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Change detection in urban and rural driving scenes: Effects of target type and safety relevance on change blindness

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ABSTRACT

The ability to detect changes is crucial for safe driving. Previous research has demonstrated that drivers often experience change blindness, which refers to failed or delayed change detection. The current study explored how susceptibility to change blindness varies as a function of the driving environment, type of object changed, and safety relevance of the change. Twenty-six fully-licenced drivers completed a driving-related change detection task. Changes occurred to seven target objects (road signs, cars, motorcycles, traffic lights, pedestrians, animals, or roadside trees) across two environments (urban or rural). The contextual safety relevance of the change was systematically manipulated within each object category, ranging from high safety relevance (i.e., requiring a response by the driver) to low safety relevance (i.e., requiring no response). When viewing rural scenes, compared with urban scenes, participants were significantly faster and more accurate at detecting changes, and were less susceptible to "looked-but-failed-to-see" errors. Interestingly, safety relevance of the change differentially affected performance in urban and rural environments. In urban scenes, participants were more efficient at detecting changes with higher safety relevance, whereas in rural scenes the effect of safety relevance has marginal to no effect on change detection. Finally, even after accounting for safety relevance, change blindness varied significantly between target types. Overall the results suggest that drivers are less susceptible to change blindness for objects that are likely to change or move (e.g., traffic lights vs. road signs), and for moving objects that pose greater danger (e.g., wild animals vs. pedestrians).

1. Introduction

The ability to detect changes is crucial for safe driving: we must notice when another vehicle pulls out ahead, when an in-vehicle alert appears, or when advisory signs are updated. However, research demonstrates drivers often fail to detect changes (Charlton and Starkey, 2013; Zhao et al., 2014), which is referred to as *change blindness* (Rensink et al., 1997). Accurate change detection while driving is associated with safer decision-making (Caird et al., 2005; Edwards et al., 2008), and in-depth crash analyses suggest approximately 9% of serious injury crashes involve a driver failing to detect hazards (Beanland et al., 2013).

Several paradigms have been used to explore change blindness (Jensen et al., 2011). The most common methods used in driving-related research are flicker tasks, one-shot tasks, and simulated driving scenarios. In flicker tasks, two alternating images are presented for a fraction of a second each (240–500 ms), separated by a brief (80–500 ms) blank screen that masks visual transients (Rensink et al., 1997). The sequence "flickers" between images until the observer determines whether they differ. One-shot tasks use a similar format, but each image is presented only once and stimulus durations are often longer (e.g., 10–15 s; Zhao et al., 2014). Simulated driving paradigms embed change detection tasks within a driving simulator scenario. Some simulator studies mask changes with brief occlusion periods (Lee et al., 2007; Shinoda et al., 2001; Velichkovsky et al., 2002; White and Caird, 2010), whereas others have changes occur naturalistically, for example, changing between repeated drives on the same road (Charlton and Starkey, 2013; Harms and Brookhuis, 2016; Martens and Fox, 2007).

Previous research has examined how change detection in driving scenes is affected by factors including target relevance, driving experience, familiarity with the road environment, and secondary

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task engagement. Key findings are summarised in the following subsections.

1.1. Target relevance

Observers are faster and more accurate at detecting changes to targets that have greater relevance to the overall scene context (Rensink et al., 1997) or are personally meaningful (Marchetti et al., 2006). Similarly, drivers are better at detecting changes to driving-relevant targets, compared with irrelevant targets (Galpin et al., 2009; Mueller and Trick, 2013; Velichkovsky et al., 2002; Zhao et al., 2014). One caveat is that many studies use broad definitions of "relevant" and "irrelevant". Relevant targets include vehicles, pedestrians, and road signs, whereas irrelevant targets include buildings, dumpsters, and mailboxes (Galpin et al., 2009; Mueller and Trick, 2013; Velichkovsky et al., 2002). This raises a potential confound, as irrelevant targets are typically stationary objects positioned off-road and farther from the driver's central focus. Moreover, these studies group together multiple driving-relevant targets, which vary considerably in their importance to safe driving.

Two simulator studies provided more systematic manipulation of relevance within a single class of targets (Lee et al., 2007; Shinoda et al., 2001). In the first study, a "no parking" sign changed into a "stop" sign, and target placement was systematically manipulated. Drivers were significantly less likely to notice the changing sign when they were following another car, or when it occurred mid-block, compared with when it occurred at an intersection (Shinoda et al., 2001). Arguably, stop signs are equally relevant regardless of where they appear; however, drivers *expect* signs at intersections to convey more meaningful information. In another study, Lee et al. (2007) tested drivers' ability to detect changes to vehicles that were either parked, moving ahead, or moving behind. Drivers were most sensitive to lead vehicles moving closer to them (simulating sudden braking) and were least sensitive to changes involving parked vehicles. This suggests drivers are more efficient at detecting changes with greater safety relevance; however, safety relevance was confounded with target location (Lee et al., 2007).

Finally, a French study using a one-shot task manipulated the relevance of changes involving cars (Koustanaï et al., 2012). A car was either added or moved (e.g., to simulate turning, or to appear closer) within a driving scene, and task instructions were varied to manipulate the relevance of these changes. Participants were better at detecting changes when instructed to make driving-related judgements about the scene (e.g., whether it was safe to turn or cross the intersection). Participants were also better at detecting a car appearing in urban versus rural environments, which the authors suggested could be due to contrast and salience (which was lower in rural images) and/or expectations (i.e., drivers expect cars to appear suddenly in urban areas; Koustanaï et al., 2012).

1.2. Driving experience

Change blindness research in non-driving domains consistently indicates that domain-experts are less susceptible to change blindness for expertise-related changes, compared with domain-novices (Feil and Mestre, 2010; Reingold et al., 2001; Werner and Thies, 2000). For instance, American football experts are faster than non-experts at detecting changes to football-related images that meaningfully alter game formations, but not at non-meaningful or non-football-related changes (Werner and Thies, 2000). Comparable findings have been obtained for chess masters (Reingold et al., 2001) and physics experts (Feil and Mestre, 2010). However, research examining the effects of driving experience on change detection has yielded mixed results (Zhao et al., 2014).

One approach for examining experience effects is to compare drivers with non-drivers. An English study comparing non-drivers and drivers found no significant difference in performance on a driving-related flicker change detection task (Galpin et al., 2009). The authors suggested their driver group may have had insufficient experience (average 70 months). For example, novice drivers and non-drivers may show similarities because non-drivers have experience as "backseat drivers", which can confer familiarity with road environments and driving routes (von Stülpnagel and Steffens, 2012).

Following this, a Chinese study compared change detection ability in non-drivers and drivers with on average 33 months' experience (Zhao et al., 2014). The Chinese study used a one-shot task and inserted a central fixation point on half the trials. Drivers and non-drivers performed similarly on trials with no fixation point, replicating Galpin et al.'s (2009) results. When the fixation point was present, non-drivers were significantly less accurate than drivers at detecting driving-related and peripheral changes (Zhao et al., 2014). The authors suggested driving experience helps facilitate more efficient processing of driving-related and peripheral elements while fixating centrally.

Other studies have compared change detection abilities among drivers with varied experience. In a US study comparing young novice drivers (average 6 months' experience) to more experienced young drivers (average 7 years' experience), both groups performed similarly on driving-related changes but novices were less accurate at irrelevant changes (Mueller and Trick, 2013). One explanation is that experienced drivers are more efficient at processing driving-related information, so they have greater capacity remaining for processing irrelevant information. This is consistent with Zhao et al.'s (2014) findings, whereby drivers showed superior detection of peripheral changes compared with non-drivers. Further, a French study comparing novice drivers (average 1.3 years' experience) with more experienced drivers (average 5.6 years' experience) found that the experienced drivers were significantly more accurate at change detection when the task required them to judge whether it was safe to traverse an intersection, but not when the task involved simply viewing the images (Koustanaï et al., 2012).

Finally, an Australian study found that after accounting for simple reaction time differences, drivers with <3 years' experience were significantly *faster* at detecting driving-related changes, compared with drivers who had >10 years' experience (Wetton et al., 2010). Notably, this study's "novice" group had as much experience as "experienced" drivers in some other studies (e.g., Zhao et al., 2014). Overall it seems that experience-related differences in change detection ability are most likely when comparing drivers with either non-drivers or very inexperienced drivers.

1.3. Familiarity

Some studies have examined the effect of environmental familiarity on change detection (Charlton and Starkey, 2013; Harms and Brookhuis, 2016; Martens and Fox, 2007). These studies use similar methods: all recruited groups of drivers to complete 20–25 simulated drives over several days or weeks. Whereas most studies assess short-term changes (i.e., detecting a change within the past second), familiarity studies typically assess long-term change detection, such as when a speed limit has changed. Overall, these studies suggest that familiarity increases drivers' sensitivity to certain environmental elements but impairs others. For instance, familiar drivers are faster at detecting a target vehicle (Charlton and Starkey, 2013). These benefits are offset by substantial change blindness to other aspects of the environment, even for safety relevant changes. Many drivers failed to detect when an intersection sign changed from granting them priority to requiring them to give