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How safe is tuning a radio?: using the radio tuning task as a benchmark for distracted driving

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ABSTRACT

Drivers engage in non-driving tasks while driving, such as interactions entertainment systems. Studies have identified glance patterns related to such interactions, and manual radio tuning has been used as a reference task to set an upper bound on the acceptable demand of interactions. Consequently, some view the risk associated with radio tuning as defining the upper limit of glance measures associated with visual-manual in-vehicle activities. However, we have little knowledge about the actual degree of crash risk that radio tuning poses and, by extension, the risk of tasks that have similar glance patterns as the radio tuning task. In the current study, we use counterfactual simulation to take the glance patterns for manual radio tuning tasks from an on-road experiment and apply these patterns to lead-vehicle events observed in naturalistic driving studies. We then quantify how often the glance patterns from radio tuning are associated with rear-end crashes, compared to driving only situations. We used the pre-crash kinematics from 34 crash events from the SHRP2 naturalistic driving study to investigate the effect of radio tuning in crash-imminent situations, and we also investigated the effect of radio tuning on 2,475 routine braking events from the Safety Pilot project. The counterfactual simulation showed that off-road glances transform some near-crashes that could have been avoided into crashes, and glance patterns observed in on-road radio tuning experiment produced 2.85–5.00 times more crashes than baseline driving.

1. Introduction

When drivers divert visual attention away from the road to perform a secondary task, they temporarily expose themselves to a higher risk of missing or responding slowly to roadway events (e.g., a lead vehicle braking) or losing control of the vehicle. Manual radio tuning, which is one of the earliest non-driving tasks introduced into the car, has served as a reference task when considering acceptable risks of visual-manual secondary tasks (Angell et al., 2006), as it "imposes only a moderate and socially accepted level of risk" (Young et al., 2008 p. 100), is "reasonably-demanding", and "represents a plausible benchmark or driver distraction potential beyond which new systems, functions, and features should not go" (in Alliance of Automobile Manufacturers (AAM) Guidelines; Driver Focus-Telematics Working Group, 2006). National Highway Traffic Safety Administration (NHTSA) also agreed that manual radio tuning task is an appropriate reference task and that the AAM guideline "make a strong case for basing the maximum amount of distraction associated with a task on the level of distraction" (NHTSA, 2013 p. 24831). Hence, radio tuning has been extensively studied as a benchmark activity in assessing the "threshold" demand of in-vehicle systems, with a particular focus on glance distribution. A common criterion of 2.0 s (i.e., glance away from the road over 2.0 s is considered dangerous) was derived from the 85th percentile of off-road glance duration in Rockwell (1988) study of a radio tuning task. And this criterion or modest adaptations of it have been used as a threshold of long off-road glances in numerous papers, reports, and policies (NHTSA, 2013; Victor et al., 2014). Studies have also reported the relative workload of visual-manual systems in relation to the radio tuning task (Angell et al., 2006; Greenberg et al., 2003; Tijerina et al., 1998). More recently, radio tuning task has also been used to compare the demand characteristics of mixed-mode voice initiated interfaces (Reimer et al., 2014) and overall attentional strategies naturalistic driving with secondary tasks (Seaman et al., 2017).

Nevertheless, studies have used different protocols for the radio tuning task. There are various tasks that can be done within a single radio system (Regan et al., 2008, p. 364), and this adds variability to

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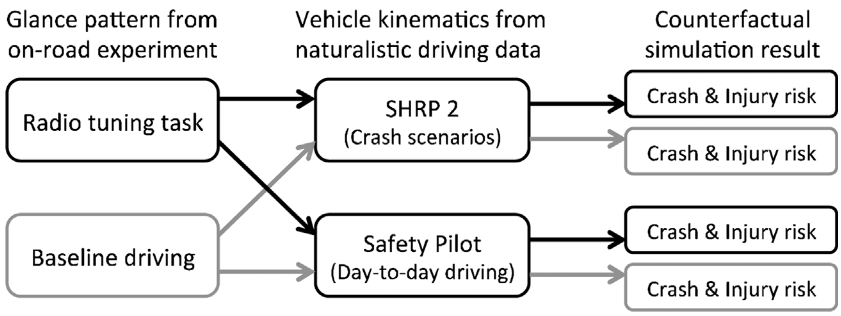

Fig. 1. Structure of the current study.

the radio tuning task itself. Radios can be tuned with preset buttons or continuous dial-and-seek (e.g., "easy" or "hard" task in Angell et al., 2006; Reimer et al., 2014). The "standard" radio tuning task in the Crash Avoidance Metrics Partnership study (Angell et al., 2006) was dial-and-seek (corresponding to the "hard" task in Reimer et al., 2014) that consisted of multiple subtasks: turning on the radio, switching to FM band, and tuning from a wrong frequency band to a target frequency band by rotating a manual knob. Note that dial-and-seek could be completed with push buttons in other studies, where push buttons serve the role of seeking up or down the radio frequencies (Perez et al., 2013). Radio systems have evolved and now are embedded in more complex and multifunctional systems with touchscreen interface. For these reasons, NHTSA reported that the 85th percentile of total eyes off road time (TEORT) for the radio task varies from 8.0 to 15.8 s depending on the make and model of vehicles (Perez et al., 2013). Thus, it is difficult to use the radio tuning as a true "reference" given such variability.

To overcome this weakness, AAM has suggested using a radio tuning task with detailed steps as a reference task (AAM Guidelines 2006, pp. 46–48) and set the maximum TEORT limit at 20 s. NHTSA suggested 12 s as one of the acceptance criteria in recent guidelines (NHTSA, 2013). Note that NHTSA also requires considering any off-road glances when calculating TEORT, whereas AAM considers only glances to the device (i.e., radio).

Although these studies made an effort to measure demand of the manual radio tuning task with off-road glance durations, the risk associate with the radio task has not been estimated − at least not for the more modern radio tasks. Studies typically use glance features as surrogates for the risk that drivers might encounter by not attending to the forward roadway, but the gap in the research is that we do not know the degree of crash and injury risk, which is the actual safety outcome, the radio tuning task creates. One might use crash and near-crash data collected from naturalistic settings and infer the association between distraction and risk, but the number of incidents is limited (Perez, 2012). Then what is the level of the acceptable risk? How does radio tuning affect crash frequency and severity, which are the only true measures of risk?

In this study, we use counterfactual simulation to estimate the crash risk of a modern radio tuning task that follows AAM guidelines (Reimer et al., 2013), using the drivers' actual sequence of glances while driving on a highway with an instrumented vehicle and apply them to 34 crash events and 2,475 braking events from two naturalistic driving data sources. We simulate outcomes associated with drivers distracted by radio tuning and not distracted by any task ("baseline" driving). One set of naturalistic driving data includes actual crash events (SHRP2; Transportation Research Board of the National Academy of Sciences, 2013), and the other set of data was extracted from every day braking behavior (Safety Pilot; Bezzina and Sayer, 2014; for previous work on counterfactual simulations using everyday braking behavior, see Woodrooffe et al., 2012). The risk of a rear-end crash was calculated by applying driver glance patterns collected from on-road experiments to the kinematics from the naturalistic driving data and simulating drivers' reactions to each event. This study extends the study of Bärgman et al. (2015), which estimated the risks associated with Rockwell's (1988) radio task glance distribution using counterfactual simulations, with more safety critical events and actual glance sequences.

2. Methods

2.1. Counterfactual simulation

Counterfactual simulation takes a real-world observation and explores how alternate events (e.g., driver braking behaviors) might influence the outcome (e.g., crash frequency, crash severity). By applying different behaviors instead of the original driver's behavior, counterfactual simulations can estimate the full distribution of likely outcomes that could have occurred. In transportation safety research, counterfactual simulation has been used for variety of purposes: to identify how the surrogate events (e.g., traffic conflicts) are related to the actual crashes (Davis et al., 2011), to access the performance of Advanced Driver Assistance Systems (McLaughlin et al., 2008; Sander, 2017), and to estimate the effect of off-road glances (Bärgman et al., 2015).

In the current study, we use the counterfactual simulation of rear-end collisions caused by lead vehicle braking. We replace the original drivers' glance pattern and braking response in the naturalistic driving data with the glance patterns associated with a radio tuning task and baseline (no secondary task) driving from an on-road experiment (Fig. 1). A driver reaction model generates the counterfactual brake response, based on the combination of glance behavior patterns and kinematics.

In the events observed in the naturalistic driving data, the lead vehicles started braking and the distance between the lead vehicle and the following vehicle decreased. Such a decrease in headway distance increases the optical size (i.e., visual looming) of the lead vehicle, which guides drivers to initiate a braking response (Markkula et al., 2016). Visual looming is defined as inverse tau, and in the current study, we chose the time when the inverse tau (τ^{-1}) exceeded 0.2 s^{-1} as the "anchor point" − the starting point of simulation. Tau (τ) is calculated by dividing the horizontal optical angle of the rear end of the lead vehicle with the expansion rate (time derivative of the optical angle) of the lead vehicle and is an optically defined time to collision (TTC). This is the visual looming cue that the driver in the following vehicle is likely to perceive the lead vehicle as a threat and initiates evasive maneuver (Victor et al., 2014; Markkula et al., 2016). We modeled urgent braking response where the drivers respond at $\tau^{-1} > 0.2\,s^{-1}$. This threshold is the first possible instance for the driver to perceive the situation, and the drivers initiated braking after crossing the threshold. This assumption was based on analysis of driver reactions to critical events in naturalistic driving data (Markkula et al., 2016). The Markkula et al. (2016) study showed a remarkable decrease in brake reaction times when the driver's last glance away from the road returned to the road after $\tau^{-1} > 0.2\,s^{-1}$, indicating reactions time being highly dependent on context, such as situation urgency.

Fig. 2 shows the data sources used for the simulation. Glance patterns were based on the on-road experiment data, while the lead vehicle data were based on the naturalistic driving data. The speed of the