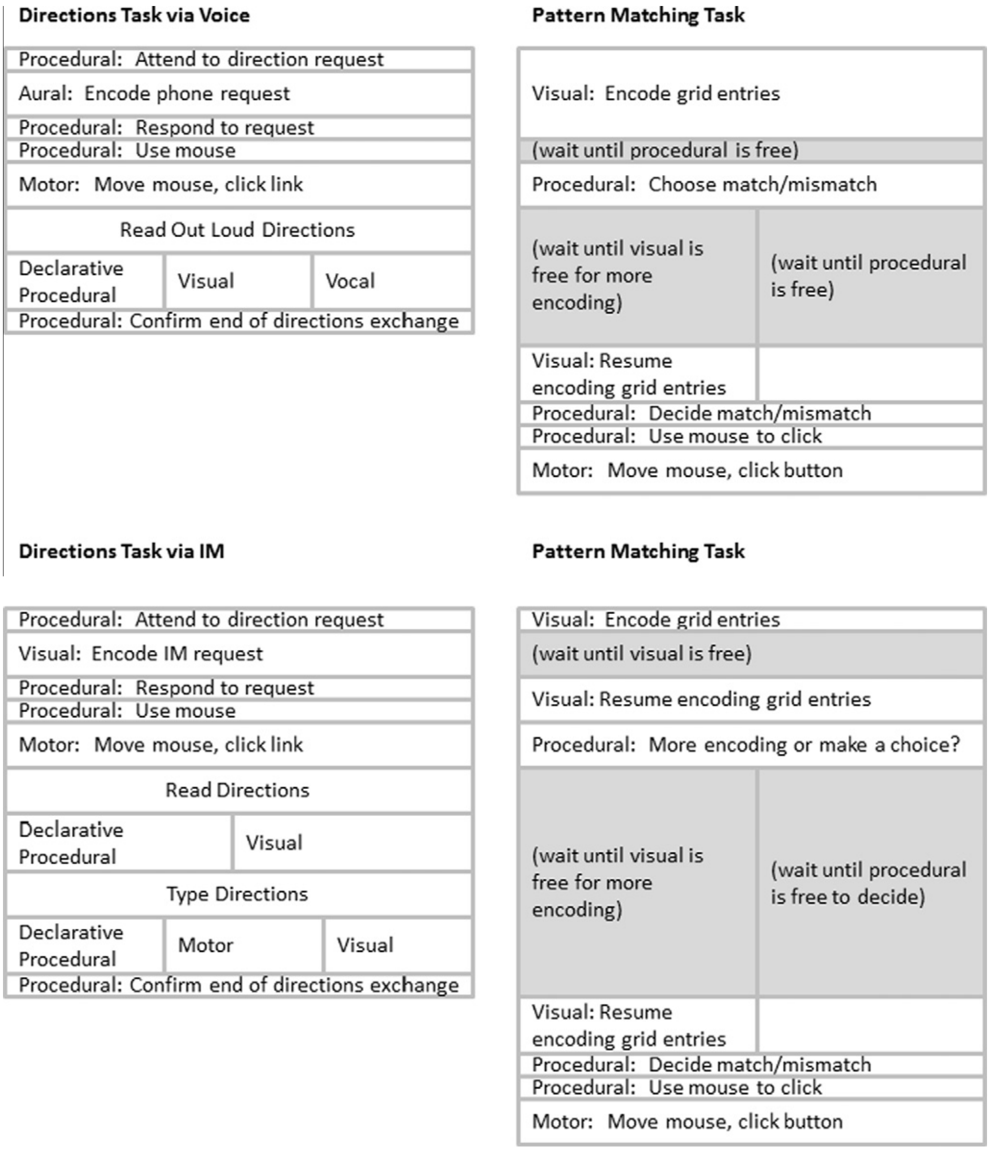

Fig. 2. Storyboard presentations of multitasking with voice chat (top panels) and with IM (bottom panels) based on the threaded cognition theory. Note: in the multitasking IM condition, waiting periods are longer during the typing of responses to the confederate because visual resources are tied up.

During the baseline single-task phase, participants were asked to complete as many Match/Mismatch trials as possible within the allotted time of 2 min. Upon every response, the computer provided feedback by updating the number of trials attempted and the number of correct answers achieved. Throughout the task, a countdown clock showed the remaining time in minutes and seconds (see Fig. 1).

3.2.2. The directions task

The cover story was that a college student (the confederate) was within walking distance to a coffee shop in Chicago and needed to arrive on time for an important job interview. To ensure motivation and attention to both tasks, participants were instructed to focus on completing as many matching trials as possible and at the same time do their best to help the confederate reach the destination within the allotted time of 6 min. To encourage equal attention to both tasks, students were offered a $10 gift card to a department store as an incentive if they were in the top 20% based on the sum of their performances on both tasks. After the experimenter helped establish the contact with the confederate via IM or voice chat, the participant clicked a button on the computer to start the multitasking phase.

As shown in Fig. 1, the directions were presented in the bottom half of the computer screen in the form of hyperlinks labeled as street names. Clicking a hyperlink provided the directions on how to get from one street to the next street. Participants were given 11 hyperlinks to guide the confederate to the destination and the typical conservation between the confederate and the participant unfolded as follows:

- *Confederate*: I see E. Kinzie, what do I do now?
- *Study participant*: Turn right onto E. Kinzie St. Go.1 mile.

The confederate was trained to initiate similar requests 11 times over the course of the multitasking phase. In between requests for directions, the confederate would offer filler material from a script to liven up the conversation. For example, the confederate would say, "These dress shoes are killing me," or "This city smells bad. Why do all cities smell bad?" or "I am going to miss this interview and live in my grandma's basement the rest of my life." These quips were evenly distributed throughout the chat and were assessed using a recognition memory test in the post-test.

The multitasking phase was identical in the IM and voice conditions with the exception of the mode of communication. In the voice condition, participants used a headset and microphone, essentially freeing up their hands to use the mouse to click the Match/Mismatch button. In the IM condition, the participant used the keyboard to type into a chat window and at the same time used the mouse to click the Match/Mismatch button for the matching task.

3.3. Confederates

Three graduate students were trained as confederates. To control for social cues, the confederate's identity was concealed and the same account name was used in both IM and voice conditions. In both conditions, the conversation provided by the confederates was strictly scripted. In the voice condition two female native English speakers played the role of confederate. At the end of the multitasking phase, the confederate immediately evaluated the participant on three items: the number of steps completed by the participant (up to 11 steps), and friendliness and promptness of the participant.

3.4. Measures

3.4.1. Preference for multitasking

Four items were used to assess self-perceptions about multitasking, which were rated on a 7-point scale (1 = *strongly disagree*, 7 = *strongly agree*). Items included "I think of myself as a multitasker," "when using a computer I tend to multitask," "I can get more things done when I multitask," and "I multitask whenever possible." Internal consistency of these items was acceptable (Cronbach's $\alpha = .88$) and the items were averaged to create a composite score.

3.4.2. Extraversion

Some researchers have suggested that extraversion can affect communication multitasking performance (Lieberman & Rosenthal, 2001). Four items from the Big Five Inventory (John, Naumann, & Soto, 2008) were used to measure extraversion. Items included "I see myself as someone who is talkative", "generates enthusiasm", "has an assertive personality", and "is outgoing and sociable". These items were rated on 5-point scale (1 = *disagree strongly*, 5 = *agree strongly*). The average of the four items was used as a measure of extraversion (Cronbach's $\alpha = .79$).

3.4.3. Assessment by confederate

Immediately after finishing the directions task, the confederate evaluated the participant on friendliness and promptness using a 9-point scale (1 = *not at all*, 9 = *extremely*).

3.4.4. Self-assessment

Participants were asked to provide a self-assessment of how well they performed. They were asked to indicate their agreement to the following statements using a 7-point scale (1 = *strongly disagree*, 7 = *strongly agree*): "I did a nice job on the visual comparison game;" and "I did a nice job on the directions task."

3.4.5. Recognition

To examine attention to the directions task, a quiz with eight multiple-choice questions was created to test memory for various details from the scripted conversation. For example, a question asked, "What did Jennifer say was her fate if she were to miss her meeting?" The choices were: (A) Live in my grandma's basement the rest of my life, (B) Be poor the rest of my life, (C) Not get this job, and (D) Serve coffee the rest of my life. The correct answer was A.

3.4.6. Eye fixations

Fixations represent "eye movement that stabilizes the retina over a stationary object of interest" and indicate "voluntary, overt visual attention" (Duchowski, 2007, pp. 46–47). The fixation algorithm employed by ASL is based on dwell-time detection (Karsh & Breitenbach, 1983; Lambert, Monty, & Hall, 1974). A minimum of 100 ms gaze without any gaze position change larger than 1° was used to identify a fixation. Frequency of fixations, total duration of fixations on assigned areas of interest, and the average duration of fixations on areas of interest over the course of the single and multitask phases were used as measures of overt visual attention (Rayner, 1998; Wickens & McCarley, 2008).

Eight Areas of Interest (AOIs) were defined as shown in Fig. 1. Five AOIs were related to the matching task: the two grids, the Match/Mismatch buttons, the clock, and the score. The remaining three AOIs focused on the directions task: hyperlinks to directions, directions after clicking a hyperlink, and the chat window used to convey directions to the confederate in the IM condition.

For each AOI, three metrics were computed. First, the frequency of fixations in an AOI was divided by the total number of fixations during the task phase to generate a percentage of fixations for that AOI. Higher percentage suggests greater overt visual attention. Second, duration of fixations was computed by summing the durations of the fixations within each area and dividing by the total duration of all fixations. Third, the average duration per fixation was computed by dividing the sum of the durations within an AOI and dividing by the frequency of fixations. Longer average duration of fixation indicates greater visual attention or tendency against moving the eyes away from the AOI (Duchowski, 2007).

Various diagnostics were used to determine accuracy of the eye fixation data. Eye fixation data were not included in the analysis when we detected calibration failure or the inability of the system to track the pupils for reasons such as excessive head movement or dirty contact lens (Duchowski, 2007). Eye movement data from 7 participants in the IM condition and 10 in the voice condition were used in data analysis. Those whose eye movement data were included and excluded were compared on other measures and no significant differences were found.

4. Results

We began by analyzing individual differences between experimental conditions. No significant differences were observed for preference for multitasking, extraversion, and experience with communication technologies.

4.1. Matching task performance

The baseline response rate for pattern-matching trials was computed, which was defined as the number of accurate responses registered per minute during the single-task phase. Likewise, the performance rate while multitasking was obtained by computing the number of accurate responses per minute during the multitasking phase. The incorrect response rate also was computed and found to be quite low (<1 per min) in all conditions and was not analyzed. See Table 1.

The rate of correct responses from the single-task and multitasking phases were analyzed using a 2 (Task: Single, Multi) × 2 (Mode: IM, Voice) repeated measures ANOVA with task as the repeated measure. There were a significant main effect of task, $F(1, 31) = 192.04$, $p < .001$, partial $\eta^2 = .86$, and a significant Task × Mode interaction effect, $F(1, 31) = 13.16$, $p < .005$, partial $\eta^2 = .30$.

Table 1
Performance measures for matching task, *M* (*SD*).

	Single task		Multitask	
	IM $n = 15$	Voice $n = 17$	IM $n = 15$	Voice $n = 17$
Avg. correct responses/min[a,b]	10.87 (1.67)	10.50 (1.93)	5.44 (1.91)	7.33 (2.01)
Avg. incorrect responses/min	.47 (.53)	.59 (.83)	.36 (.35)	.53 (.51)
Self-assessment of performance[c]	–	–	6.44 (.73)	5.06 (1.52)
	$n = 7$	$n = 10$	$n = 7$	$n = 10$
% Fixations (AOI 1 and 2)[a,b]	77.00 (12.55)	75.71 (12.47)	23.69 (17.96)	40.25 (18.30)
% Fixation dur. (AOI 1 and 2)[a,b]	74.34 (13.23)	74.69 (11.30)	20.92 (17.18)	39.59 (18.50)
Avg. fixation dur. (AOI 1 and 2)[a]	.25 (.03)	.27 (.02)	.21 (.05)	.24 (.05)

[a] Main effect of task ($p < .05$).
[b] Interaction effect of task × communication mode ($p < .05$).
[c] Main effect of communication mode ($p < .005$). AOI 1 and 2 were the critical areas of interest related to the matching task as shown in Fig. 1. Avg. fixation duration is in seconds.

Table 2
Performance measures for the directions task, *M* (*SD*).

	IM $n = 15$	Voice $n = 17$
Steps completed in directions task***	6.91 (2.92)	10.82 (.61)
Promptness***	5.75 (2.38)	8.71 (.59)
Friendliness	6.00 (3.67)	7.59 (2.43)
Recognition of conversational details	4.31 (1.20)	5.00 (1.41)
Self-assessment of performance	5.81 (1.17)	5.41 (1.62)
	$n = 7$	$n = 10$
% Fixations (AOIs 6 and 7)	24.18 (13.46)	27.35 (13.70)

*** $p < .001$. Total directions steps = 11. Promptness and friendliness were assessed on a 9-point scale, higher is better. Recognition memory was measured with eight multiple-choice questions. AOIs 6 and 7 were the AOIs related to the directions task as shown in Fig. 1. Self-assessment was measured on 7-point scale, higher is better.

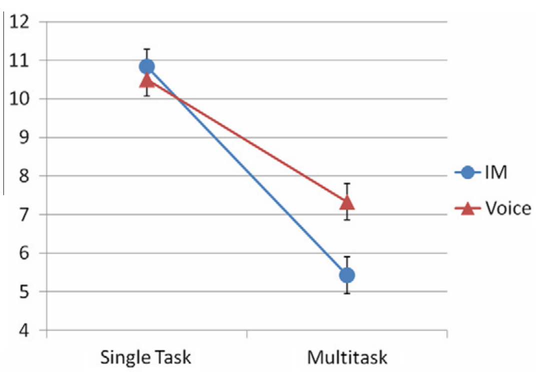

Fig. 3. Mean of correct responses per minute for matching task.

The interaction was examined in detail with three planned *t*-tests. A paired *t*-test revealed that in the IM condition, correct responses in the single-task phase ($M = 10.87$, $SD = 1.67$) was more than those in the multitasking phase ($M = 5.44$, $SD = 1.91$), $t(15) = 10.08$, $p < .001$. A similar pattern was observed in the voice condition as well ($M_{single} = 10.50$, $SD = 1.93$; $M_{multi} = 7.33$, $SD = 2.01$), $t(16) = 9.75$, $p < .001$. The deterioration in performance under both conditions supports Hypothesis 1. In addition, an independent sample *t*-test confirmed a greater drop in performance in the IM condition ($\Delta = 5.43$, $SD = 1.91$) than in the voice condition ($\Delta = 3.17$, $SD = 2.01$), $t(31) = 2.83$, $p < .01$. This interaction effect supports Hypothesis 2 which predicted lower performance in the IM condition compared to the voice condition (see Fig. 3).

4.2. Directions task performance

Performance on the directions task was compared between the IM and voice conditions (see Table 2). Participants in the voice condition completed more steps ($M = 10.82$, $SD = .61$) than those in the IM condition ($M = 6.91$, $SD = 2.92$), $F(1, 31) = 29.24$, $p < .001$, partial $\eta^2 = .49$. Also, the rating of participants' promptness by the confederate was higher in the voice condition ($M = 8.71$, $SD = .59$) than in the IM condition ($M = 5.75$, $SD = 2.38$), $F(1, 31) = 24.66$, $p < .001$, partial $\eta^2 = .44$. No differences were found in perceived friendliness by the confederate, recognition memory for conversations, and self-assessment of performance on the directions task.

4.3. Eye fixations

Eye fixations on AOIs involved in the directions task (AOIs 6 and 7 in Fig. 1) were examined and no differences were found between the IM and voice conditions, which suggests that overt visual attention dedicated to clicking on the direction links and reading the directions was similar across the two conditions. Next, eye fixations allocated to the IM Chat window (AOI 8 in Fig. 1) was examined. In the voice condition, the IM Chat window was largely ignored. In the IM condition, 14.94 percent ($SD = 10.30$) of the visual fixations during the multitasking phase were devoted to AOI 8, which was the chat window. In the next step, we examined how the allocation of fixations to the directions and IM Chat window (AOIs 6, 7 & 8) affected performance on the visual pattern-matching task (AOIs 1, 2).

4.3.1. Fewer and shorter fixations during multitasking

Hypothesis 3 predicted that during multitasking, the directions task would compete and draw visual attention away from the matching task. This was supported by both fixation frequency and duration data. The percentage of fixations on the matching grids was analyzed using a 2 (Task: Single, Multi) × 2 (Mode: IM, Voice) repeated measures ANOVA. As predicted, a main effect of task was found, $F(1, 15) = 123.09$, $p < .001$, partial $\eta^2 = .89$. The percentage of fixations on the grids decreased from 76.24 ($SD = 12.12$) percent during the single task to 33.43 ($SD = 19.49$) percent during multitasking. A similar pattern was found for fixation duration. Total fixation duration on the matching grids decreased from 74.54 ($SD = 11.72$) percent during the single-task to 31.90 ($SD = 19.82$) during multitasking, $F(1, 15) = 100.02$, $p < .001$, partial $\eta^2 = .87$. In addition, the average fixation duration was shorter ($M = 224$ ms, $SD = 47$) during multitasking than that during the single task ($M = 259$ ms, $SD = 22$), $F(1, 15) = 8.33$, $p < .05$, partial $\eta^2 = .36$.

4.3.2. Greater loss of fixations when multitasking via IM than via voice chat

Hypothesis 4 predicted that visual attention to the matching task would suffer more in the IM condition than in the voice condition. The repeated measures ANOVA on percentage of fixations on the matching grids yielded a significant Task × Mode interaction, $F(1, 15) = 4.98$, $p < .05$, partial $\eta^2 = .25$. As reported above,

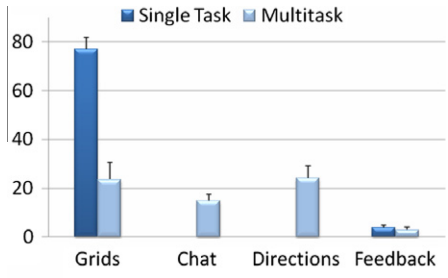

Fig. 4a. Percentage of fixations on AOIs in the IM condition.

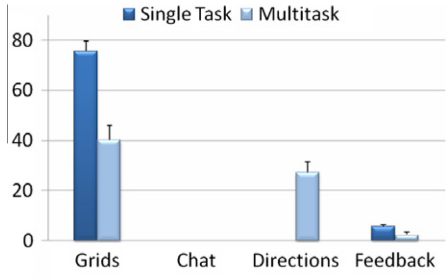

Fig. 4b. Percentage of fixations on AOIs in the voice condition.

for both communication modes, the percentage of fixations decreased from the single-task to the multi-task condition; this decrease, as predicted, was greater in the IM (53.1%) than in the voice condition (35.46%) (see Figs. 4a and 4b, and Table 1). A similar pattern was evident for the percentage of duration, $F(1, 15) = 4.28$, $p = .056$, partial $\eta^2 = .22$, which was tending toward significance at $p < .06$. However, the Task × Mode interaction was not significant for the average fixation duration on the two grids ($F < 1$).

5. Discussion

Though it is widely perceived that multitasking saves time, some tasks take longer under multitasking situations (e.g., Bowman, Levine, Waite, & Gendron, 2010) and task performance suffers when more than one task has to be accomplished within a limited amount of time. The results from this study support this understanding. A significant drop in performance in visual pattern-matching was found when a communication task was carried out concurrently, with a greater drop among those who communicated via IM than those who communicated via voice chat. Using a storyboard version of a threaded cognition model, we hypothesized that the greater loss in performance in the IM condition may be because of the competing demands on the visual perceptual resources of both tasks. Eye fixation data supported this hypothesis with fewer and shorter eye fixations on the pattern-matching grids during IM communication than voice communication.

Performance on the communication task also was examined. No statistically significant differences were found between IM and voice for fixations and duration in the areas of interest for the directions task. However, promptness of response and the number of steps completed were significantly better in the voice chat condition than the IM condition. For other outcomes, including friendliness, recognition of conversational details, and self-assessment of performance on the communication task, no significant differences were observed.

Interestingly, in spite of the poorer performance in the IM condition on both the pattern-matching task and the directions task, the self-assessments of participants in the IM condition indicated that they performed better. Perhaps it was the sense of control to respond to IM messages without being hurried that was perceived as an advantage, or more positive experience. Indeed, evidence for such delayed responses in IM can be seen in lower ratings of promptness by the confederates in IM communication. Another possibility is that processing multiple streams of information in the visual channel may allow for the *illusion* of efficiency more readily than in other modalities. Individuals may perceive visual tasks as relatively effortless (Lang, Potter, & Bolls, 1999), which may explain the tendency to combine tasks like driving and texting or watching television while doing homework (e.g., Bowman et al., 2010). This illusion highlights the importance of a new dimension of media literacy concerning optimal use of media technologies to increase work productivity and ensure machine operation safety. For example, according to the National Safety Council (2010), 25% of all car crashes can be attributed to drivers using cell phones. Considering the greater danger involved in texting while driving and the increasing popularity of texting using cell phones, larger educational efforts on multitasking literacy are warranted.

Resource theory has been the dominant framework in communication research. Much of this literature has focused on processing of television messages in which information is streamed simultaneously via audio and visual channels. Although resource theory is ideal for such synchronous processing of the audio and video in real time, communication in multitasking contexts is a more deliberate task with opportunities for strategic allocation of resources. Threaded cognition offers an alternative in which "streams of thought can be represented as threads of processing coordinated by a serial procedural resource and executed across other available resources (e.g., perceptual and motor resources)" (Salvucci & Taatgen, 2008, p.101). In this study, we have demonstrated how threaded cognition can be applied to strategic allocation of resources in a multitasking situation involving a complex communication task.

Threaded cognition provides an account of human ability to juggle two or more tasks. By maintaining a number of goal threads and strategically allocating resources, threaded cognition suggests that it is possible to juggle two or more tasks, albeit with performance tradeoffs. Performance in these multitasking situations depends in large part on the definition of success, the tasks involved, the context of the task, and the level of motivation to succeed in the different tasks involved. Except for some critical activities, such as driving, the immediate loss in performance from multitasking or task-switching may be gained somewhere down the line, and humans are faced with challenges of the optimal distribution of resources to achieve the best outcomes. How we optimize resources allocation when multiple tasks compete for our attention at the same time is an exciting area for research.

Particularly, communication researchers can contribute to the designing of communication technologies that improve the outcomes of resources allocation during multitasking. For example, complex dynamic tasks themselves, such as driving, can be viewed as multitasking. Monitoring traffic, monitoring directions, monitoring speed, steering, and shifting gears can be considered as multiple threads, which can be overwhelming to new drivers. Having a passenger help with the monitoring tasks eliminates a few competing threads and can be quite helpful (Salvucci & Taatgen, 2008). Similarly, the global positioning system (GPS) technology assists driving by partially freeing up recourses needed for the directions thread. Based on findings in this study, in most situations, using GPS voice guidance should be preferred over GPS image guidance because aural resources are available to the directions thread while visual resources are occupied by threads of monitoring traffic and speed.

If additional tasks, such as texting and talking on phone, are conducted while driving, they increase the number of required threads. Based on our findings, with the same communication content, texting is expected to have a worse impact on the driving task than talking on phone because it demands simultaneous use of visual resources and motor resources. In general, to improve driving safety, innovative communication technologies and automobile designs should consider ways to eliminate threads or free up resources required by the driving task and needed communication tasks while driving.

Limitations of this study include the small sample size and the lack of eye-movement for almost half of the participants. However, it should be noted that no differences were observed on the behavioral outcomes between those for whom eye movement data were usable and not usable. Another limitation is the use of student samples, which limits the extrapolation of the results to a general population. Future research should address these limits. In addition, creating consistency in conversation and experimental manipulations during the directions task was a challenge, which was handled through training of the confederates and the use of a scripted dialogue. It is worthwhile to invest efforts to design more innovative methods to achieve external validity as well as consistent experimental control.

In spite of these limitations, this study demonstrates the use of a threaded cognition theoretical approach to communication multitasking research. One of the key findings was the poorer performance in the IM condition, which seemed to be caused by competition for visual resources that was evident from the fewer eye fixations. Future research should inquire further into differences in capacity between visual and aural processing, as well as differences in how individuals perceive their capacities for processing in these two modes. Threaded cognition theory does not distinguish between the capacities of various perceptual modalities, but treats these perceptual pools as having equivalent capacities that are expandable and limited in the same ways. Communication research on competing modalities—both in television viewing and communication multitasking—suggest that people frequently overestimate and overtax their capacity to process visual information, especially in combination with other tasks. With the proliferation of visually-based mediated communication such as emailing, text-messaging, and video communication, research on visual multitasking will become increasingly important.

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