Conversation Disrupts Change Detection in Complex Traffic Scenes

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A set of studies examined the effects of cognitive distraction on visual scanning and change detection in natural traffic scenes. Experiment 1 found that a naturalistic hands-free phone conversation could disrupt change detection, thereby degrading the encoding of visual information and increasing the frequency of undetected changes. Data also revealed a tendency for conversation to impair knowledge-driven orienting of attention in older adults. Experiment 2 found that an attentive listening task produced no such effects. Actual or potential applications of this research include the design of displays and interventions to minimize the effects of cognitive distraction on human performance.

INTRODUCTION

The ability to notice behaviorally meaningful objects and events in the visual surroundings is fundamental to an operator's capacity to maintain performance in a complex environment. Indeed, Endsley's (1995) widely cited model of situation awareness recognizes the perception of task-relevant information in the environment as the foundational stage of knowing and understanding "what is going on around you" (Endsley, 2000, p. 5). It is less obvious, however, how easily perception and attention may fail. Despite people's impressions of a detailed and continuous visual world, human performance data indicate that lapses of perception and attention are frequent and often consequential. Jones and Endsley (1996), for example, found that 76% of pilot errors were attributable to failures of perception and attention. Similarly, attentional lapses have been implicated as an important cause of various forms of traffic error (Langham, Hole, Edwards, & O'Neil, 2002; Larsen & Kines, 2002).

Recent findings in the study of visual performance have corroborated the suggestion that perception is less comprehensive than introspection suggests. Evidence demonstrates that attention is generally necessary for the conscious perception of objects within a static scene (Mack & Rock, 1998) as well as for the detection of events within a scene (Pringle, Irwin, Kramer, & Atchley, 2001; Pringle, Kramer, & Irwin, 2004; Rensink, O'Regan, & Clark, 1997; Simons & Levin, 1997). Under common circumstances, visual events generate localized transient signals – motion or flicker – which capture attention and ensure that changes within an operator's surroundings are noticed. When the transient signal produced by an event is somehow masked, however, the event itself may go unattended and therefore undetected.

Even seemingly obvious changes can thus fail to reach awareness, a phenomenon known as *change blindness* (Simons & Levin, 1997). To avoid such perceptual failure, an observer must rely on effortful, attentive scanning (Hollingworth, Schrock, & Henderson, 2001; Rensink et al., 1997) to actively encode objects and note changes to them. Bottom-up/stimulus-driven and top-down/knowledge-driven processes guide such scanning, helping to ensure that changes are detected more easily when made to objects that are physically salient or meaningful within

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the context of a scene (Pringle et al., 2001, 2004). Nonetheless, changes to important and physically conspicuous objects often go unnoticed.

The study of change blindness has provided basic researchers with insight into the cognitive and neural bases of conscious perception. The implications of the phenomenon, however, extend into applied domains. Data indicate that change blindness can result from a variety naturalistic visual events, including saccades (Grimes, 1996), blinks (O'Regan, Deubel, Clark, & Rensink, 2000), egomotion (Wallis & Bülthoff, 2000), occlusion of a changing item (Simons & Levin, 1998), and the presence of irrelevant transient signals (O'Regan, Rensink, & Clark, 1999). As such, change blindness can occur outside of contrived laboratory settings (Simons & Levin, 1998) and is likely to mediate visual performance in real-world tasks and circumstances. An understanding of the mechanisms and processes underlying change detection might therefore provide insight into the limits of human perception and cognition outside the lab. By the same token, change detection may serve as a gauge of perceptual-cognitive performance under varying circumstances.

One applied use of the change detection paradigm has been in the study of the effects of cognitive distraction on perceptual performance. An experiment by Richard et al. (2002) examined the effects of a secondary task on reaction times (RTs) for the detection of changes in traffic scenes. Meant to simulate a hands-free cellular phone conversation, the loading task required participants to listen to and remember a short declarative sentence presented through a speaker. A test of sentence memory followed each trial. Control conditions required observers to perform the change detection task alone. Notably, the pairing of an auditory secondary task with the visual primary task minimized the possibility of sensory or peripheral conflict. Data nonetheless revealed that change detection was reliably slowed by the imposition of the distracting task. This was true, interestingly, even for changes that were highly meaningful within the context of the scenes presented. In other words, top-down/knowledge-driven processes did not seem to attenuate the effects of the loading task.

This implies that distraction may impair the perception of even highly task-relevant stimuli. In light of evidence for an important role of eye movements in mediating change detection (Hollingworth et al., 2001), along with findings that nonvisual cognitive workload can modify saccadic behavior (e.g., May, Kennedy, Williams, Dunlap, & Brannan, 1990; Recarte & Nunes, 2000, 2003), Richard et al. (2002) speculated that the effect of distraction in the change detection task might be to disrupt observers' oculomotor scanning.

EXPERIMENT 1

The aim of the current work was to further explore the consequences of hands-free cellular phone conversation for visual performance in a change detection task. Observers were asked to search for changes within complex traffic scenes, in which flicker of the display was used to mask the local transients produced by the changes. In Experiment 1, observers performed the change detection task either under single-task control conditions or while concurrently maintaining a casual conversation with an experimenter's confederate. Naturalistic conversation was chosen as the secondary task to simulate the form of cognitive load that would obtain from cellular phone use, a common real-world distraction. In dual-task conditions of Experiment 2, observers performed the change detection task while listening attentively to a conversation between others. Eye-tracking data were recorded along with RTs and error rates. Target objects were varied in salience and in meaningfulness so that the effects of distraction on stimulus-driven and knowledge-driven processes could be assessed.

Two questions were of particular interest. First, what is the effect of distraction on oculomotor behavior and visual encoding during search for change? As noted, eye movements appear to play an important role in change detection. More specifically, data from Hollingworth et al. (2001) indicate that changes in the flicker paradigm are rarely detected until after they have been fixated. Other findings indicate that saccadic behavior is also subject to interference from nonvisual secondary tasks. Recartes and Nunes (2000), for instance, found that imposition of a cognitive loading task modified drivers' fixation durations and altered oculomotor scan patterns in an on-road task. It is thus possible, as postulated by Richard et al. (2002), that the degrading effects of the distracting task they employed were mediated by changes in observers' oculomotor scanning behavior. Another possibility is that distraction might impair change detection by degrading the attentional processing of foveated information. Strayer, Drews, and Johnston (2003), for example, found that a mock hands-free cell phone conversation disrupted the encoding of foveal information into memory in a simulated driving task as well as in a computer-based laboratory task. Jolicoeur (1999) reported similar findings. One goal of the present work was therefore to use eye-tracking data to assess the effects of distraction on eye movements and visual encoding in a change detection task.

The second question of interest was, how does the ability to detect changes under distracting conditions change with age? Earlier studies have shown that older adults often suffer greater dual-task interference than do young adults (e.g., Alm & Nilsson, 1995; Hancock, Lesch, & Simmons, 2003; Kramer, Larish, Weber, & Bardell, 1999). Older adults might therefore be expected to suffer greater consequences than younger adults from the distracting task during change detection. A second goal of the current work was to test this possibility. Finally, a second experiment was conducted to examine the consequences of attentive listening on change detection performance; past research has indicated that the cognitive interference produced by listening is less severe than that produced by the demand to engage in conversation.

Method

Observers. The participants were 14 younger adults, mean age = 21.4 years, and 14 older adults, mean age = 68.4 years. All observers were native English-language speakers, had corrected visual acuity of 20/40 or better, and had held a driver's license for at least 1 year prior to the date of testing.

Apparatus and stimuli. Visual stimuli were presented on a 121.92 × 167.64 cm flat screen display (ImmersaDesk). Viewing distance was approximately 83.8 cm, although observers were free to move their heads. Eye movement data were recorded using an Applied Science Laboratories eye and head tracker (Model 501) with temporal resolution of 60 Hz and spatial resolution of 1° of visual angle. Stimuli were 80 daytime pairs of photographs depicting urban and suburban traffic scenes as viewed from a driver's vantage point. One image within each pair was unaltered, whereas 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 or removal of an object to or from the depicted scene. All modified objects were rated by naive observers as being high or low in salience (i.e., physical conspicuity) and high or low in meaningfulness (i.e., relevance to the driver's task); see Pringle et al. (2001) for details of the rating procedure. A 2 × 2 analysis of variance (ANOVA) using salience (high vs. low) and meaningfulness (high vs. low) as factors found no significant differences in the distance of changes from the center of the display, $F(1, 76) = 1.061$, $p = .306$ for main effect of salience, $F < 1$ for main effect of meaningfulness, $F(1, 76) = 2.713$, $p = .104$ for interaction.

Procedure. Observers performed a change detection task in an experimental procedure employing the flicker paradigm of Rensink et al. (1997). Figure 1 illustrates the stimuli and events within a typical trial. On 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 the local transients that changes would otherwise have produced and, thus, to force attentional search of displays (Rensink et al., 1997). Upon detecting a change, the observer pressed a button to terminate the stimulus and then described the detected change to the experimenter. The RT for the button press was recorded, and the accuracy of the described change was noted. The trial was terminated if the observer failed to detect the change within 60 s. A response was considered an error if the participant falsely reported a change that was not present or if the trial ended without a response.

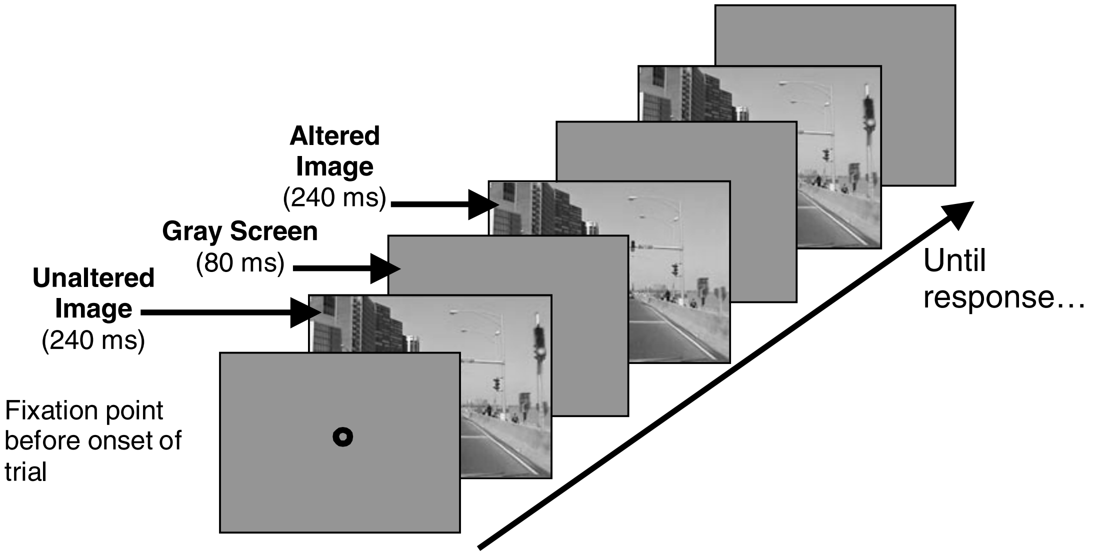

Figure 1. Stimuli and course of events for a typical trial of the change-detection task.

Observers completed 40 single-task trials involving only the change detection task and 40 dual-task trials requiring them 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 a pair of 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 visual stimulus presentation. Conversations were casual, covering topics such as television shows and hobbies. Single- and dual-task trials were run in alternating blocks of 20, with the order of blocks counterbalanced across participants. The order of stimuli was varied randomly across observers, with each stimulus pair appearing once per observer. An experimental session began with five single-task practice trials, using stimuli that were not employed in experimental trials.

Analysis. Eye-tracking data from trials on which the eye tracker lost the participant's 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.

Results

For omnibus analysis, error rate and RT data were submitted to separate four-way mixed ANOVAs, with age as a between-subjects factor and task load (single vs. dual), salience (high vs. low), and meaningfulness (high vs. low) as within-subjects factors. To simplify our presentation, we note here that all three of these dependent variables showed highly reliable main effects of age, salience, and meaningfulness, all $ps < .001$, consistent with earlier reported findings (Pringle et al., 2001, 2004). With one exception, noted later, the analyses produced no three-way or higher interactions involving task load, stimulus salience, or stimulus meaningfulness in either this experiment or the next. Data are therefore plotted separately as functions of salience and meaningfulness, collapsed across values of the alternative characteristic. Our presentation will focus primarily on those interactions involving task load, the variable of foremost interest.

Error rates. Figure 2 presents mean error rates. Error rates were reliably higher during conversation than under single-task conditions, $F(1, 26) = 13.083$, $p = .001$. Data showed no first-order

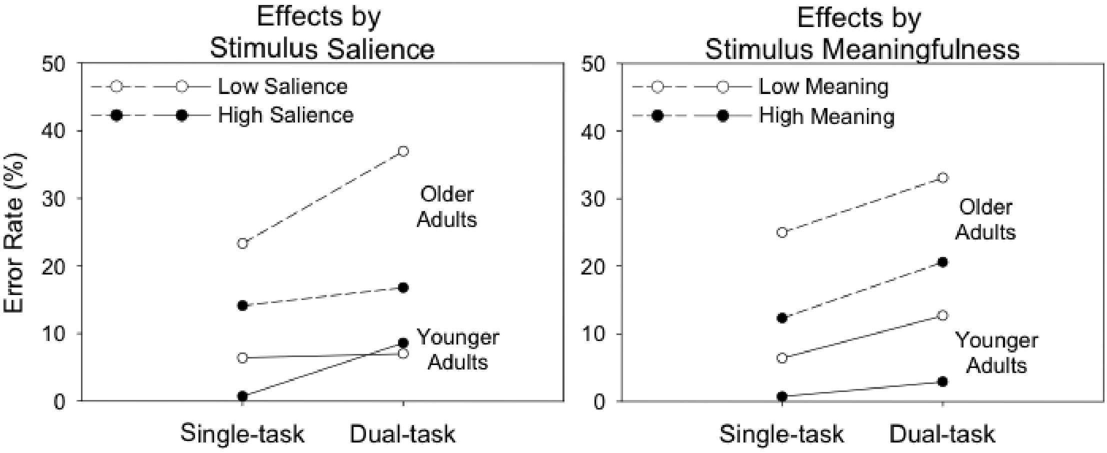

Figure 2. Error rates for Experiment 1.

interaction of Age × Task Load, *F*(1, 26) = 1.351, *p* = .256, and no reliable interactions involving task load and stimulus meaningfulness, all *p*s > .250, but did produce a three-way interaction of Age × Salience × Task Load, *F*(1, 26) = 13.815, *p* = .001. For closer analysis of this effect, data from younger and older observers were collapsed across levels of target meaningfulness and submitted to separate two-way ANOVAs with task load and target salience as factors. Results indicated that for younger observers, the disruptive effects of conversation were greater for high-salience target objects, *F*(1, 13) = 5.193, *p* = .040, whereas for older observers interference was marginally more pronounced with low-salience targets, *F*(1, 13) = 4.588, *p* = .052.

The overwhelming majority of errors were misses – trials on which the observer failed to detect the change within the allotted time – with fewer than 1% being false reports of a change that was not actually present. Additional analyses were conducted to determine why miss rates were inflated under dual-task conditions. In particular, data were analyzed to determine whether the effect of distraction was to disrupt visual scanning, increasing the probability that observers would fail to fixate the changing region of an image, or to degrade the attentive encoding and transfer of foveated visual information into memory. To test the first possibility, we calculated and analyzed the percentage of trials on which observers fixated the target region at least one time. To test the second possibility, we reanalyzed error rates using data from only those trials on which the target was fixated once or more; these data provide an indication of the likelihood that observers detected a changing object after having directly foveated it. A fixation was classified as being on the changing object if it fell inside or within 1° of the smallest four-sided polygon that could be drawn around the target object.

Figure 3 presents mean target fixation rates. Figure 4 presents mean hit rates contingent on a target fixation. Target fixation rates showed highly significant main effects of target salience and meaningfulness, *p*s < .001, but did not vary as a function of either age or, more importantly, task load, *F*s < 1. Only one higher-level effect involving task load reached significance, a difficult-to-interpret four-way interaction of Age × Task Load × Salience × Meaningfulness, *F*(1, 26) = 7.358, *p* = .012. In total, changes in the effectiveness of visual scanning did not appear to account for the general effects of age or task load in the error rate data.

In contrast, detection rates following target foveation were poorer in older adults than in younger adults, *F*(1, 26) = 94.465, *p* < .001, and were degraded under dual-task conditions, *F*(1, 26) = 12.503, *p* = .002. Thus differences in error rate across age groups and levels of task load appeared to result from lapses in visual encoding. Detection rates following a target fixation also showed a reliable three-way interaction of Age × Task Load × Salience, *F*(1, 26) = 13.331,

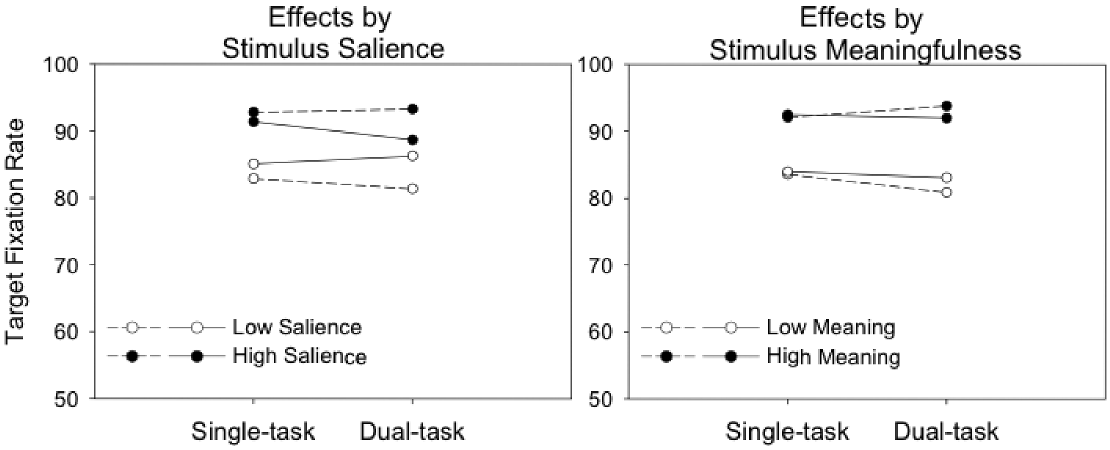

Figure 3. Percentage of trials on which a target fixation occurred in Experiment 1. Solid lines represent data for younger observers, dashed lines represent data from older observers.

p = .001, reflecting the fact that dual-task interference had similar effects on the encoding of high- and low-salience objects for younger adults but disrupted encoding of low-salience objects more than that of high-salience objects for older adults.

RTs. Figure 5 presents mean RTs for correct responses. Omnibus analysis indicated no reliable main effect of task load, $F(1, 26) = 1.773$, $p = .195$, but did produce a significant three-way interaction of Task Load × Meaningfulness × Age, $F(1, 26) = 5.529$, $p = .027$. For more detailed analysis of this interaction, data from the younger and older participants were collapsed across levels of salience and submitted to separate two-way ANOVAs with task load and meaningfulness as variables. Task load produced no main effect for either group, $F(1, 13) = 1.965$, $p = .184$ for younger participants and $F < 1$ for older participants. Beyond this, however, effects differed dramatically with age.

For younger participants, changes to highly meaningful objects were detected more quickly than changes to less meaningful objects, $F(1, 26) = 114.898$, $p < .001$. The benefits of meaningfulness, furthermore, were independent of task load, $F < 1$, and thus obtained under both single-task and dual-task conditions, $t(13) = 6.236$, $p < .001$, and $t(13) = 7.235$, $p < .001$, respectively. For older participants, RTs showed no reliable main effect of meaningfulness, $F < 1$, but instead evinced a reliable interaction of

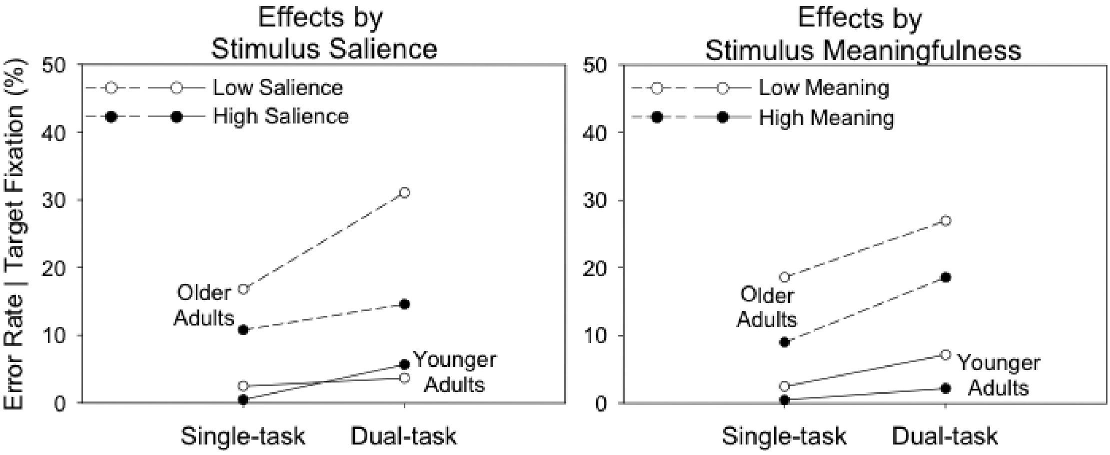

Figure 4. Target detection rates for trials on which a target fixation occurred.

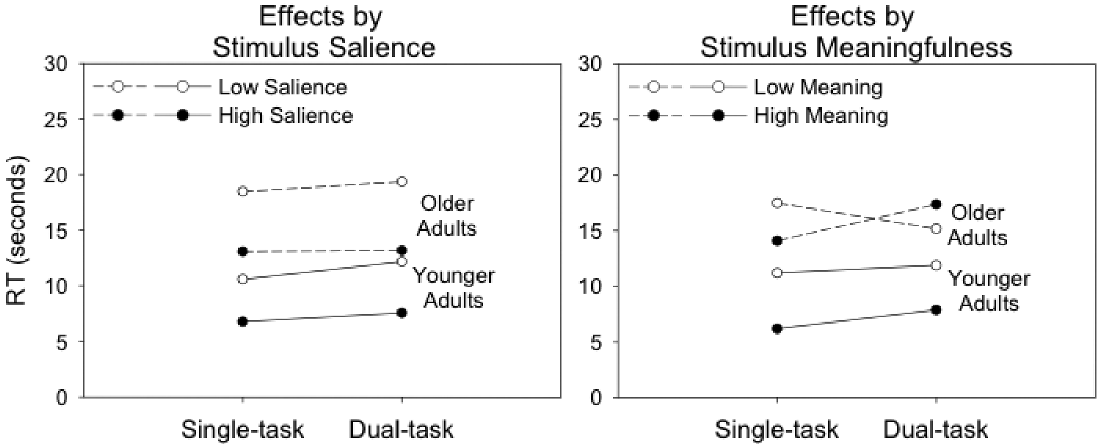

Figure 5. Manual RTs for Experiment 1.

Meaningfulness × Task Load, *F*(1, 13) = 10.987, *p* =.006, arising from the fact that the benefits of meaningfulness were eliminated under dual-task conditions. Changes to highly meaningful objects were found faster than changes to less meaningful objects only under single-task conditions, *t*(13) = 2.936, *p* = .012, not during conversation, *t*(13) = –1.754, *p* = .103.

Omnibus analysis revealed no interactions involving salience and task load, all *p*s > .250. Analysis of eye-movement data revealed a correlation of .929 between mean RTs and mean saccade frequencies (i.e., mean numbers of saccades per trial) across cells, indicating that changes in saccade frequency accounted for the majority of variance in RT data.

Fixation durations. Results from analysis of fixation durations differed from those for the aforementioned data. Evidence suggests that oculomotor behavior during scene scanning might change as a function of viewing time (Henderson & Hollingworth, 1998). This means that when viewing times are not matched between experimental conditions, an analysis that averages oculomotor data over the course of a trial may confound the effects of viewing time with the effects of the independent variables of interest. In other words, differences in mean eye movement data between experimental conditions might result spuriously from differences in mean viewing time. To circumvent this problem, we included within-trial temporal position (first, second, third...) as a variable in the analysis of fixation duration. This also allowed for examination of potential changes in dual-task interference across the course of a trial. Analysis was arbitrarily truncated at 25 fixations per trial. Because too few data points were available from each participant to allow an analysis that included object meaningfulness and object salience as factors along with temporal position, data were collapsed across levels of these variables. Analysis was thus conducted through mixed ANOVAs with age as a between-subjects factor and task load and temporal position within trial as within-subjects factors.

Figure 6 presents mean fixation durations. As is evident, fixations were briefer for older than for younger observers, *F*(1, 26) = 8.166, *p* = .008, and were briefer under dual-task than under single-task conditions, *F*(1, 26) = 57.224, p < .001. There was no interaction of Age × Task, F(1, 26) = 2.667, *p* = .115. Fixation durations also showed a tendency to decrease briefly at the onset of a trial and to increase gradually thereafter, *F*(24, 624) = 2.931, *p* < .001, suggesting that search became more careful or deliberative as a trial progressed. The effect of task load, however, was independent of temporal position, *F* < 1. Notably, the effects of conversation on fixation durations account in part for the absence of a general increase in RT under dual-task conditions, because abbreviated fixation durations would have worked to offset any effects that might otherwise have inflated RTs. Indeed, a statistical analysis of saccade frequencies similar to that of the error rate and RT data produced a reliable effect of task load,

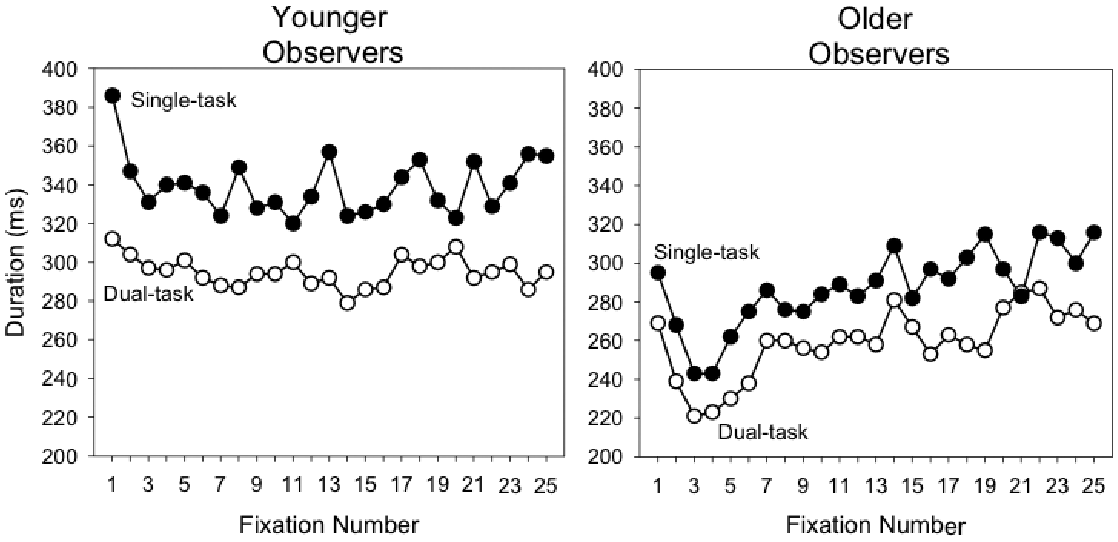

Figure 6. Oculomotor fixation durations for Experiment 1.

F(1, 13) = 10.048, *p* < .007, indicating that larger numbers of eye movements were needed to detect the target during conversation than was the case otherwise.

Control analysis. These results indicate that the cognitive load imposed by conversation may differentially impair top-down and bottom-up processes in older and younger adults, as evidenced by the interaction of Age × Salience × Task Load in the error rate data and the interaction of Age × Meaningfulness × Task Load in the RT data. As noted earlier, changes across different levels of meaning and salience did not differ significantly in eccentricity. Nonetheless, a control analysis was conducted to ensure that interactions of task load with age, object salience, and object meaningfulness were not attributable to nonsignificant variations in target eccentricity between stimulus conditions. For this, data were first grouped according to a median split based on the distance of the changing object's center of gravity from the center of the display and were then submitted to separate mixed ANOVAs, with age as a between-subjects factor and task load and change eccentricity (above median vs. below median) as within-subjects factors. Analyses revealed no reliable interactions of Task Load × Change Eccentricity, *ps* > .250, and no reliable interactions of Age × Task Load × Eccentricity, *ps* > .150. These results indicate that the interactions of age, task load, and change meaningfulness/salience in the analyses reported thus far were not attributable to a potential confound of target eccentricity with target meaningfulness or salience.

Discussion

Results indicate that the cognitive workload imposed by casual conversation can hinder change detection, and they begin to illuminate mechanisms by which these costs were effected. For observers of both age groups, conversation produced a significant increase in the frequency of undetected changes, primarily attributable to lapses in the encoding of visual information within the course of a fixation. However, conversation also led to decreases in the efficiency of oculomotor search, as measured by the number of saccades necessary to successfully detect and identify changes. The form of this effect differed across age groups. For younger observers, conversation produced an increase in the number of saccades necessary for change detection, independent of the salience and meaningfulness of the changing object. For older observers, conversation led to no general increase in the number of eye movements needed to detect a change but did attenuate the benefits of object meaningfulness. Changes to meaningful objects were found faster than changes to nonmeaningful objects only under single-task conditions. For both age groups, conversation led to a reliable decrease in mean fixation duration. The implications of these effects will be considered further in the General Discussion following Experiment 2.

EXPERIMENT 2

Experiment 1 found that naturalistic conversation could disrupt detection of transient-masked changes in real-world scenes. The second experiment was conducted to specify more precisely the source of this interference. Past studies have found that attentional visual processing is disrupted more severely by speech production than by speech comprehension (Recarte & Nunes, 2003; Strayer et al., 2003; Strayer & Johnston, 2001). This suggests that attentive listening, unlike active conversation, should have little effect on change detection. Experiment 2 tested this speculation. The methods were similar to those of the first experiment except that under dual-task conditions, observers were asked to listen to a conversation carried on by others rather than to participate in a conversation themselves.

Method

Observers. The participants were 13 young adults, mean age = 20.64 years, and 13 older adults, mean age = 67.33 years, who participated for pay. All were native English-language speakers, had corrected visual acuity of 20/40 or better, and had held a driver's license for at least 1 year prior to the date of testing.

Apparatus and stimuli. Visual stimuli and displays were identical to those of the first experiment. Auditory stimuli were a series of tape-recorded conversations between a confederate and a younger or an older partner. Conversations were conducted in a manner similar to those between confederates and participants in the first experiment. The confederate initiated conversation by asking a question of her partner, then maintained the conversation by prompting her partner as necessary with follow-up questions or with new questions on a different topic. Conversations covered topics similar to those in the first experiment.

Procedure. The procedure for the change detection task was identical to that of Experiment 1. On dual-task trials, participants were asked to listen attentively to a tape-recorded conversation that was played as they performed the change detection task. Single- and dual-task trials were run in alternating blocks of 20, with the order of blocks counterbalanced across participants. Each participant listened to a recorded conversation between a confederate and a young adult partner for one block of dual-task trials and between a confederate and an older adult partner for the other dual-task block. To ensure that participants would attend to the secondary task, a brief battery of open-ended short-answer questions about the material discussed in the recorded conversations was administered after each block of dual-task trials. Participants were informed at the outset of the experiment that their memory for the conversations would be tested.

Analysis. Eye-tracking data from trials on which the eye tracker lost the participant's gaze position for more than 5% of the duration of the trial were again 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 the eye-movement and RT data that will be described are for trials on which the observer responded correctly.

Results and Discussion

Posttest attentive listening accuracy. Mean accuracy for posttest attentive listening was 70.46% for younger observers (range = 61%–83%) and 60.52% for older observers (range = 31%–83%). These values were significantly different, $t(23) = 2.23$, $p = .036$.

Error rates and RTs. Omnibus statistical analyses of error rates and RTs were identical to those employed in Experiment 1. Main effects of age, object salience, and object meaningfulness were all highly reliable in both dependent variables, ps > .001, and were in the same direction as those in the first experiment. No interactions involving task load were significant, all ps > .3 for error rates, all Fs < 1 for RTs. Effects of age, salience, and meaningfulness therefore are not discussed further, and data are collapsed across these variables to simplify presentation. Mean error rate was 10.07% under single-task conditions and 10.27% under dual-task conditions, and mean RT was 11.73 s under single-task conditions and 12.78 s under dual-task conditions. Neither variable produced evidence for a main effect of task load, $F < 1$ for error rates, $F(1, 23) = 2.00$, $p = .171$ for RTs. An analysis of statistical power revealed that the probability of detecting a main effect of task load as large as that in the error rate data of Experiment 1 (percentage of variance accounted for = 33.5%) was greater than .8.

Fixation durations. Analysis of fixation durations was identical to that of Experiment 1. Mean duration was 320 ms under single-task conditions and 322 ms under dual-task conditions for younger observers when collapsed across temporal position and 298 ms under single-task conditions and 296 ms under dual-task conditions for older observers. Analysis again produced a reliable main effect of temporal position, $F(24, 552) = 4.562$, $p < .001$, but, in contrast to the first experiment, revealed no reliable main effect of age, $F(1, 23) = 1.899$, $p = .181$. Most importantly, the current data revealed no reliable effect of task load on fixation durations, $F < 1$, and no reliable interactions involving task, all ps > .25. Thus, whereas conversation produced a reliable decrease in fixation times for observers in both age groups, attentive listening had little effect on oculomotor dwell times. An analysis of statistical power revealed that the probability of detecting a main effect of task load at least half as large as that in the fixation duration data of Experiment 1 (percentage of variance accounted for = 68.8%) was greater than .8. In sum, the data suggest that the attentive listening task in Experiment 2 did little to disrupt visual change detection.

GENERAL DISCUSSION

A pair of experiments examined the effects of secondary nonvisual task load on participants' ability to attentively detect changes within real-world traffic scenes. In Experiment 1, participants conducted a hands-free conversation while performing a change-detection task. For both age groups conversation produced an increase in error rates, driving up the frequency with which observers failed to detect changes, and a decrease in oculomotor fixation durations. For younger participants, conversation also produced a small generalized increase in the number of saccades needed on each trial to detect a change, whereas for older participants dual-task conditions appeared to eliminate the benefits of object meaningfulness to change detection; changes to meaningful objects within a scene were detected more quickly than changes to less meaningful objects under single-task conditions, but not during conversation. Experiment 2 found no similar effects from a secondary task that required participants to listen attentively to a dialogue between others, suggesting that the interference observed in Experiment 1 was largely the result of the demand that the observers actually be engaged in conversation.

Oculomotor Scanning and Visual Encoding

The eye movement data of Experiment 1 indicate that participants were no less likely to fixate the target region during the course of search under-dual task conditions than under single-task conditions but, after having fixated the changing region, that they were less likely to detect it. Increases in error rate that occurred during conversation were thus produced primarily by degradation of visual encoding within the course of a fixation. This finding concurs with that of Strayer et al. (2003), who found that simulated cellular phone conversations impaired participants' memory even for stimuli presented at the point of regard. However, the present results also demonstrate that scanning is not immune to the distracting effects of conversation. For younger participants, more saccades were necessary to detect a change on each trial under dual-task conditions than under single-task conditions. For older participants, the average number of saccades per trial needed to notice a changing item was similar under both the dual-task and single-task conditions. The benefit of target meaningfulness to change detection, however, was eliminated on dual-task trials. For both age groups, therefore, the efficiency of oculomotor search was impaired during conversation.

It is interesting to speculate whether the degradations of visual scanning and encoding that occurred in the dual-task conditions in Experiment 1 were in part the result of the decrease in oculomotor fixation durations that occurred during conversation. In reading and visual search, briefer fixation durations are often indicative of lower cognitive processing demands (e.g., processing of high-frequency words or easily discriminable objects; Hooge & Erkelens, 1996, 1998; Rayner, 1998). Taking single-task performance as normative, however, implies that fixations during conversation in Experiment 1 may have been detrimentally brief. Existing data indicate both that foveal analysis during visual search becomes more error-prone as fixation durations are reduced (Hooge & Erkelens, 1996) and that peripheral saccade target selection becomes less efficient (Hooge & Erkelens, 1999). Change detection might thus have been degraded in the dual-task conditions of Experiment 1 in part because the abbreviated fixation durations that obtained during conversation allowed too little time for the adequate encoding of foveated visual information and/or peripheral analysis of potential saccade targets.

Alternatively, and perhaps more simply, the abbreviated fixation durations that obtained during conversation might merely have reduced the probability that a change would take place within the course of a given fixation. That is, when fixation durations were shorter, the likelihood of the stimulus flipping from one image to the next during the course of a dwell on the target region would have been lower. This by itself might have made change detection more difficult.

In either case, the tendency toward reduced fixation durations during language production, an effect that has been reported elsewhere (Recarte & Nunes, 2000), is counterintuitive. One way to account for this finding might be within a model of eye-movement programming in which fixation durations are limited by a deadline for saccade initiation. Within such a model, ongoing visual analysis is terminated prematurely if the saccade deadline is reached before information processing within the course of a fixation has completed. The deadline for movement initiation is presumably set according to the anticipated demands of visual processing within a fixation (Hooge & Erkelens, 1998). Considered within this framework, the present data suggest that one effect of conversation on oculomotor behavior may be to induce a shorter-than-optimal saccade deadline, perhaps demonstrating a failure of operators to adequately monitor the success of their own cognitive processes and adjust their processing strategies accordingly.

Further research will be necessary to test this speculation and otherwise determine what role, if any, abbreviated fixation durations serve in mediating the consequences of distraction. It is important to note, however, that Strayer et al. (2003) found that visual processing of foveated information was poorer during hands-free cellular phone conversations than during single-task conditions even after controlling for differences in fixation duration. Changes in fixation duration alone are therefore unlikely to fully account for the effects of conversation on change detection in the current study.

Age-Related Changes

Previous studies have found that older adults frequently experience greater interference under dual-task conditions than do young adults (e.g., Alm & Nilsson, 1995; Hancock et al., 2003; Kramer et al., 1999). The results of the current Experiment 1 showed no overall difference in the magnitude of dual-task interference for older and younger adults during naturalistic conversation (i.e., no two-way interactions of Age × Task Load) but did exhibit differences in the patterns of interference suffered by participants of different ages. One such difference was a curious tendency for younger participants' error rates to show greater dual-task costs in the detection of low-salience targets, whereas older participants showed greater costs in the detection of high-salience targets. One possible explanation of these results, which should be examined in additional research, is that older adults attempted to protect their performance with the difficult-to-detect low-salience targets at the expense of performance on the high-salience targets.

A more striking age-related interaction was evident in the RT and saccade frequency data. As noted, older but not younger participants showed a decrease in the benefits of target meaningfulness during conversation. Under the dual-task conditions of Experiment 1, in other words, older participants apparently lapsed in their ability to rapidly orient attention toward the meaningful aspects of a scene and away from less meaningful aspects. This finding accords with earlier, single-task evidence that older adults may be less efficient than young adults in exploiting target meaningfulness during visual search of natural scenes and suggests than older adults may experience a selective loss of their capacity for top-down or knowledge-guided search (Humphrey & Kramer, 1997; Pringle et al., 2001, 2004). One implication of this is that the cognitive interference produced by conversation and other forms of distraction may be especially detrimental to the performance of older adults in real-world circumstances, where, by definition, only meaningful objects and events need be noticed.

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