# Conversation Disrupts Visual Scanning of Traffic Scenes

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## 1. Introduction

It is well documented that the ability to effectively scan a visual scene is modulated by the perceptual and cognitive demands of the observer's search task, with increases in visual workload effecting changes to both overt attention, the eye movements made in searching the environment, and covert attention, the processing which occurs within the span of a single fixation of the eye (see Crundall, et al, 1998, for review). More poorly understood are the effects of non-visual workload on search and representation of the visual environment. Experimental data as well as everyday experience indicate that multiple-task performance is generally facilitated when input and output channels are distributed across perceptual modalities and response effectors (Wickens & Holland, 2000). Nonetheless, evidence demonstrates that cognitive interference can impair multiple-task performance even when structural interference—that is, competition for sensory mechanisms and response effectors (Kahneman, 1973)—is eliminated.

With the burgeoning popularity of in-vehicle technology, and in particular the growing use of cellular phones on the road, the consequences of cross-modal and cognitive interference for visual performance have become of increasing concern. Intuition, manifest in legislation banning only the use of hand-held cellular phones in vehicles, suggests that the effects of such technology on drivers' performance will be largely structural. Accumulating data, however, demonstrate that conversation alone, absent the demand to hold or manipulate any apparatus, can impair driver performance, delaying responses to sudden events, for example, and disrupting manual control (e.g., Strayer & Johnston, in press; Alm & Nilsson, 1995). Other studies provide indirect evidence that visual scanning of the environment may likewise suffer interference from the cognitive workload imposed by conversation. Recartes and Nunes (2000), for example, found changes in drivers' on-the-road saccadic behavior as a consequence of various secondary cognitive tasks, noting, among other effects, a decrease in fixation durations during performance of a verbal (word generation) task.

The aim of the present experiment was to examine the effects of naturalistic conversation on observers' scanning and consequent representation of visual scenes. Toward this end, observers were asked to perform a *change detection* task. Events in the visual environment commonly produce local transient signals that attract attention and ensure that meaningful changes to an observer's surroundings are perceived. When the transient produced by an event, however, is masked—for example by saccadic suppression (Grimes, 1996) or an occluder (Simons & Levin, 1998)—the event itself may go unattended and undetected. Changes within a scene can thus fail to reach awareness even when they occur seemingly in full view of an observer, a phenomenon known as *change blindness* (Simons & Levin, 1997). To avoid such perceptual failure and maintain situation awareness in a dynamic and complex environment, an observer must rely on attentive scanning, actively encoding objects and noting changes to them (Rensink, et al, 1997). An observer's ability to detect changes unaccompanied by attention-capturing transients therefore provides a functional measure of attentional scanning performance. Here, observers were asked to search for changes within complex traffic scenes, either while concurrently maintaining a conversation or under single-task control conditions. Of interest were the effects of conversation on observers' accuracy and speed of detection, and on saccadic behavior during search; past research, as described above, suggests that visual scanning may be disrupted by the workload imposed by conversation, and that change detection may concomitantly be impaired. Because previous studies have found that elderly subjects tend to suffer greater multiple-task interference than do younger subjects (e.g., Alm & Nilsson, 1995; Kramer et al., 1999), two age groups, one of relatively young observers and the other of older observers, were run.

## 2. Method

### 2.1 Participants

Fourteen younger observers, mean age = 21.43 years, and fourteen older observers, mean age = 68.43 years, participated. All participants were native English speakers, had corrected visual acuity of 20/40 or better, and had held a driver's license for at least one year prior to the date of testing.

### 2.2 Apparatus & Stimuli

Visual stimuli were presented on a 121.92 cm x 167.64 cm display (ImmersaDesk). Viewing distance was approximately 83.8 cm, though observers were free to move their heads. Eye movement data were recorded using an Applied Science Laboratories eye and head tracker (Model 501). Stimuli were pairs of photographs depicting urban and suburban traffic scenes as viewed from a driver's perspective. One image within each pair was unaltered, while the second was digitally modified to differ in a single detail from the first. Potential modifications included changes to the color, size, orientation, or location of an object, and the addition/removal of an object to/from the depicted scene.

### 2.3 Procedure

Observers performed a change detection task in an experimental procedure employing the flicker paradigm of Rensink, et al (1997). Each trial, the observer viewed a repeating cycle of four displays: an unaltered image (240 ms), a gray screen (80 ms), the modified version of the first image (240 ms), and another gray screen (80 ms). The observer's task was to detect and report the difference between the unaltered and altered images. The gray screens interposed between images served to mask local transients which changes would otherwise have produced, and thus to force attentional search of displays (Rensink, et al, 1997). Upon detecting a change, the observer made a button press on a joystick to terminate the stimulus, then described the detected change to the experimenter. Reaction time (RT) for the button press was recorded, and accuracy of the described change was noted. If an observer failed to detect a change after 60 seconds, the trial was terminated and the response was considered an error.

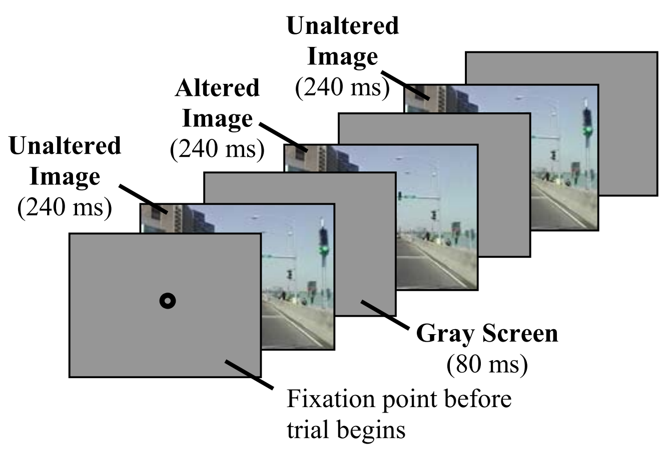


**Figure 1.** Stimuli and sequence of events within a typical trial. Note that traffic light visible at the far right of the unaltered image is absent from the altered image.

Each observer completed 40 single-task trials, involving only the change detection task, and 40 dual-task trials, which required the observer to perform the change detection task while conversing with a confederate. To discourage them from discussing the visual stimuli or modulating their pace of conversation in response to the difficulty of visual search, the observer and confederate were located in different rooms. The observer communicated with the confederate by speaking into a clip-on microphone, and by listening through speakers mounted below the visual display. Observers' conversations were therefore akin to hands-free cellular phone conversations. Dual-task trials began with the confederate initiating conversation. The experimenter began stimulus presentation after the participant had begun speaking (responses were timed from the beginning of stimulus presentation). Conversation continued until the target of search was located, or until the end of the 60 second period allotted for the trial. Conversations were casual, covering topics such as television shows and hobbies. Single- and dual-task trials were run in alternating blocks of twenty, with order of blocks counterbalanced across subjects. An experimental session began with five single-task practice trials.

### 2.4 Analysis

Eye-tracking data from trials on which the eye-tracker lost the subjects' gaze position for more than 5% of the duration of the trial were discarded. This resulted in a loss of data from approximately 3% of all trials. Error rate and RT data from these trials were retained. All eye movement and RT described below are for trials on which the observer responded correctly.

## 3. Results

Accuracy of performance was modulated by both age and task. Mean error rate for younger observers was 5.00% under single task conditions, 8.75% under dual-task conditions. Mean error rate for older observers was 21.79% under single-task conditions, 29.64% under dual-task conditions. Error rates were thus significantly higher for older than for younger observers, $F(1, 26) = 54.761$, $p < .001$, and more notably, were significantly higher under dual-task than under single-task conditions, $F(1, 26) = 16.264$, $p < .001$. The interaction of age by task failed to reach significance, $F(1, 26) = 2.036$, $p = .165$. The majority of errors were misses, on which the observer failed to detect any change prior to the end of the trial, rather than false reports of changes which were not actually present.

Surprisingly, though mean RTs were longer for older than for younger observers, $F(1, 26) = 82.651$, $p < .001$ (see also Pringle, 2000; Pringle et al, 2001), they did not differ significantly between dual- and single-task trials, $F(1, 26) = 1.518$, $p = .229$, nor did they evince a significant interaction of age by task, $F < 1$. Mean RT for younger observers was 10.35 seconds under dual-task conditions, 9.16 seconds under single-task conditions. Mean RT for older observers was 15.74 seconds under dual-task conditions, 15.55 seconds under single-task conditions. As such, while conversation led observers to miss changes more frequently, it did not appear to increase the length of time with which detected changes were found.

Eye tracking data illuminate these behavioral effects. Overall, gaze was fixed on or within one degree of the changing object at the time of the observer's response on 83% of all trials for younger observers and on 77% of all trials for older observers. Though this value was marginally smaller for older than for younger observers, $F(1, 26) = 3.186$, $p = .086$, it did not vary significantly as a function of task, nor did it evince an interaction of age and task, $F$'s < 1. Thus, as in earlier studies in which eye movements were monitored during change detection (Hollingworth, et al, 2000; Zelinsky, 2001), observers searched displays overtly and rarely executed a response while they were not fixating on or very near the changing object. Mean number of fixations per trial was significantly larger under dual-task than under single-task conditions, $F(1, 26) = 11.225$, $p = .002$. For younger observers, the mean number of fixations per trial was 20.17 under single-task conditions and 27.21 under dual-task conditions, for older observers, 39.65 under single-task conditions and 42.07 under dual-task conditions. Thus, as measured by the number of saccades necessary to detect and respond to the changing item, search was less efficient during conversation than otherwise. Given past evidence that extrafoveal information about the changing object's location can be used to guide fixation toward the target region (Hollingworth, et al, 2001; Zelinsky, 2001), this result suggests that one effect of conversation was to hinder attentional guidance and compromise saccade selectivity. Unsurprisingly, the mean number of fixations per trial was larger for older than for younger observers, $F(1, 26) = 83.804$, $p < .001$. The interaction of age by task, however, failed to reach significance, $F(1, 26) = 1.755$, $p = .197$.

Fixation durations were reliably shorter during conversation than under control conditions, $F(1, 26) = 16.469$, $p < .001$. For younger observers, mean fixation duration was 332 ms under single-task conditions, 301 ms under dual-task conditions. For older observers, mean fixation duration was 295 ms under single-task conditions, 262 ms under dual-task conditions. Thus, casual conversation produced changes in fixation durations similar to those effected by performance of a word generation task (Recartes & Nunes, 2000). Notably, the concurrent effects of the secondary task on numbers of fixations and on fixation durations together account in large part for the absence of a significant effect of task on RT. While the smaller number of fixations made under single-task conditions would otherwise have produced a significant decrease in RTs, the countervailing increase in fixation durations attenuated this effect. Fixation durations were significantly shorter for older than for younger observers, $\underline{F}(1, 26) = 7.288$, $\underline{p} = .012$, but the interaction of age and task failed to reach significance, $\underline{F} < 1$.

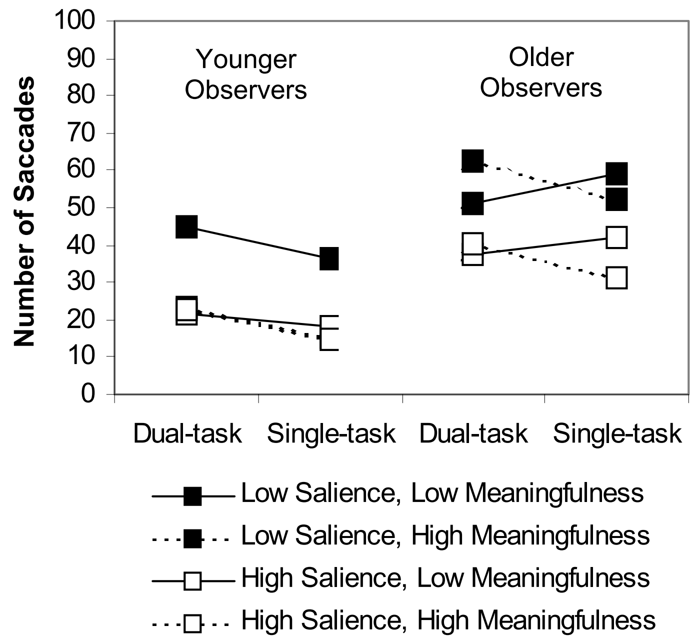


**Figure 2.** Effects of change meaningfulness and salience on dual-task interference.

Further insight as to the consequences of conversation come from analysis of the effects of change meaningfulness and salience on eye movements. All changes made to the images used in the current study were rated by naïve observers as being high or low in salience (i.e., physical magnitude) and high or low in meaningfulness (i.e., relevance to the driver's task) (see Pringle, et al, 2001). Figure 2 presents mean numbers of fixations per trial under dual- and single-task conditions as a function of these variables. Overall, salient changes were found with fewer fixations than non-salient changes, and meaningful changes with fewer fixations than non-meaningful changes (see also Pringle, et al, 2001). More telling are the effects of salience and meaningfulness on the degree of interference imposed by the secondary task. For younger observers, dual-task interference was independent of both salience, $F(1, 13) = 1.487$, $p = .244$, and meaningfulness, $F < 1$. For older observers, interference was independent of salience, $F < 1$, but was modulated by change meaningfulness, $F(1, 13) = 6.389$. $p = .025$. More specifically, dual-task conditions increased the number of fixations necessary to locate meaningful changes, but decreased the number of necessary to locate non-meaningful changes. As such, data suggest that one effect of conversation for older observers was to disrupt knowledge-driven search, that is, to impair observers' ability to guide visual scanning with knowledge of what objects and events are relevant to a driver's task.

## 4. Discussion

An experiment asked younger and older observers to perform a change detection task using real-world traffic scenes, either while concurrently maintaining a conversation, or under single-task control conditions. Results demonstrate that even simple conversation can disrupt attentive scanning and representation of a visual scene. Error rates for change detection were higher during conversation than under single-task conditions, and larger numbers of saccades were necessary to locate and respond to the changing item. Additionally, fixation durations were reduced under dual-task conditions, suggesting that detrimental effects of conversation on performance may have, at least in part, been the result of abbreviated time available for perceptual analysis and saccade planning.

Critically, observers' conversations in the current experiment were "hands-free"; dual-task conditions did not require observers to hold or manipulate any apparatus beyond the joystick and response button which were also used under single-task conditions, nor to visually inspect any additional stimuli. Thus, the interference imposed by conversation was apparently not structural, but cognitive. More specifically, the finding that increased numbers of saccades were necessary for change detection in dual-task conditions suggests that one effect of conversation was to impair peripheral guidance of attention toward the target. For younger observers, this appears to have been a fairly generalized disruption, independent of change salience and meaningfulness. Older observers, conversely, suffered both a generalized disruption of search, evinced by an increase in the number of saccades per trial which was independent of change salience, and a more specific disruption of knowledge-driven search, evinced by a decrease in the benefits of change meaningfulness to target detection. This suggests that dual-task interference may be especially harmful for older observers' performance in real-world circumstances, where by definition only meaningful changes need be detected.

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