The impact of driver distraction on car following behavior

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ABSTRACT

Engagement in distracting activities is among the leading causes of car crashes. In recent years, there has been a rapid increase in the availability of Smartphone and other connected and infotainment devices, also within the vehicle, and in their widespread use even when driving. This trend exacerbates their potential negative effects on driving. Thus, an understanding of the impact of distraction on driver behavior is essential in order to support the development of effective technology and policy solutions to mitigate its potential risk.

Microscopic simulation models have been successfully used as a tool for investigating and evaluating the operation of traffic systems and different intelligent transportation systems (ITS) applications. Their use has been gaining popularity, especially with the advancement of computer power. The performance measures available from simulation models are much more detailed than the subjective measures based on human observers and can cover more operational scenarios than can be evaluated by observers in the field, whose time for collection of field data is limited.

Car following behavior is one of the main building stones of microscopic simulation models. It is defined when the subject vehicle follows the vehicle in front of it (the leader) and reacts to its actions. Chandler et al. (1958) and Herman et al. (1959) developed the simplest model of linear car-following model assuming a constant sensitivity term. Gazis et al, (1961) developed GM model where they considered a non-linearity in the sensitivity of the response to the spacing and the subject vehicle speed. Studies that followed this line of research over the years tried to improve the model by suggesting different sets of parameters for acceleration and deceleration decisions to reflect different alertness levels and accounting for anticipation (Herman and Rothery (1965), Subramanian (1996), Ahmed (1999)). Despite these improvements, all developed models fall in the category of ideal world where no crashes occur.

Data that would include both driving behavior and distraction states is difficult to collect. Therefore, the approach of this research is to use data that was collected from a simulator experiment that focuses on driver's performance while undertaking several distraction activities. 101 participants completed a simulator experiment in which they drove four scenarios while being engaged in different distracting activity. These scenarios includes talking on a hand-held cell phone, texting, eating and a control scenario with no secondary task. Drivers were instructed to drive as they would normally do in the real world. They were not allowed to pass the vehicle in front. This was also indicted by the markings on the road. Each scenario was composed of six sections. The leader's speed in each section was constant in a speed that was determined in one of four of speed ranges: 20-40, 40-60, 60-80, and 80-100 km/h. the duration of constant speed section was 40 seconds when the speed was in the range of 20-80 km/h, and 30 seconds when the speed was over 80 km/h. When the leader changed its speed between sections, it was with a constant acceleration or deceleration rate that varied between 0.4 and 2.5 m/sec^2. The speeds and the accelerations in each case were chosen randomly from uniform distributions. Data on the longitudinal and lateral position, speed and acceleration of the subject vehicle and other vehicles in the scenario was collected in the driving simulator at a resolution of 0.5 seconds. From this raw data, other variables of interest, such as distances between vehicles, relative speeds and headways were calculated.

This data is used to estimate car following models for drivers that are engaged in the various activities. The well-known GM model (Gazis et al. 1961) was used for this purpose. It assumes that the follower is stimulated to change its speed by the leader relative speed. The sensitivity to that stimulus depends on the subject's speed and the spacing between the two vehicles. The model is given by:

$$a_n(t) = \alpha \frac{V_n(t)^{\beta}}{\Delta X_n(t-\tau_n)^{\gamma}} \Delta V_n^{front}(t-\tau_n) \qquad (1)$$

Where α , β and γ are model parameters. $a_n(t)$ and $V_n(t)$ are the acceleration and speed of the subject vehicle, respectively. $\Delta X_n(t-\tau_n)$ is the spacing between the subject and leader. $\Delta V_n^{front}(t-\tau_n)$ is the leader relative speed (the leader speed less the subject speed). τ_n is the reaction time. The models developed earlier by Chandler et al. (1958) and Gazis et al. (1959) can be derived from this model as special cases. It should be mentioned that the macroscopic flow-speed relationship developed by Greenshields (1934) can be derived from the GM Model by setting β= 0 and γ = 2. No rigorous framework for estimating the model was provided.

The GM model was estimated separately for each of the four activities that were undertaken in the experiment. Different sets of parameters were also estimated for acceleration and deceleration conditions. The maximum likelihood method was used in all estimations.

Variable	Parameter value			
	Talking	texting	eating	Control case
Car following acceleration				
Constant	0.107 (3.71)	0.026 (2.279)	0.175 (3.49)	0.125 (4.33)
Space headway, m	0.252 (3.21)	0.462 (3.89)	0.039 (0.45)	0.154 (2.366)
Relative speed, m\sec	0.431 (7.35)	0.431 (4.49)	0.579 (8.28)	0.562 (10.35)
Ln($\sigma_{cf,acc}$)	0.71 (-26.54)	0.66 (-28.37_	0.63 (-30.9)	0.612 (-37.62)
Car following deceleration				
Constant	-0.3 (-3.86)	-0.05 (-1.68)	-3.08 (-1.91)	-1.42 (-2.3)
Space headway, m	-0.43 (-7.19)	-0.19 (-2.2)	-1.17 (-6.71)	-0.91 (-6.79)
Relative speed, m\sec	1.125 (9.52)	1.39 (5.51)	1.14 (7.8)	1.35 (10.39)
Ln($\sigma_{cf,dec}$)	0.85 (-10.78)	0.81 (-12.09)	0.74 (-17.6)	0.77 (-16.6)

Table 1-Estimation results for the GM Model

Table (1) presents the estimation results. The sensitivity terms are positive for car following acceleration and negative for car following deceleration, the impacts of the variables are significantly smaller with texting and somewhat smaller for eating and cell phone use .The magnitude of sensitivity to a negative relative leader speed is much larger than the sensitivity to a positive one. This is expected since a negative relative speed stimulus may have safety implications whereas a positive relative leader speed stimulus only suggests a possible speed advantage to the driver. As expected, the parameter associated with this term is positive for both acceleration and deceleration, which implies a positive correlation between the relative leader speed and the acceleration the subject applies.

The estimated coefficients of the space headways are negative for deceleration car following and positive for acceleration car following. For deceleration car following this is expected since the underlying safety concern increases when the spacing is reduced. In the case of acceleration car following, as the space headway increase drivers may tend to follow the speed of the leader less and in this case γ^{acc} would be positive. The speed parameter for the car following acceleration and deceleration models wasn't significant, and therefore, was dropped from the specification, such as Gazis et al. (1961) and Ahmed (1999).

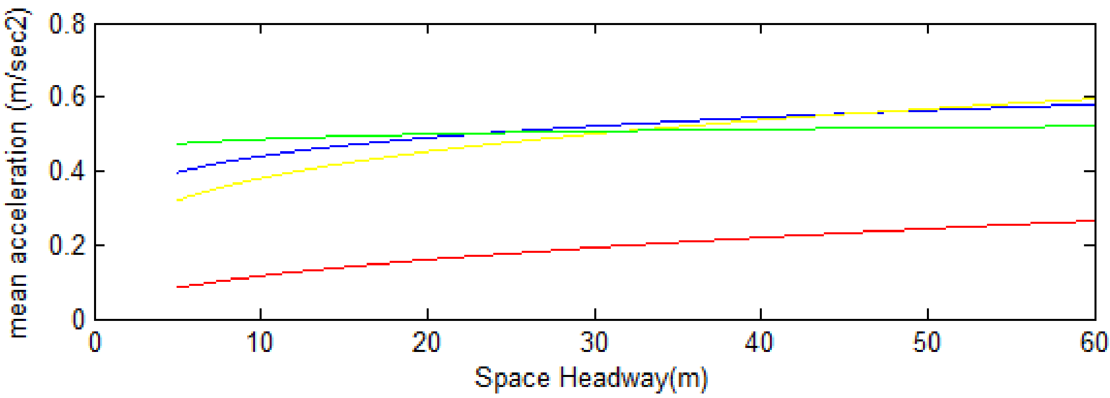

Figure 1: Effects of spacing headway on the mean car following acceleration

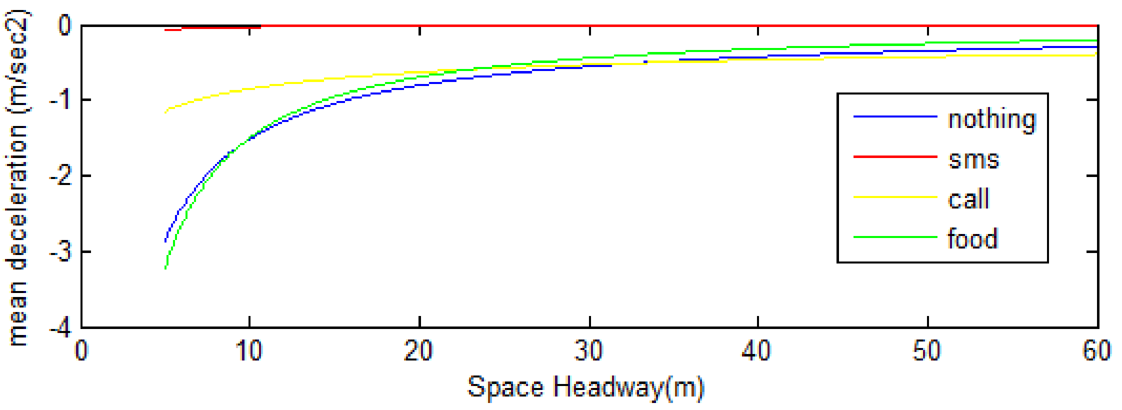

Figure2 : Effects of spacing headway on the mean car following deceleration

Figure 1-2 shows the effect of different variables on the mean car following acceleration and deceleration. In these figures the following default values are assumed: the subject speed is 15m/sec, space headway is 25 m and the relative speed is 5 (or -5) m/sec.

Car following acceleration and deceleration increases with the headway spacing the same for eating activities and the control case, talking in the phone increase less than them while the effect of texting is negligible.

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