Keep Your Eyes on the Road: Young Driver Crash Risk Increases According to Duration of Distraction

Bruce G. Simons-Morton, Ed.D., M.P.H. a,*, Feng Guo, Ph.D. b, Sheila G. Klauer, Ph.D. b, Johnathon P. Ehsani, Ph.D. a, and Anuj K. Pradhan, Ph.D. a

a Division of Intramural Population Health Research, Eunice Kennedy Shriver National Institute of Child Health and Human Development, Bethesda, Maryland
b Virginia Tech Transportation Institute, Virginia Tech University, Blacksburg, Virginia

Article history: Received July 19, 2013; Accepted November 19, 2013

Keywords: Adolescents; Risk taking; Cell phone use; Secondary task; Teenage driver; Naturalistic driving methods

ABSTRACT

Purpose: Secondary task engagement that distracts the driver is a contributing factor to motor vehicle crashes among adults. However, the association between eye glance duration and crash risk with novice teenage drivers has not been determined.

Methods: Vehicles of 42 newly licensed teenage drivers were instrumented with cameras, accelerometers, Global Positioning System(s) (GPS), and other devices. Data were collected continuously for 18 months. Crashes and near crashes (CNCs) were identified by examining highly elevated gravitational force events. Video footage of the 6 seconds prior to each CNC and randomly sampled non-CNC road segments were coded for the duration of eye glances off the forward roadway and the presence of secondary task engagement. The likelihood (odds ratios) of CNC due to eye glance behavior was calculated by comparing the prevalence of secondary task engagement and duration of eyes off road prior to CNC with the prevalence and duration of eyes off road during non-CNC road segments.

Results: Crash risk increased with the duration of single longest glance during all secondary tasks (OR = 3.8 for >2 s) and wireless secondary task engagement (OR = 5.5 for >2 s). Single longest glance provided a more consistent estimate of crash risk than total time eyes off the forward roadway.

Conclusions: Those eye glances away from the forward roadway involving secondary tasks increased the likelihood of CNC. The longer the duration of eye glance away from the road the greater the risk, regardless of type of secondary task. Education and policy discouraging secondary task engagement, particularly for prolonged periods, is warranted.

© 2014 Society for Adolescent Health and Medicine. All rights reserved.

IMPLICATIONS AND CONTRIBUTION

The longer teenage drivers’ eyes were off the forward roadway for any reason the greater the crash risk. Effective education and policy is needed to discourage secondary task engagement among novice teenage drivers.

There is growing recognition that distraction is a contributing factor in many motor vehicle crashes [1–5]. Driver distraction has been defined as the “diversion of attention away from activities critical for safe driving toward a competing activity” [6]. Tasks that are subordinate to the driving activity, termed secondary tasks, that can lead to distraction include the use of personal electronic devices, personal hygiene, eating and drinking, reaching for objects in the vehicle, and adjusting the radio and other equipment on the steering wheel or center console [7]. The use of cell phones and other wireless technologies among novice teen drivers may be particularly concerning, given teenagers’ reliance on electronic devices, lack of driving experience, and high crash rates [8,9]. Moreover, secondary task engagement coupled with impairment...
due to alcohol, drugs, or fatigue, could be particularly problematic for teenage drivers.

Secondary tasks that take drivers’ eyes off the forward roadway [10,11], reduce visual scan [12], and increase cognitive load [13] may be particularly dangerous. According to analyses of data from the 100 Car Naturalistic Driving Study of adult drivers, eye glances away from the forward roadway of 2 seconds duration and longer doubled the risk of a crash or near crash [14]. Another analysis of this naturalistic study concluded that cumulative or total duration of eye glance away from the forward roadway was associated with crash risk [15]. Where single longest glance may represent the complexity of a particular secondary task and the associated demands on attention, the total duration of eyes off the road represents a general pattern of inattention. However, the risk associated with single longest eye glances relative to cumulative eye glances off the forward roadway has not been determined.

The Naturalistic Teenage Driving Study (NTDS), conducted with 42 newly licensed teenage drivers, objectively evaluated driver distraction in the seconds proximal to actual crashes and near crashes using data recording devices installed in the participants’ vehicles, as in the 100 Car Study. Analyses of data from NTDS and the 100 Car Study data found that that secondary task engagement, including dialing, texting, reaching for objects, and eating, increased teenage drivers’ risk of a crash or near crash, but only dialing increased risk among experienced adult drivers [16]. One common characteristic of these tasks is they cause the driver to look away from the forward roadway. Dialing and texting are of particular concern, given the prevalence of personal electronic device use [7,16,17], evidence that these activities increase crash risk [11–13,16], and the increasing number of jurisdictions limiting their use while driving [17].

Analyses of the 100 Car Study of high-mileage drivers over age 18 years indicated that longer eye glances were associated with greater risk [14], but no previous analyses have examined the association between the duration of eyes off the road and crash risk among novice teenage drivers. The purpose of the current research is to examine among newly licensed teenage drivers the association between crash risk and the duration of eyes off the road during secondary tasks. Accordingly, we compared the likelihood of a crash or near crash (CNC) when drivers were visually distracted for various durations with the likelihood of drivers being visually distracted during non-CNC road segments. Specific research hypotheses were formulated for total duration of eye glances (TEOR) and single longest eye glances off the roadway (LGOR) for all secondary tasks and for the subset of wireless secondary tasks, as follows.

Hypothesis 1: Risk increases with each additional second of the LGOR (>1 s, >2, >3, >4, and >5 s).

Hypothesis 2: Risk increases with each additional second of TEOR (>1 s, >2, >3, >4, and >5 s).

Hypothesis 3: Risk is greater for LGOR and TEOR related to wireless compared with all secondary tasks.

**Method**

**Participants**

A sample of 42 newly licensed teenage drivers (22 females, 20 males) from southwest Virginia, in the United States, was recruited and their personal vehicles were instrumented as described [18]. Participants were eligible if they had held a driver’s license for 3 weeks or less at study initiation. According to the study protocol, which was approved by the Virginia Tech Institutional Review Board, each participant could receive compensation of $1,800 in monthly and end-of-the-study incentives for completion of the 18 months of the study.

**Equipment**

Participants drove vehicles instrumented with a data acquisition system developed at the Virginia Tech Transportation Institute [10]. These systems included four cameras (forward view, rear-view, driver’s face view, and over-driver’s-shoulder view) and a suite of vehicle sensors that included multiaxis accelerometers and Global Positioning Systems. Video and driving performance data were collected continuously for the duration of the study.

**Design**

A case-cohort approach was used to evaluate the CNC risk associated with time eyes off the forward roadway. The 6-second non-CNC road segments (controls) were randomly sampled from the NTDS data. The number of control road segments for each driver was proportional to that driver’s mileage. On average, one control road segment was sampled for every 50 miles traveled. The prevalence of time eyes off the road for various durations during the 6 seconds prior to each CNC was compared with the prevalence of time eyes off the road for those durations during randomly sampled non-CNC road segments according to secondary task engagement.

**Crash and near crash**

The dependent variable combined crashes and near crashes (CNC), which were identified by two highly trained Virginia Tech Transportation Institute coders who viewed the video footage 6 seconds before each high gravitational force event (e.g., braking higher than .65 gravitational force). Subsequently, each event needed to be confirmed by a supervisor. A crash was defined as any physical contact between the vehicle and another object. A near crash was defined as any circumstance requiring a last moment physical maneuver that challenged the vehicle’s physical limitations to avoid a crash. Hence, near crashes are similar to crashes in every way, except that physical contact was narrowly avoided. By definition, near-crashes are safety critical events in the same sense that “near misses” are considered safety critical events, for example, in aviation [19], medicine [20], and industry [21,22]. The combination of crashes and near crashes (CNC) has been demonstrated to be a reliable surrogate for crashes, which tend to occur too infrequently to be useful in small naturalistic studies [23].

**Eyes off the road**

The predictor of interest was the time eyes were off the forward roadway. The video footage 6 seconds prior to each CNC was coded for secondary task engagement and eye glance duration. Following the same protocol, coders viewed the video footage of the 6-second control road segments for secondary task presence and eye glance duration. Two dependent variables: (1) single longest glance of eyes off the roadway (LGOR); and (2) total duration of eyes away from the roadway (TEOR) were
LGOR and TEOR to avoid nonindependence problems. Each CNC and non-CNC segment was incorporated to detect the effect of various CNC and non-CNC segments throughout the driving duration. LGOR was calculated as the duration of the single longest eye glance off the forward roadway (LGOR) involving all secondary tasks and the subset of wireless secondary tasks. TEOR was calculated separately for wireless task engagement, a subset of all secondary tasks.

### Calculated Results

LGOR was calculated as the duration of the single longest glance away from the forward roadway during the 6-second window prior to a CNC involving a secondary task and during control road segments. TEOR was calculated as the sum of time the driver’s eyes were not on the forward roadway during the 6-second windows prior to each CNC involving a secondary task and during the 6 seconds of each control road segment. LGOR and TEOR were calculated separately for wireless task engagement, a subset of all secondary tasks.

### Analyses

Odds ratios (ORs) were estimated using mixed effects logistic regression models, which included a driver-specific random term to incorporate the effect of multiple CNC and non-CNC segments from the same driver. Each CNC and non-CNC segment was categorized into durations of >1.0 s, >2.0 s, >3.0 s, >4.0 s, and >5.0 s for both LGOR and TEOR. Separate models were fitted for each threshold value for LGOR and TEOR. In addition, CNCs and non-CNC segments in which the driver engaged in wireless device use were selected and the ORs of driver-glance for this subset of secondary tasks were estimated.

### Results

#### Participants

The 42 participants included 22 females and 20 males with an average age of 16.4 years (SD = .22), 90.5% of whom were white (vs. 7.1% Asian and 2.4% other) and 41.5% of whom were 10th graders (2.4% in ninth grade and 56.1% in 11th grade) [18].

#### Secondary tasks. Table 1 shows the secondary tasks evaluated. Wireless tasks are presented as a subgroup of all secondary tasks.

### Longest glance off roadway and crashes or near-crashes

Table 2 and Figure 1A,B show the CNC likelihood for five durations of single longest glance off the forward roadway (LGOR) involving all secondary tasks and the subset of wireless tasks. For all secondary tasks, the odds of a CNC were 1.7 times higher when a single longest glance off the road was longer than 1 second as compared with when it was less than 1 second. This increased monotonically as eye glance length increased, such that the odds of a CNC were 6 times higher for LGOR > 3 s.

For wireless secondary tasks, the odds of a CNC were 5.5 times greater when the single longest glance off the forward roadway was >2 s and more than 10 times greater when LGOR was >3 s.

### Crashes or near crashes due to total time eyes off road

Table 3 and Figure 2A,B show the odds ratios of a CNC of various durations of total time eye off road for all secondary tasks and for the subset of wireless secondary tasks. TEOR >2 s in length were associated with a 70% increased CNC likelihood.

### Table 1

<table>
<thead>
<tr>
<th>Secondary task</th>
<th>Description/Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tasks other than wireless</td>
<td>Reaching for inanimate, nonphone object</td>
</tr>
<tr>
<td>Reaching for object</td>
<td>Adjusting on center stack or steering wheel: climate control, radio, vehicle system on center stack</td>
</tr>
<tr>
<td>Using radio/HVAC</td>
<td>Operating; window control, seat belt, mirrors/sun visor</td>
</tr>
<tr>
<td>Vehicle operations</td>
<td>With or without utensils; open or closed container; with or without lid or straw</td>
</tr>
<tr>
<td>Eating/drinkings</td>
<td>Prolonged look out of vehicle: crash or highway incident pedestrian, animal, construction zone, inanimate object, unknown object</td>
</tr>
<tr>
<td>Roadside object</td>
<td>Talking/listening: hand-held or hands free</td>
</tr>
<tr>
<td>Wireless tasks</td>
<td>Dailing phone using key strokes</td>
</tr>
<tr>
<td>Cell phone: reaching</td>
<td>Locating, reaching for, picking up phone</td>
</tr>
<tr>
<td>Texting/Internet</td>
<td>Text messaging, e-mail, Internet use</td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Distraction for all secondary tasks</th>
<th>Odds ratios</th>
<th>Confidence intervals</th>
<th>Significance</th>
<th>#subjects</th>
<th>#CNC (&gt;)</th>
<th>#CNC (&lt;)</th>
<th>#Baseline (&gt;)</th>
<th>#Baseline (&lt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater than 1 second versus &lt;1 s</td>
<td>1.7</td>
<td>1.3</td>
<td>2.2</td>
<td>&lt;.001</td>
<td>42</td>
<td>96</td>
<td>181</td>
<td>1,266</td>
</tr>
<tr>
<td>Greater than 2 seconds versus &lt;2 s</td>
<td>3.8</td>
<td>2.6</td>
<td>5.6</td>
<td>&lt;.001</td>
<td>42</td>
<td>40</td>
<td>237</td>
<td>258</td>
</tr>
<tr>
<td>Greater than 3 seconds versus &lt;3 s</td>
<td>4.0</td>
<td>3.4</td>
<td>10.7</td>
<td>&lt;.001</td>
<td>42</td>
<td>19</td>
<td>258</td>
<td>90</td>
</tr>
<tr>
<td>Greater than 4 seconds versus &lt;4 s</td>
<td>7.2</td>
<td>3.3</td>
<td>15.7</td>
<td>&lt;.001</td>
<td>42</td>
<td>11</td>
<td>266</td>
<td>47</td>
</tr>
<tr>
<td>Greater than 5 seconds versus &lt;5 s</td>
<td>8.9</td>
<td>3.3</td>
<td>24.1</td>
<td>&lt;.001</td>
<td>42</td>
<td>7</td>
<td>270</td>
<td>27</td>
</tr>
</tbody>
</table>

### Table 3

<table>
<thead>
<tr>
<th>Distraction for wireless secondary tasks</th>
<th>Odds ratios</th>
<th>Confidence intervals</th>
<th>Significance</th>
<th>#subjects</th>
<th>#CNC (&gt;)</th>
<th>#CNC (&lt;)</th>
<th>#Baseline (&gt;)</th>
<th>#Baseline (&lt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater than 1 second versus &lt;1 s</td>
<td>1.3</td>
<td>.4</td>
<td>3.9</td>
<td>.648</td>
<td>27</td>
<td>17</td>
<td>5</td>
<td>112</td>
</tr>
<tr>
<td>Greater than 2 seconds versus &lt;2 s</td>
<td>5.5</td>
<td>1.9</td>
<td>15.9</td>
<td>.002</td>
<td>27</td>
<td>9</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td>Greater than 3 seconds versus &lt;3 s</td>
<td>10.9</td>
<td>1.8</td>
<td>66.0</td>
<td>.010</td>
<td>27</td>
<td>3</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>Greater than 4 seconds versus &lt;4 s</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greater than 5 seconds versus &lt;5 s</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The category >1 included the glances in the other categories. >2 include glances 2 s and longer, etc. Separate models were fitted for each threshold value for LGOR and TEOR to avoid nonindependence problems. Values not included. Values not included.

**Note:** The category >1 included the glances in the other categories. >2 include glances 2 s and longer, etc. Separate models were fitted for each threshold value for LGOR and TEOR to avoid nonindependence problems.
(1.7 times greater risk); CNC likelihood increased monotonically from 2 to 5 seconds.

For wireless tasks, the likelihood of a CNC for total time eyes off the road (TEOR) for wireless tasks was higher at most durations, but given the wide confidence intervals none of the odds ratios were significant.

Discussion

The purpose of this research was to determine the association between CNC and the duration of eye glance of novice teenage drivers. We hypothesized that crash risk would increase with each additional second of the single longest glance of eyes off the roadway, a standard measure of distraction, and also with each additional second of the total time eyes off the roadway, a measure that represents a general pattern of inattention. We examined distraction involving all secondary tasks and the subset of wireless tasks.

Our findings confirm our first hypothesis that the duration of the single longest glance off the forward roadway would increase CNC risk, which was found to occur for durations >1 s involving all secondary tasks and >2 s for those involving wireless tasks, and odds ratios increased with each additional second of distraction. Fortunately, there were few events of wireless use >4 s, although there were more when all secondary tasks were combined. Four seconds of continuous distraction is a very long duration of inattention, even under relatively uncomplicated road conditions. The findings with respect to our second

Figure 1. Crash or near-crash likelihood for five durations of single longest single glance off forward roadway (LGOR) involving (A) all secondary tasks; (B) wireless secondary tasks*. * >1 included the glances in the other categories >2 included glances in the categories >2, >3, etc.; separate models were fitted for each threshold value for LGOR and TEOR to avoid issues of nonindependence. s = seconds.
hypothesis that each additional second of total time with eyes off the forward roadway would be associated with an increase in CNC risk was also confirmed for all secondary tasks starting at >2 s, but not for wireless tasks. The findings are consistent with research on older drivers [24]. Although both measures of eye glance were useful, our data indicate that LGOR was somewhat more consistently associated with CNC risk.

The third hypothesis of this study was that the association of CNC with eye-glance durations related to wireless device use, relative to all secondary tasks, would be greater because wireless tasks often contribute substantially to cognitive load [25]. The data confirm this hypothesis for single longest eye glance, but not for total time with eyes off the forward roadway. The finding suggests that multiple short glances (each less than 1 second) may be less risky than eye glances lasting >1s. It could not be determined in the current study whether the pattern of distraction among novice teenage drivers favored longer durations of eye glances off the forward roadway compared with adults or if the duration of eye glances related to wireless or other secondary tasks was more dangerous during certain driving conditions than others; for example, driving straight ahead on moderate speed roads with little traffic compared with maneuvering through an intersection in heavy traffic.

Simulation [25,26] and test track research [27] indicate that novice teenage drivers are not as adept as experienced adult drivers at managing secondary tasks such as dialing a cell phone during complicated driving maneuvers. Other simulation research has shown that novice drivers are more likely than adults to look away from the road for longer periods during in-vehicle secondary tasks [28]. Even when secondary tasks do not lead to eyes off the forward roadway, they can increase cognitive load and reduce visual scanning behavior [29]. Previously, we reported that CNC was much more likely for novice teenage drivers than experienced adults for many secondary tasks (only cell phone dialing increased risk for both teens and adults) [16]. We concluded that inexperienced teenage drivers might experience greater CNC risk due to secondary task engagement because they have longer eye glances away from the forward roadway or engage in these tasks under more dangerous driving conditions. Based on the findings presented in this paper, we conclude that longer duration eye glances increase CNC risk. It seems likely that secondary tasks that take the driver’s eyes off the forward roadway pose greatest CNC threat because they prevent the driver from seeing and responding to unexpected road hazards.

Considerable policy attention has been devoted to wireless device use while driving, particularly for newly licensed teenage drivers [17]. Our findings on single longest glance off the forward roadway provide support for policies that restrict electronic device use for teenagers while driving. Previous naturalistic driving research has found that talking on a cell phone was not associated with an increased CNC risk for novice teenagers or adult drivers [16,24], presumably because drivers can maintain forward vision while talking. However, tasks involving modern cell phones, including reaching for, answering, dialing, text messaging, and Internet use, were associated with CNC risk. The findings of this study indicate that any secondary task that takes the driver’s eyes off the forward roadway can increase crash risk, consistent with policy initiatives designed to discourage secondary task engagement.

As the evidence accumulates that distraction is an important cause of crashes, the need for intervention increases. As noted, state policies restricting cell phone use are proliferating, but as was learned in the efforts to increase safety belt and car safety seat use, and to reduce drinking and driving [30], enforcement and public awareness and support are needed. A variety of educational efforts, possibly through driver education, parental management programs, insurance company efforts, and transportation organization activities, is needed to create a publicly supported safety culture that discourages drivers, particularly young drivers, from engaging in secondary tasks while driving.

Implications of our findings include the need for education and policy designed to reduce secondary task engagement among novice teenage drivers. Driver education and parent supervised practice driving and independent driving management provide opportunities to educate young drivers to the risks associated with secondary task engagement while driving and train them to maintain their focus on the forward roadway. Policies that discourage wireless device use may have potential to reduce risk, but it is unknown whether policies directed at novice teenagers or to all drivers are more effective in reducing the intended behaviors and decreasing crashes.

The small sample of volunteer participants from a single region may limit generalization and the power to detect some
associations. Research has demonstrated that near crashes are a good surrogate for crashes [23], but it should be noted that most of the crashes were not severe, only a few caused personal injury. Also, it should be noted that eye glance and secondary task were assessed independently and the durations of LGOR and TEOR were attributed to the presence of a secondary task during the 6 seconds prior to a CNC or randomly sampled non-CND road segments. Therefore, the drivers may not always have been engaged in the specific secondary task the entire period their eyes were off the forward roadway. Research with larger and more diverse samples is needed to examine the variability in the duration of secondary task engagement and risk among drivers of different ages and under various driving conditions, including at night and under the influence of alcohol.

We found that eye glance away from forward roadway involving secondary tasks increased the likelihood of CNC. The single longest glance was a more consistent measure of distraction than total time eyes off the forward roadway. In general, CNC risk increased the longer the period of distraction, regardless of task type. Based on these findings we conclude that secondary task engagement that takes a teenage driver’s eyes off the forward roadway for any reason increases the likelihood of CNC. The findings are consistent with education and policy that discourage secondary task engagement among teenage drivers.

References