Talking on the Phone While Driving: The Effects of Divided Attention on Change Detection

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The proposed study focuses on change detection in a driving scenario, with the concurrent task of talking on a cell phone. The purpose of this study is to investigate how attention divided between talking on a hands-free device and driving induces change blindness for a visual stimulus. Eighty participants will partake in a virtual drive simulation from a driver’s viewpoint. Participants will engage with a dynamic driving scene while either concurrently maintaining a conversation on a hands-free device or concentrating solely on the driving task. The scene will be intermittently interrupted by a flicker, in which one object, the target stimuli in the scene, will change. Participants will be asked to report the location of the changed target and its schematic relevance to a driving scene. Longer gaze fixations on the target will be indicative of change detection, and shorter fixations will represent change blindness. Past research has shown that individuals are more likely to detect items with semantic relevance to a driving scene, as well as changes that are centrally located. It is expected that participants whose attention is divided between talking on a cell phone and driving will experience impaired change detection. Participants are expected to exhibit change blindness for semantically irrelevant targets in central regions, which is exacerbated for semantically irrelevant targets in marginal areas.

Change Blindness

A large portion of road accidents can be attributed to perceptual errors of the driver (Galpin, Underwood & Crundall, 2008). These cognitive errors can be categorized as “failing to look” or “looking but failing to see”. The former can be understood as an incomplete visual search, such as a failure to check side mirrors or the blind spot in a car. The latter is referred to as change blindness, or the inability to notice or report a change in a visual stimulus following a brief disruption (Simmons, 2000). In other words, change blindness occurs when a change is not detected in two pictures presented sequentially given that they are separated by a brief disruption in time. Examples of disruption include an eye blink, eye movements, or if the individual is simply paying attention to something else (Galpin et al., 2008).

In traditional change blindness experiments, such as the ‘Flicker Paradigm’, participants are presented a visual scene and a modified version of the same visual scene sequentially with a visual distractor or blank screen in between (Reinsink, O’Reagan and Clark, 1997). Two scenes are alternated at a fast rate and participants are instructed to report when they detect a change. Past research has revealed that in these typical change blindness paradigms, participants are remarkably poor at detecting even very obvious changes in still photos (Simmons, 2000). This impairment in change detection is evident for changes in dynamic scenes as well. For example, using eye tracking methods, research by Martens (2011) demonstrated that over 40% of participants who were looking directly at target changes in motion did not notice them. These findings converge on the understanding that change blindness for target changes is a robust effect, evident in both static and dynamic scenes.

In a meta-analytic review on change blindness research, Simons (2011) outlined the importance of focused attention in change detection. He proposed that if observers could perceive an entire scene with a single attentional

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fixation, all changes in the scene would be detected at equal rates. Contrary to predictions, it was found that individuals must scan an image and encode the scene in fragments as drivers do with continual searches throughout their visual field. In order to preserve visual information about an object’s properties from one view to the next, observers must explicitly recall representations of the initial object and recode information of its changed state. Changed objects that are not recoded perceptually may be inaccurately recalled. Given the infinite number of features and objects in a natural scene, the act of paying attention is crucial. However as past research shows, focused visual attention may not always be sufficient to ensure change detection (Martens, 2011; Simons, 2011).

One explanation for the failures in change detection involves the semantic relevance of the targets (Galpin et al., 2008). Cognitive schemas provide information on what to expect in an environment, and subsequently guide attention accordingly (Pani, 2000). Features in a scene that align with viewer’s schema are attended to, whereas features that do not fit in an activated schema may be missed. This suggests that change detection is an active search process, whereby individual objects are selectively encoded and compared sequentially across views (Simons & Levin, 1997). Contingent on the idea that schemas guide attention based on mental pictures and expectations in the environment, an observer with a driving related schema will be more likely to notice features in the environment that are relevant to driving. Galpin and colleagues (2009) provided evidence for this claim in a driving change blindness paradigm. They found that participants demonstrated longer glance durations and were more likely to detect changes pertaining to a road scene, such as traffic lights and stop-signs. Conversely, participants who looked at driving-irrelevant targets for a shorter period of time were more likely to miss the changes. Using eye tracking methods, Martens (2011) demonstrated that longer glances at targets indicate an awareness of a change, whereas shorter glances may lead to change blindness even when an individual is looking directly at a target. Together, these findings demonstrate that changes related to the specific context of a scene are more likely to be detected and that this detection can be indicated by longer glances. Additionally, while individuals may visually perceive targets irrelevant to the current task, they may still fall subject to change blindness, which is characterized by shorter glances.

**Divided Attention While Driving**

Operating a vehicle makes extensive demands on visual perception (Lee et al., 2014). However, the voluntary division of attention between visual and auditory tasks is common among drivers. In 2014, an estimated 9% of Americans drive during the day while talking on the phone or texting. Based on cell phone records, estimates indicate that cell phone use while driving increases the risk of an accident fourfold (Klauer et al., 2014). Sanbonmatsu and colleagues (2016) demonstrated that participants talking on the phone not only made more severe driving errors than those not talking on the phone, but also reported that they were less aware of the safety of their driving.

Strayer and colleagues (2003) proposed that cell phone use disrupts driving performance by diverting attention to a context other than the one directly associated with driving. Therefore, the use of cell phones alters the way drivers attend to stimuli. Even though drivers may be directing their gaze at an object, they fail to encode it if their attention is directed elsewhere (Strayer et al., 2003). In the case of divided attention, the combination of two cognitively demanding tasks cause a conflicting demand for resources, which may exceed some people’s cognitive capacities (Richard et al. 2002). Strayer and colleagues (2003) examined how cell phones induced failure of visual attention in simulated driving. They suggested that the performance on visual attention tasks results from
the interference of visual and auditory information.

To promote safe driving, drivers are reminded of the need for a persistent visual search, and the danger of diverting attention to unrelated tasks. Research has demonstrated that change blindness to distal road conditions results from diverting attention from the road (Martens, 2011). Furthermore, Strayer and colleagues (2003) showed that cell phone use while driving results in divided attention between an auditory-verbal-vocal task (act of speaking on a cell phone) and driving (a visual-spatial-manual task). Little research has investigated how divided attention may further induce change blindness. Research in this area lacks evidence on the specific types of changes in the driving visual field that multitasking drivers may miss (Martens, 2011). Since it has been shown that change detection involves focused attention, it is plausible that limiting attention, presumably through the combined demand for resources of multiple cognitive tasks, will decrease sensitivity to scene changes.

In the proposed study, a change blindness paradigm will be applied to a dynamic driving task to investigate the effects of a concurrent auditory-verbal talk and response on change detection. Eye tracking measures will be used to examine participant's change detection for targets that are marginally or centrally located, and which are either schematically relevant or irrelevant to a driving scene. Of interest to this particular proposal are factors that may exacerbate change blindness including the location and semantic relevance of target change. It is hypothesized that semantically irrelevant targets will be missed more often by drivers using their cell phone due to attention being diverted from the driving domain-related tasks. In comparison, targets relevant to the road scene are more likely to be detected. It is also hypothesized that targets in the central location of the scene will be more likely to be detected than targets in marginal areas. Driving related target changes in both marginal and central areas of the screen are expected to be detected more often than driving irrelevant targets. These effects are expected to be moderated by the concurrent task of talking on a cell phone. Interactions between three factors of cell phone use, target location, and target relevance are predicted to outline perceptual errors in driving scenes and dual task interference on driving.

**Methods**

**Participants**

Eighty participants will be recruited from Queen’s University. Participants will be compensated with a course credit or with five dollars for their participation. This study will be advertised on printed posters around the school campus and on the Queen's online psychology participant pool for undergraduate students. Participants are required to have normal vision and to possess a driver's license of a G2 class or above. This study will aim to have an equal number of female and male participants. Participants will be between the ages of 18-22, with an estimated mean age of 20 years old.

**Materials**

**Driving Task.** his experiment will use a similar virtual driving apparatus to that of Sanbonmatsu and colleagues (2016), who investigated the use of cell phones while driving. The DriveSafetyTM DS-600 simulator will be used to create a virtual driving scene in a car. The DriveSafetyTM DS-600 will consist of a Ford Focus cab, facing a large projector screen. The simulator vehicle is based on automatic transmission in a compact passenger sedan.

Following the methods of Sanbonmatsu and colleagues (2016), the driving scenario will be designed using DriveSafety HyperDrive Authoring Suite. The driving scene will be projected onto the
screen in front of the DriveSafety TM DS-600 simulator. The dynamic visual scene will consist of a 10 km section of a four lane wide suburban road, with traffic moving in both directions. Both industrial and residential buildings will be distributed along the scene, over green space. Movement of the vehicle simulation of the car will be controlled by the car’s pedal, and indicated on the speedometer located in the dash. Using a foot to hold down the pedal, the speedometer will read a fixed speed of 60 km/hr, or 0 km/hr if their foot is off of the pedal. All other car controls will be disabled. The video of the driving scene will be interrupted every 5 seconds with a brief ‘flicker’, where a white screen will be presented for 400 ms, after which the driving scene will resume.

**Target Stimuli.** One hundred and twenty pairs of target stimuli will be used across trials, of which 60 pairs are schematically relevant and 60 are driving unrelated targets. Targets will appear as part of the driving scene throughout each trial. The original target will appear before the flicker, and an altered version of the target will be presented after the flicker in the same location, creating a ‘change’. The targets will be selected on the basis of pilot data, where changes that are too easy or too difficult will be eliminated. The types of targets are outlined in Table 1. Targets will be positioned throughout the scene in marginal or central areas of the screen. There will be an equal distribution of driving related targets and driving unrelated targets in both areas.

The screen will be divided into three sections along the horizontal axis for subsequent of target location. The central 50% of the screen will be termed 'central' and the two 25% portions of the screen on the left and right will be considered 'marginal'. The variables of semantic relevance (driving relevant and driving irrelevant) and location of changes will be examined to determine participant’s change detection scores.

**Hands-free phone conversation.** Participants will use a hands-free iPhone 7s provided by the experimenter. The cell phone will be linked to the Bluetooth feature of the car, which will be connected to the car speakers. In the control condition, the cell phone will be in the simulator, with the Bluetooth feature on. This set up allows the control group to verbally report the changes they saw in the driving scene after each trial. In the experimental group, the cell phone will be used by the participants to maintain a conversation with a confederate and to report the changes they detected at the end of each trial.

**Eye Tracking.** Change detection will be measured by glance duration on targets using the Tobii X50 eye tracker. Similar to materials used in a study by Martens (2011), eye movement will be followed with the Tobii X50 eye tracker. Glance direction and duration of fixation on targets will be measured using the eye tracker. The eye tracker has an accuracy of 0.5°, and binocular tracking occurs at a rate of 50 Hz (Martens, 2011). The Tobii X50 eye tracker will be set up in front of participants on the dash of the car without obstructing their view of the screen.

**Procedure**

When participants arrive for the experiment, they will be given a short description of the experiment and will be asked to give signed informed consent for their participation. They will first complete a general demographics questionnaire and a questionnaire designed to assess their interest in potential phone conversation topics for the experimental condition. This method of collecting conversation topics of participant’s interest is adopted from Strayer and colleagues (2003), who found that merely listening to
verbal recordings is not sufficient to produce the dual task interference found between a phone conversation and driving.

Each participant will undergo the control condition (without cell phone conversation) and the experimental condition (with conversation) in a randomized order. Both conditions will consist of 60, 1 min trials. There will be a 10 min break in between conditions, used as a washout period to ensure that the first condition does not affect the second condition’s results. Each trial in both control and experimental conditions will begin with a single tone 200 ms beep, at which time a white screen will then change to the virtual driving scenario, and end with the same white screen. To replicate a standard change blindness flicker task, every 5 s the screen will flicker for 400 ms to replicate a blink. In each trial, one distinct change in the scene will occur after the flicker. This will be the "target" change. The order in which the changes will happen will be randomized between each trial. Participants will be familiarized with the driving simulation using a standardized sequence of five 1 min trials, during which there will be an automatic calibration process for the Tobii eye tracking equipment. Glance duration to points on the screen and targets will be measured in milliseconds.

Participants will be instructed to sit in the DriveSafetyTM DS-600 simulator and adjust the driver’s seat to a comfortable height and position. Participants will sit approximately 25.5 cm away from a steering wheel, measured from their breastbone to the center of the wheel, and to place their hands on the wheel in the position they are usually most comfortable driving. Although the steering wheel will not have any control on the car’s movement in the actual driving simulation, it will enable participants to feel as if they are in an actual vehicle. There will be a pedal on the driving simulator, which participants will be asked to maintain a speed of 60 km/hr. If participants reach a speed of 10 km/hr above or below 60 km/hr, the present trial will be terminated, and they will be brought to a fixation screen before starting the next trial. The maintenance of an ongoing speed is enforced to engage participants in a driving task that requires control of the vehicle, making the experience fairly generalizable to the real world.

Participants will be instructed to watch the screen projecting the virtual driving simulation in front of them and to pay attention to everything they would normally pay attention to while driving. Participants will be told to look for changes in the driving scene, and to pay particular attention to drive-related changes, with regards to the safety of their drive (stop lights, speed bumps, other car brake lights, etc.). They will be asked to report the changes they saw at the end of each trial. No specifics of the targets will be communicated to participants.

In the experimental condition, participants will concurrently engage in a cell phone conversation with a confederate using a hands-free Bluetooth feature. The confederate and participant will discuss topics of interest to participant that were identified in the initial questionnaire. The call will be initiated prior to beginning the dual task scenario to avoid any manual manipulation of the cell phone during the task. Thus, any interference in performance of the task is expected to be due to the conversation itself. In order for participants to report the changes they detected, at the end of each trial they will be instructed to briefly halt their conversation to tell the confederate what they have observed.

**Experimental Design**

A mixed 2 x 2 x 2 design will be used. The between group variables was distracted driving (on a cell phone or not), and the within group variables were road relevance (was the change semantically relevant to a driving scene or not) and location of change. For the latter, the
screen will be divided into three sections along the horizontal axis. The central 50% of the screen will be termed “near” and the two 25% portions of the screen on the left and right will be considered “far”.

Change detection will be measured by glance duration on targets using the Tobii X50 eye tracker in milliseconds. Verbal responses of change detection will be compared to eye tracking data to check the reliability of the eye tracking measures. In accordance with Martens (2011) who found that shorter glances averaging 407 ms predicted change blindness, 405 ms will be used as a minimum glance duration threshold to indicate change blindness. Whereas longer glances averaging 1803 ms predicted awareness of a change, and 1800 ms will be used as a minimum threshold for target change detection. Glance duration measures for each participant will be collected and averaged between participants for each trial.

Proposed analyses

Response times to correctly detect changes will be subject to a 2 x 2 x 2 ANOVA across the factors of divided attention (conversation versus no conversation), location (marginal versus central) and target relevance to driving (semantically related versus unrelated).

Discussion

Cell phone conversations have been shown to alter the way that drivers attend to stimuli in the driving environment (Sanbonmatsu et al., 2016). With the increase in multitasking among drivers, and the proven impairments divided attention has on visual perception, research in this field is important for accident prevention and improving road safety (Galpin et al., 2008; Sanbonmatsu et al., 2016). The focus of the current study is to contribute to the growing body of research on attention and to establish a greater understanding for the perceptual errors experienced while driving. This study seeks to accomplish this by demonstrating how the concurrent use of cell phones while driving affects the rate of change blindness, as well as a deepened understanding in the role of semantic relevance and location in change detection.

Findings from this study would lay groundwork for research on how divided attention may determine the magnitude of change detection. In demonstrating how concurrent use of cellphone use determines the rate of change blindness, prevention efforts can be appropriately designed to increase the degree of attention allocated to the driving scene versus the cell phone conversation.

Additionally, this research would establish evidence for identifying the specific types of target changes that multitasking drivers typically miss. While multitasking between driving and talking on a cellphone, driver’s experience competing schemas at the auditory and visual level (Richard et al., 2002). These schemas interfere with the driver’s expectations of their environment, and consequently impairs their reaction cues. Therefore, elements of a target will only be retained if attention is focused on the changing features. With an established framework on the sorts of changes missed by travers, driver’s education classes may include modules to expose learning drivers to frequently missed targets, to inaugurate said targets into their driving-related schemas.

The first limitation of this study is the use of a repeated measures design. This could incur the risk of carryover effects and expectancy effects, where participation in one trial effects their performance on another. For example, in past research on change blindness, change detection in flicker paradigms may improve with the subject’s improved memory of change location, and awareness of oncoming changes (Galpin et al., 2008). A second limitation pertains to the conversations between the participant and experimenter. Engagement levels and subjective interests used as the content of conversation will vary between
participants, making this a potential confound. The conversations are intended to be interesting and casual to replicate real life hands-free cell phone conversations while driving. Future studies should standardize conversations across participants while still maintaining their interest and engagement. Furthermore, the present study only focuses on front facing perspective of a vehicle, which limits the generalizability to a real world driving context. In a real-world context, drivers rotate between directing their attention in front of them and to checking side and rear-view mirrors for oncoming traffic, emergency vehicles, and pedestrians. In this case, drivers may exhibit inattentional blindness to targets in front of them, where missing a change is caused by simply not looking at the target because their attention is elsewhere as opposed to change blindness where the driver is looking at the target but fails to see the change (Galpin et al., 2008).

References


### Tables

*Examples of Far and Near Driving-Related and Driving-Unrelated Scene Changes Used*

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