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National Surface Transportation Safety Center for Excellence

Distraction Index Framework

Final Report

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EXECUTIVE SUMMARY

This document serves as the final report for Distraction Index Framework, a National Surface Transportation Safety Center for Excellence (NSTSCE) research project that attempted to gain a greater understanding about the potential crash risk and behavioral adaptations that are associated with the use of high-functionality infotainment systems. The study used naturalistic data collected in partnership with General Motors Corporation. The original goal of the study was to examine naturalistic usage patterns of high-functionality infotainment systems.

The usage of a radio while driving has long been considered socially acceptable. Automotive interface design guidelines even use radio tuning as a reference task (i.e., a sample task whose demands should not be exceeded when performance is concurrent with driving) in their suggested tests. As automotive systems develop further, however, infotainment systems have begun to offer an array of entertainment and information-related capabilities that extend beyond the basic radio. An important concern, therefore, is whether or not usage of these emerging infotainment systems will remain within the range of relatively low-risk activities to perform while driving (where radio use has typically fallen in the past). This investigation examined how frequently drivers with access to an advanced and novel infotainment system were involved in crash and near-crash situations over a 4-week period. This assessment included whether the use of the infotainment system was related to the crash or near-crash event, and the documentation of various driver behaviors. In addition, detailed analyses of eye glance patterns in varying situations of infotainment system usage were completed to quantify the level of visual demand that the infotainment systems pose under naturalistic use.

The original study included 17 participants who drove a vehicle equipped with a high-functionality infotainment system for a period of approximately four weeks. The vehicle was instrumented with a standardized data acquisition suite.

The initial study approach was to find instances of crash and near-crash situations in the data set and infer the influence of infotainment system interactions on the risk of crashes and near-crashes. As will be described later, this initial analysis yielded very little data. Therefore, a subsequent analysis was proposed and performed, where previously identified instances of infotainment system use were classified based on their duration. This classification yielded subsets of data that were analyzed to detect and identify patterns in driver behavioral adaptations due to the use of the infotainment system.

The data set, while relatively small, yielded a number of interesting findings. In most cases, these findings are not powerful enough to be conclusive, but show interesting and potentially meaningful trends. In general:

- Infotainment system or cell phone use were present on about 10% of the near-crashes, compared to the 2% of driving time during which infotainment systems were used.
- Use of infotainment systems had measurable demands on the driver’s visual resources.
- Use of infotainment systems had limited or no measurable effect on the control of the vehicle.

- Infotainment systems showed trends towards a reduced propensity of response to unexpected events on the forward roadway, especially when those events were peripheral to the visual field.
- The estimates of crash risk derived from some of these measures place infotainment system use risk at a level higher than “normal” driving, but lower than other visual-manual control tasks that are often performed while driving. These estimates are consistent with the presence of radio tasks in the crash record, at very low levels.

Finally, the analytic approach that was taken in analyzing this study would provide an appropriate basis from which to derive a distraction index, if applied to data in which more distracting activities were undertaken by drivers. While it was not anticipated in advance that drivers would manage their attention to the road as effectively as they did during most infotainment tasks, the metrics and analysis methods which were applied to this study have established a foundation upon which to build further efforts toward a distraction index that could quantify crash risk on the basis of task attributes, driving kinematics, and driving behaviors. In particular, the addition of methods for evaluating attention to events occurring on the road (both centrally and peripherally) in conjunction with glance metrics appears to be a fruitful new development worth pursuing in future work.

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LIST OF ABBREVIATIONS AND SYMBOLS

ANOVAs	Analyses of Variance
LCD	Liquid crystal display
NSTSCE	National Surface Transportation Safety Center of Excellence
TEORT	Total eyes-off-road time
TTC	Time to collision

CHAPTER 1. BACKGROUND

This document serves as the final report for Distraction Index Framework, a National Surface Transportation Safety Center for Excellence (NSTSCE) research project that attempted to gain a greater understanding about the potential crash risk and behavioral adaptations that are associated with the use of high-functionality infotainment systems. The study used naturalistic data collected in partnership with General Motors Corporation. The original goal of the study was to examine naturalistic usage patterns of high-functionality infotainment systems.

The usage of a radio while driving has long been considered socially acceptable, even in current times when distraction has become a large area of focus, as is evidenced by ongoing efforts to summarize ways to measure distraction.[(1)] Automotive interface design guidelines even use radio tuning as a reference task (i.e., a sample task whose demands should not be exceeded when performance is concurrent with driving) in their suggested tests.[(2)]

As automotive systems develop further, however, infotainment systems have begun to offer an array of entertainment and information-related capabilities that extend beyond the basic radio. An important concern, therefore, is whether usage of these emerging infotainment systems by drivers will remain within the range of relatively low-risk activities to perform while driving (where radio use has typically fallen in the past). Or, in contrast, whether the larger video screens, the higher-information-density functions (e.g., iPod, satellite radio), and the larger number of controls being introduced in current production and aftermarket infotainment systems will become a source of additional distraction that may increase crash risk. This investigation examined those issues by leveraging an existing small-scale naturalistic driving data set documenting driver usage of high-functionality infotainment systems. Similar naturalistic driving databases have been used successfully in the past to establish links between distraction behaviors and crashes or near-crashes.[(3,4)]

While radio usage tasks have been the subject of much research,[(5,6,7,8)] the information provided by these studies has been limited. Some studies have used laboratory settings which reduces the applicability of the results. Other studies have tested technology that is now outdated, due to the ever-changing nature of infotainment systems. Current systems broaden the number of modes between which a driver may switch to obtain music or entertainment. They also extend the length of searches for songs or types of media that can be sought by a driver hunting for something to hear, as the titles of albums, artists, and even pictures from album covers are now displayed, and other new functions are available. Newer infotainment systems also typically now include capabilities beyond entertainment – such as navigation support, address book capability, and other capabilities.

In contrast with prior work, this investigation examined how often drivers with access to an advanced and novel infotainment system were involved in crash and near-crash situations over a 4-week period. This assessment included whether the use of the infotainment system was related to the crash or near-crash event, and documentation of various driver behaviors. Of particular note is the implementation of a data coding protocol that documents the presence and detection of events, an important and often neglected element in driving distraction research.[(5, 9, 10,11)] In addition, detailed analyses of eye glance patterns in varying situations of infotainment system usage were completed to quantify the level of visual demand that the infotainment systems pose under naturalistic use.

OVERVIEW OF THE DATA SET USED IN THE CURRENT STUDY

The original study included 17 participants who drove a vehicle equipped with a high-functionality infotainment system for a period of approximately four weeks. Participants used one of two different experimental vehicles as their own for this period of time. The vehicle was delivered to the participant at the beginning of the study and picked up at the end of the 4-week-minimum participation period. Both vehicles were instrumented with aftermarket infotainment systems (Table 1). Throughout their involvement in the study, participants did not receive any instruction on the system nor were they provided with any information about the specific purpose of the study (i.e., to observe interactions with the infotainment system). Drivers did not receive any monetary compensation for participating in this study beyond the use of the experimental vehicle. However, drivers were recruited to ensure that they had higher-than-average interest in listening to music and were capable of using entertainment-related technology. The drivers in the study were unfamiliar with the systems selected for study.

The vehicle was instrumented with a standardized data acquisition suite, based on the one used for the 100-Car Study.[12] The data acquisition system continuously collected audio (from the infotainment system), video, and driving performance data, triggered on the ignition signal. The digital video was collected from four different video cameras positioned to show the driver's face, a view over the driver's shoulder, the forward driving scene, and a close-up view of the infotainment system. All four views were multiplexed into one video stream for later observation and analysis by trained reductionists.

Table 1. Experimental vehicles and infotainment systems.

Vehicle	Infotainment System	Features
2002 Cadillac STS	Clarion VRX755VD	- Folding 7" color liquid crystal display (LCD) touch-screen - AM/FM radio - CD/DVD/MP3 player (DVD image locked out when the vehicle was not in parking gear) - Sirius™ receiver (satellite radio) - iPod™ interface (an iPod™, with the software necessary to add content to it and approximately 80 songs, was provided to each participant) - Steering wheel controls for volume and fader
2005 Ford Crown Victoria	Pioneer AVIC-N2	- Folding 7" color LCD touch-screen - AM/FM radio - CD/DVD/MP3 player; JPG picture reader (DVD playback locked out when the emergency brake was not engaged) - Sirius™ receiver (satellite radio) - iPod™ interface (an iPod™, with the software necessary to add content to it and approximately 80 songs, was provided to each participant) - Navigation System o Map, favorite address entries, and the first screen of the points of interest were the only features active while the emergency brake was not engaged

CHAPTER 2. STUDY METHODS

The initial study approach was to find instances of crash and near-crash situations in the data set and infer the influence of infotainment system interactions on the risk of crashes and near-crashes. As will be described later, this initial analysis yielded very little data. Therefore, a subsequent analysis was proposed and performed, where previously identified instances of infotainment system use were classified based on their duration. This classification yielded subsets of data that were analyzed to detect and identify patterns in driver behavioral adaptations due to the use of the infotainment system.

CRASH AND NEAR-CRASH ANALYSIS

Identification of potential crash and near-crash events was achieved by overlaying the vehicle performance data against vehicle kinematics signatures described in Dingus et al.[(12)] Trained data analysts then watched the video for the potential crash and near-crash events and assessed their validity. Valid events were then subjected to additional data coding that provided information about driver behaviors and eye glance patterns surrounding the event.

Eye glance pattern coding was completed for the duration of the kinematic trigger, including 10 seconds before and 5 seconds after the start and end of the event, respectively. This additional reduction time allowed for the analysis of complete initial and final glances, and was otherwise excluded from analysis. The eye glance metrics that were analyzed included:

- Number of glances
- Average glance durations
- Total glance durations
- Glance rate
- Percent of glances based on frequency and duration
- Total eyes-off-road time (TEORT)
- Percent TEORT

These measures were calculated by eye glance location and split into driving- versus non-driving-related categorizations.

Given the relatively small data set, results were calculated mainly in terms of frequency counts. T-tests were used to assess statistically significant differences in eye glance patterns. Significance was detected using a Type I error of 0.05.

ANALYSIS OF BEHAVIORAL ADAPTATIONS TO DIFFERENT TYPES OF INFOTAINMENT USAGE EVENTS

All interactions with the infotainment system in this data set had been previously identified and cataloged. The cataloging process classified interactions depending on the inferred driver goal. Eye glance coding was completed for a subset of these interactions and for a set of baselines that were matched to the interactions based on duration and vehicle speed.

The current study used a subset of the interactions and matched baselines for which eye glance coding had already been completed. Those interactions were classified based on their purpose, which could be one of the following:

- Listen for something else
- Adjust volume
- Adjust settings
- Navigation
- Other

The duration of interactions within each of these categories was then used to select the subset used in the current study. Specifically, interactions within each of the categories specified above were classified in bins based on their durations. Baselines were treated as a separate category during the selection process. Three percentile levels were chosen to represent events of Lower, Middle, and Higher durations: < 10^{th}, 45^{th}-55^{th}, and >90^{th}, respectively. Durations were calculated from a driver's initial physical contact with the system until that contact ceased after the goal was achieved. There could be pauses between successive operations, as long as the data coder inferred that these operations were steps to reach the same goal. In those cases, the successive operations were grouped into the same interaction. Therefore, interactions could range from a single button press to long periods with multiple button presses and interspersed pauses. When more than one goal was identified within the same interaction (e.g., the participant browsed through different stations to find something he/she wanted to listen to and then performed a quick volume adjustment), the data coder assigned the interaction to what was judged to be the primary goal (it would have been "Listen for something else" on the previous example).

Trained event coders then answered the questions shown below. Coders were asked to use a combination of video views and synchronized kinematic data plots in making their assessments. Additional instructions provided to coders are embedded in the following list (boldface type is used to highlight the questions and choices from any additional instructions):

- **Were there any noticeable and unintentional lane deviations during the event?**
  - **Yes** – driver unintentionally drifted out of lane position at least once
  - **No** – driver maintained a controlled lane position at all times
- **How many unintentional lane deviations can be observed?**
  - **Enter number**. If none are observed, leave 0.
  - DO NOT enter anything other than a number in this field. (Including no spaces)
- **If there was a potential event, what was that event? Pick the option that most closely describes the situation. If there were multiple events, pick the most severe.** Include expected but potentially hazardous scenarios. (Examples include: a lead vehicle braking, whether or not it resulted in a critical event; and a pedestrian waiting to cross that the driver should be aware of.)
  - **No noticeable event**
  - **A lead vehicle is traveling in same direction with lower steady speed**
  - **A lead vehicle is traveling in same direction while decelerating**
  - **Another vehicle traveling in same direction is encroaching in this vehicle's lane**

- **Oncoming traffic is encroaching in this vehicle's lane**
    - **Another vehicle is crossing this vehicle's path**
    - **A vehicle is merging into this vehicle's lane**
    - **Pedestrian is present**
    - **Pedalcyclist or other non-motorist is present**
    - **Animal is present**
    - **Object is present**
    - **Other** (describe in comments column of Excel log, such as start of work zone)
- **For the potential event listed above, what was the sync number at which you can first identify the event?** (e.g., the first sync at which the lead vehicle's brake lights are visible.)
    - **Enter number**. If "No Noticeable Event" above, leave 0.
    - DO NOT enter anything other than a number in this field. (Including no spaces)
- **How does the driver react to the event?**
    - **Not Applicable – No Events**
    - **No apparent avoidance maneuver**
    - **Braking and Steering**
    - **Throttle Release and Steering** (if throttle graph not available, assume a deceleration is due to braking)
    - **Accelerating and Steering**
    - **Braking Only**
    - **Throttle Release Only**
    - **Accelerating Only**
    - **Steering Only**
- **If there is a maneuver, what is the Sync number at which the driver initiated the maneuver?**
    - **Enter number**. If "No Noticeable Event" or "No avoidance maneuver" above, leave 0.
    - DO NOT enter anything other than a number in this field. (Including no spaces)
- **Was the driver glancing forward at the onset of the event? (this is the sync you entered as the start of the event)**
    - **Not Applicable – No Events**
    - **Yes** – driver was looking forward
    - **No, but glance is driving-related -** driver was looking somewhere other than forward, but the glance is related to the driving task
    - **No, glance is NOT driving related** – driver was looking somewhere other than forward for a reason not related to driving (e.g., radio)
- **Were there any more (additional) less severe but noticeable events?**
    - **Yes** – more than one noticeable event occurred.
    - **No** – only the one event occurred or no event occurred.
- **If any, please provide a narrative of the other, less severe events.**
    - **Enter text**. If "No" on above, leave blank.

Several additional dependent variables were generated based on the data coder answers to these questions:

- Lane deviation rate (lane deviations/minute)

- Peripheral or central classification of the event, when one was present (with respect to a driver glancing forward)
- Whether the driver reacted to the event
- Response time (sec) – defined to lapse from the time when a stimulus was first visible on video to the time when a response was observed

Data from the eye glance reduction for each of these infotainment system interaction events were split into three phases. The first was a pre-event phase ("Pre"), covering the 10 sec prior to the onset of the infotainment system interaction. The second was the event phase ("Event"), covering the time from the initial button press until the end of the final button press on the sequence. The third was a post-event phase ("Post"), which covered the 10 sec after the end of the infotainment system interaction (note that this was longer than the 5-second period used in the Crash and Near-Crash Analysis). Baselines were artificially broken up in a similar fashion for comparison purposes, but included no infotainment system interaction.

For each of these phases during an infotainment system interaction, the following dependent variables were calculated:

- Glance rate to the infotainment system
- TEORT
- Percent of glances directed to the infotainment system (based on total glance duration)
- Percent of the number of glances to the infotainment system that were over 2 sec in duration

The analysis used chi-square tests to assess significant differences on frequency counts based on the reduction answers, as well as analyses of variance (ANOVAs) for some of the continuous variables that were generated (e.g., reaction time). ANOVAs were also used to test for statistically significant effects on the variables derived from the eye glance pattern coding. The independent variables were the Type of Interaction (Listen for Something Else, Adjust Volume, and Baseline; others were excluded from the analysis because of their low frequency in the sample), the Duration Classification for that interaction ($<10^{th}$ percentile – "Lower"; 45^{th} - 55^{th} percentile – "Middle"; and $>90^{th}$ percentile – "Higher"), and the Timing of the observation with respect to the interaction (Pre, Event, Post). Significance was detected using a Type I error of 0.05. Post hoc tests used the Tukey correction factor.

CHAPTER 3. STUDY RESULTS

CRASH AND NEAR-CRASH ANALYSIS

The analysis of potential crash and near-crash events yielded no crashes and 46 near-crashes. While there were a sizable number of triggers identified, relatively few were determined to be valid events (Table 2). Infotainment system use was a contributing factor in a small proportion of the near-crash events (3 out of the 46 cases; 6%). Cell phone use as a contributing factor was observed in 2 out of the 46 cases (4%). Fitch and Hanowski [13] observed a prevalence of about 9% usage across several naturalistic driving data sets.

Table 2. Trigger analysis results.

Trigger Type [12]	Number of Triggers	Determined to be Valid*
Button-Push	12	0
Longitudinal Deceleration >0.4g (>0.5 g)	410 (60)	39 (14)
Lateral Acceleration > 0.7g	19	0
Low Forward Time to Collision (TTC)	10	7
Transient Yaw Rate	1306	9

* - Some valid events were identified by more than one trigger; while 55 triggers were valid, they accounted for only 46 unique near-crash events.

The coding process classified the valid events into different categories, depending on the type of conflict that was observed (Table 3), for cases where infotainment system use was present and for cases in which it was absent.

Table 3. Frequency of different near-crashes observed as a function of infotainment system or cell phone use.

Traffic Conflict	Infotainment or Cell Phone Use Present	Infotainment or Cell Phone Use Absent
Animal Crossing		1
Braking to Turn		1
Lead Vehicle Backing		1
Lead Vehicle Decelerating	2	18
Lead Vehicle Incurring on Lane		5
Lead Vehicle Stopped		3
Left Turn Across Path (subject driver)		1
Oncoming Traffic/Oncoming Traffic Turning Across Path		5
Parking Lot		1
Passing on the Right		1
Pedestrian/Pedestrian Incurring		3
Single Vehicle	3	1

Events were also classified (Table 4) based on where the participant was glancing when the precipitating event occurred (if applicable), the extent to which the driver detected relevant objects and events on the forward roadway, the reaction time (if applicable), and the type of reaction. Note that the "Infotainment Use Absent" category included one event for which there was no forward roadway video. This event is not included in the table counts. T-tests identified some significant differences in eye glance patterns (Table 5) between near-crashes where infotainment use was observed and near-crashes where infotainment use was not observed.

Table 4. Distribution of different descriptors of the driving situation across infotainment system use.

Behavior	Infotainment Use Present	Infotainment Use Absent
Forward Glance at Event Onset	3 Glancing / 2 Not Glancing	29 Glancing / 11 Not Glancing
Driver Detection of Relevant Events on the Forward Roadway	1 All / 3 Some / 1 No Events to Detect	27 All / 11 Some / 1 None / 1 No Events to Detect
Response Time	0.4 sec, SD=0.6 (NS*)	1.1 sec, SD=0.9 (NS*)
Response Type	3 Braking / 2 Not Applicable	28 Braking / 8 Braking and Steering / 3 Steering / 1 Not Applicable

* - Difference was not statistically significant

Table 5. Statistically significant eye glance measures.

Eye Glance Measure	Infotainment Use Present	Infotainment Use Absent	*p*-value
Glance Rate to the Rearview Mirror	0.0 (glances/min)	1.3 (glances/min)	p=0.013
Percent Number of Glances to the Rearview Mirror	0.0 %	5.6 %	p<0.01
Percent Number of Glances to the Left Mirror	1.6 %	7.5 %	p=0.030
Average Duration of Glances Forward	2.7 sec	5.0 sec	p<0.01
Average Duration of Driving-Related Glances	2.7 sec	4.6 sec	p=0.029

ANALYSIS OF BEHAVIORAL ADAPTATIONS TO DIFFERENT TYPES OF INFOTAINMENT USAGE EVENTS

Given the diverse nature of the types of infotainment system use events selected, widely ranging durations were observed at the thresholds used to select events (Table 6). Some infotainment use events (e.g., Adjust Volume) were also more common than others. Overall, 533 infotainment use events and matched baselines were considered for inclusion in the analysis.

Table 6. Frequencies and threshold durations of specific event types on the data sample.

Type of Event	<10th percentile Time (sec)/*N*	45th-55th percentile Time (sec)/*N*	>90th percentile Time (sec)/*N*
Listen for Something Else	0.5 / *63*	8.0 – 12.7 / *63*	44.1 / *64*
Adjust Volume	0.6 / *69*	1.4 – 1.8 / *81*	7.7 / *93*
Adjust Settings	0.4 / *2*	0.8 – 1.1 / *2*	8.5 / *2*
Other	0.4 / *7*	3.4 – 5.1 / *7*	28.0 / *7*
Navigation	0.4 / *9*	1.7 – 3.9 / *9*	25.1 / *9*
Baselines	0.5 / *13*	1.8 – 2.4 / *16*	19.3 / *17*

The Listen for Something Else and Adjust Volume events showed a trend indicating an increased likelihood of observable lane deviations as the duration of the event increased. This trend was not observed in the Baseline data (Figure 1). There was a statistically significant difference in the frequencies, with the Listen for Something Else Middle and Higher duration categories having larger frequencies of lane deviations than the Baseline Middle and Higher duration categories, respectively. The Navigation Higher duration category (not shown in the figure) also had a higher frequency of lane deviations than did the Baseline Higher duration category.

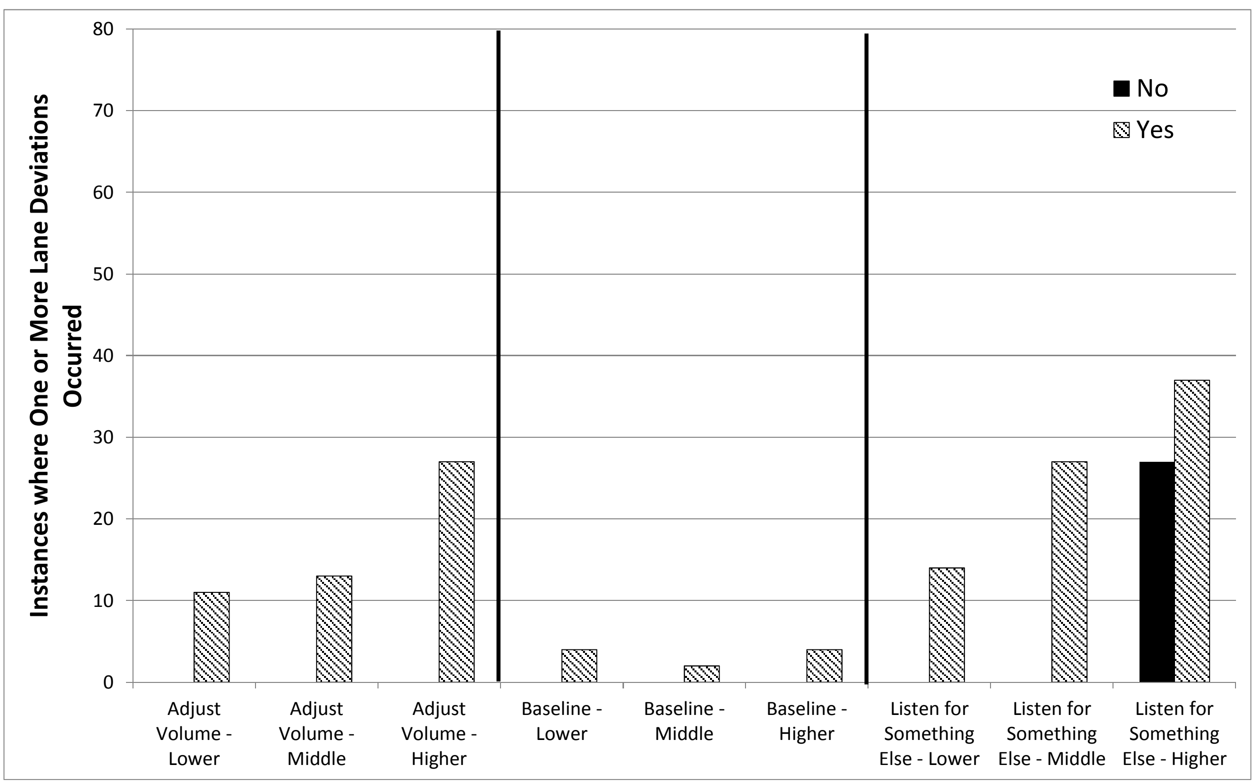

Figure 1. Chart. Number of instances where one or more lane deviations occurred. Black bars indicate that no lane deviations were observed.

These differences in frequencies of lane deviations disappeared when the rate of lane deviations was calculated, suggesting that the effect was mainly due to the differences in durations between the different types of events (Figure 2).

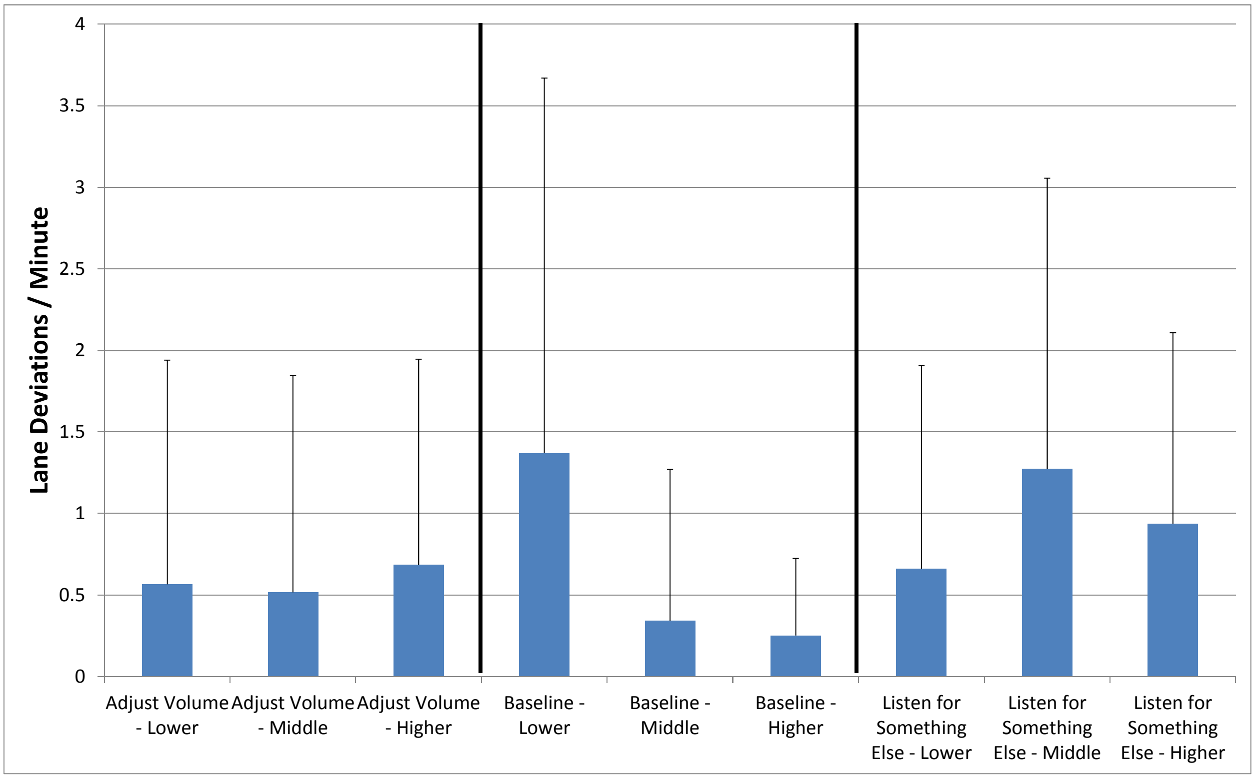

Figure 2. Chart. Lane deviation rates.

Frequencies of occurrence of potentially hazardous events were not significantly different amongst the different tasks that drivers could be performing with the infotainment system (including baselines) or the duration category. There were also no significant effects found due to the presence of a driver response to an event. However, it was observed that drivers always responded to potentially hazardous events in the Baseline conditions (where infotainment system use was not present). No significant effects or notable patterns were found in the reaction times when reactions were observed (Figure 3).

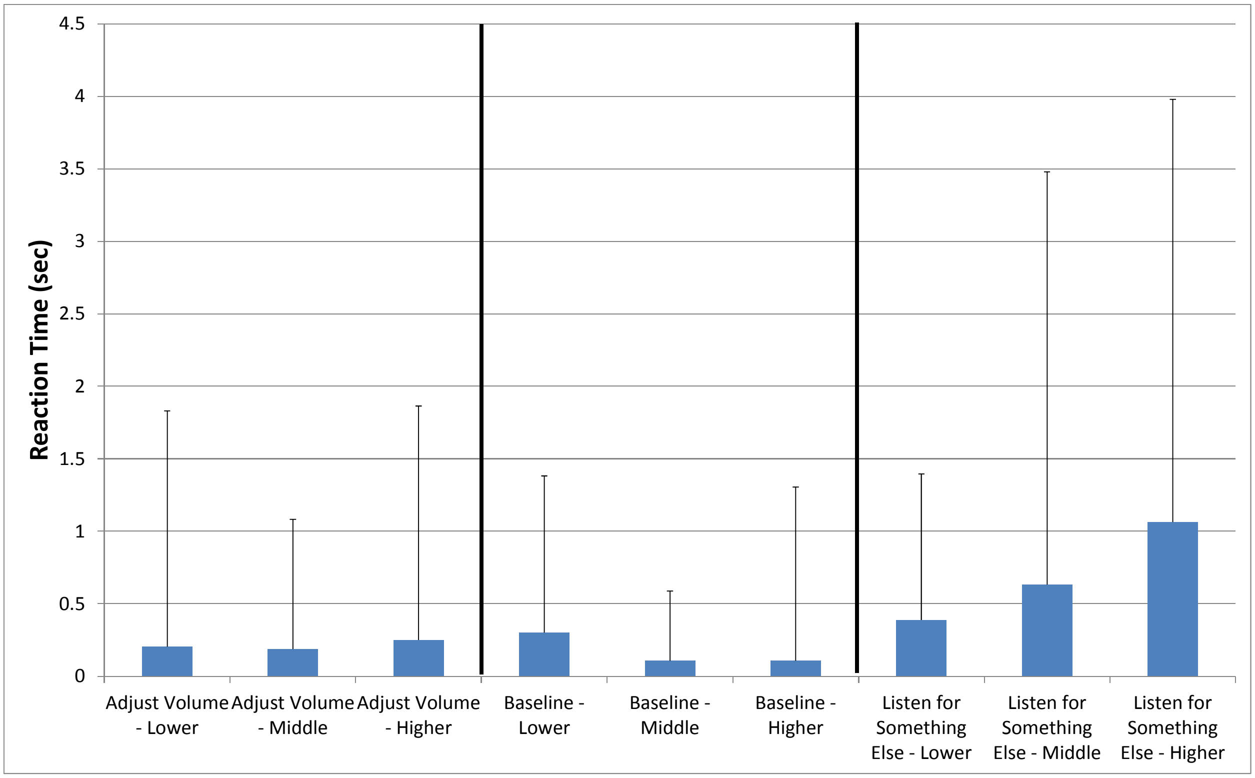

Figure 3. Chart. Reaction time (sec) to potentially hazardous events occurring in the forward roadway.

In terms of drivers' glances, there were no patterns observed in whether the drivers were glancing forward when the events occurred. There was, however, a non-significant trend for drivers to react more often to central events than to peripheral events when they were interacting with the infotainment system (Figure 4). Statistically significant differences were consistently found for the remaining dependent variables related to eye glance.

For glance rate, all independent variables and their interactions had significant effects, so the analysis focused on the three-way interaction (Figure 5). Post hoc tests for that interaction showed:

- No statistically significant differences between any of the Baseline conditions.
- Between the Adjust Volume conditions, the Lower duration event had higher average glance rates than all others except the Middle duration event. No other statistically significant differences were detected.
- Between the Listen for Something Else conditions, the Lower duration event had longer average glance rates than all others. No other statistically significant differences were detected.
- Comparisons between infotainment system interactions and baselines:
    - For the Adjust Volume conditions, the Lower duration event resulted in significantly larger average glance rates than the Middle and Higher duration events in the Baseline conditions.

- For the Listen for Something Else conditions, the Lower duration event resulted in significantly larger average glance rates than all Baseline conditions.
- No other significant differences were detected, but trends are apparent.

- Comparisons between Adjust Volume and Listen for Something Else:
  - The Listen for Something Else Lower duration event resulted in larger average glance rates than all other Listen for Something Else conditions and all Adjust Volume conditions.

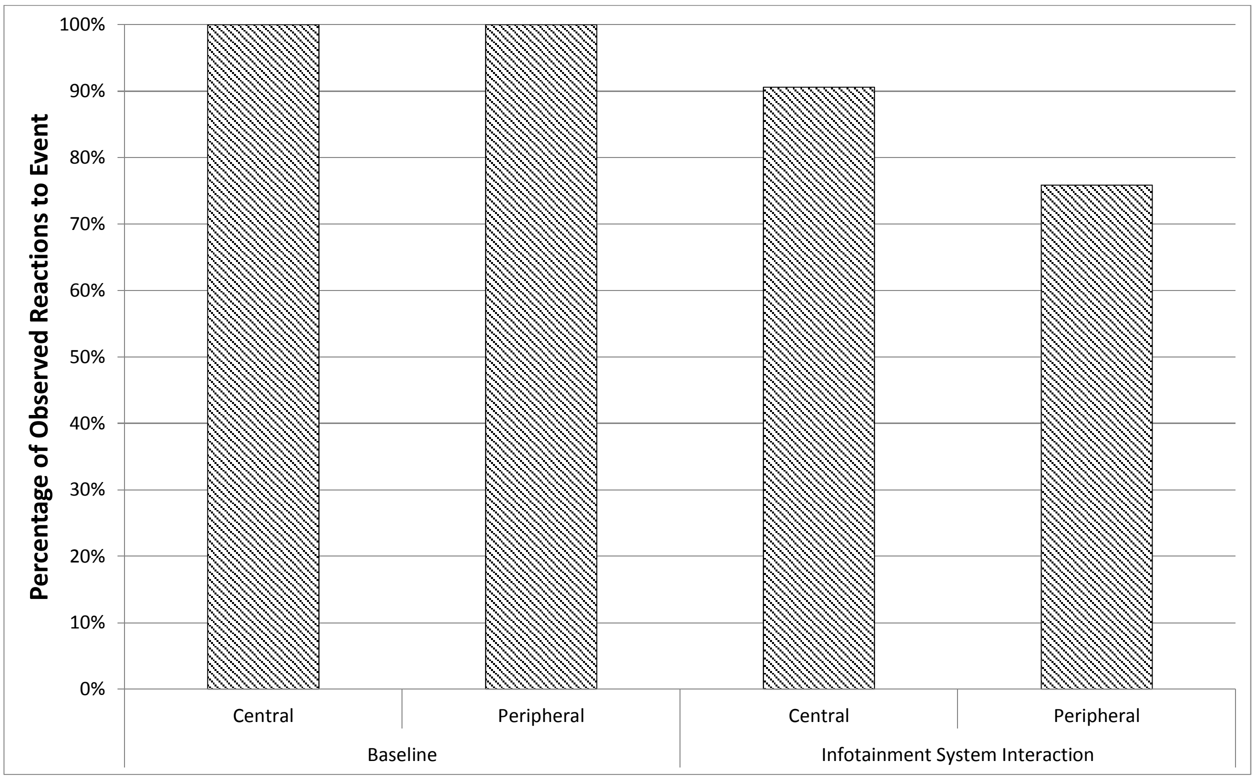

Figure 4. Chart. Percentage of responses to potentially hazardous events as a function of their location on the forward scene.

In Figure 4, Figure 5, and Figure 6 note that the Baseline conditions were split into "Pre," "Event," and "Post" conditions to match their corresponding infotainment use events. These categories are illustrated in those figures to be representative of the analysis that was performed, which used these artificial breakdowns in order to analyze time-matched samples.

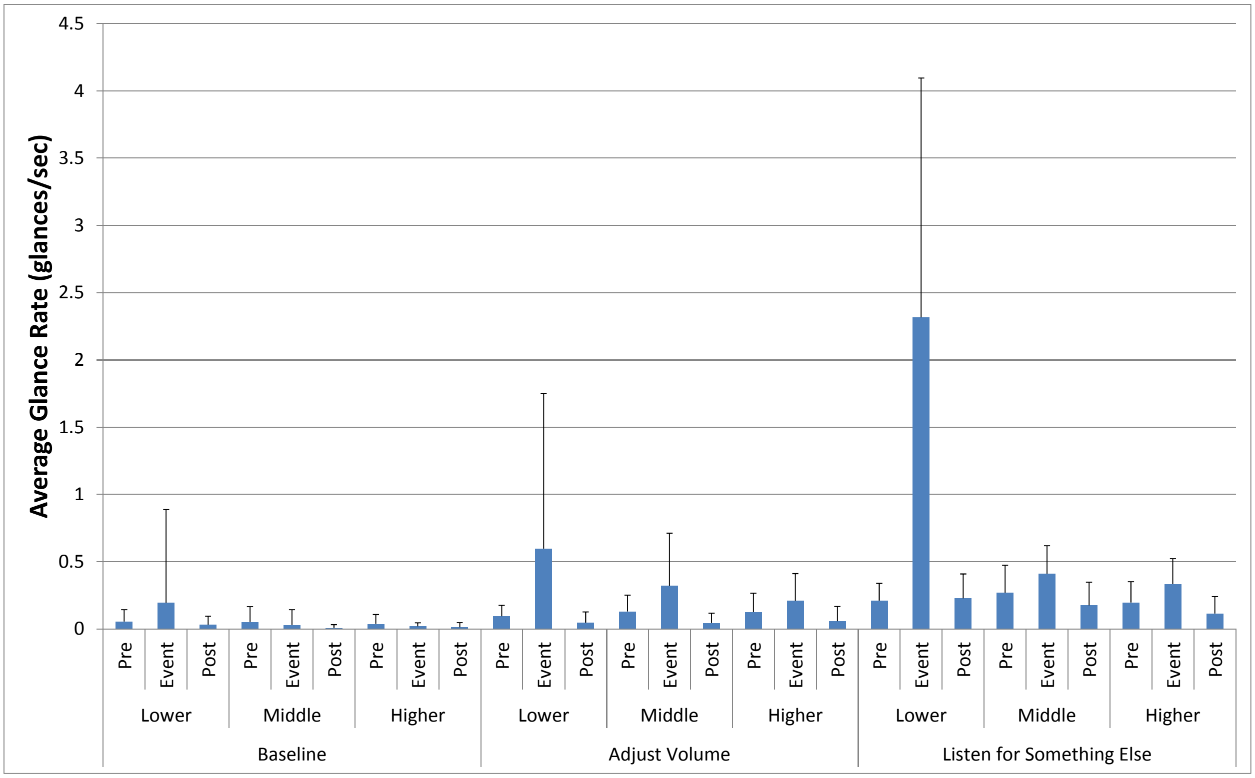

Figure 5. Chart. Glance rate as a function of the Type of interaction, the Classification based on interaction duration, and the Timing of the sample with respect to the actual interaction.

For the TEORT, the analysis also focused on the significant three-way interaction (Figure 6). Post hoc tests for that interaction showed:

- No statistically significant differences between any of the Baseline conditions.
- Between the Adjust Volume conditions, the Higher duration event resulted in higher average TEORT than the Lower and Middle duration events. No other statistically significant differences were detected.
- Between the Listen for Something Else conditions, the Higher duration event resulted in higher average TEORT than all other conditions. The Middle duration event resulted in higher average TEORT than the Lower duration event. No other statistically significant differences were detected.
- Comparisons between infotainment system interactions and baselines:
    - For the Adjust Volume conditions, the Baseline Higher duration event resulted in higher average TEORT than the Adjust Volume Lower duration event.
    - For the Listen for Something Else conditions, the Listen for Something Else Higher duration event resulted in higher TEORT than the Baseline Middle and Lower duration events. The Listen for Something Else Middle duration event resulted in higher TEORT than the Baseline Lower duration event.
- Comparisons between Adjust Volume and Listen for Something Else:
    - The Listen for Something Else higher duration event resulted in higher TEORT than the Adjust Volume Middle and Lower duration events.

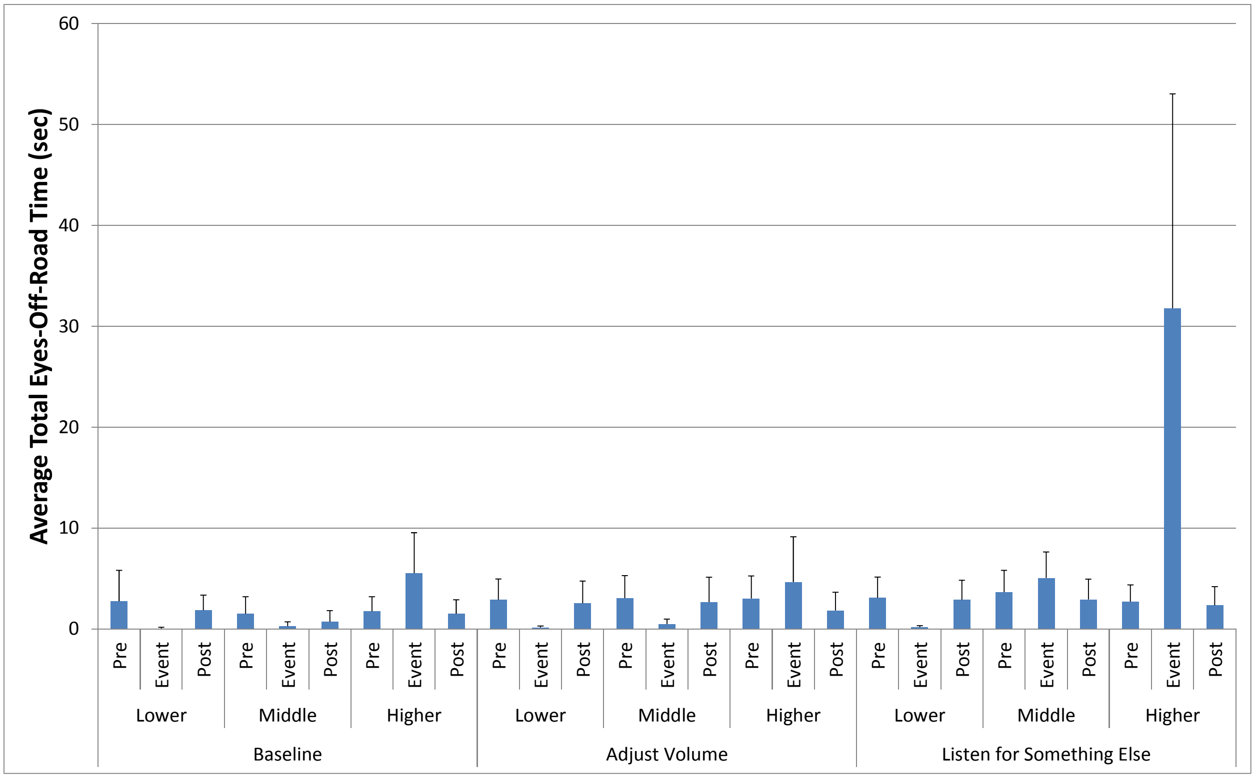

Figure 6. Chart. TEORT as a function of the Type of interaction, the Classification based on its duration, and the Timing of the sample with respect to the actual interaction.

For the percentage of glances directed to the infotainment system (using total glance duration as the percentage basis), the two-way interaction between the Type of interaction and the timing of the sample with respect to the interaction was significant (Figure 7). The following significant effects were found:

- For Baseline conditions, the Pre, Event, and Post periods all had statistically similar percentages.
- For the Adjust Volume and Listen for Something Else conditions, the Pre, Event, and Post periods were all statistically different, both within the same condition and across conditions.
- All Adjust Volume and Listen for Something Else conditions were statistically different from all Baseline conditions.
- All Listen for Something Else conditions were statistically different from the Adjust Volume conditions, except Listen for Something Else Post, which was statistically similar to the Adjust Volume Pre and Event conditions.

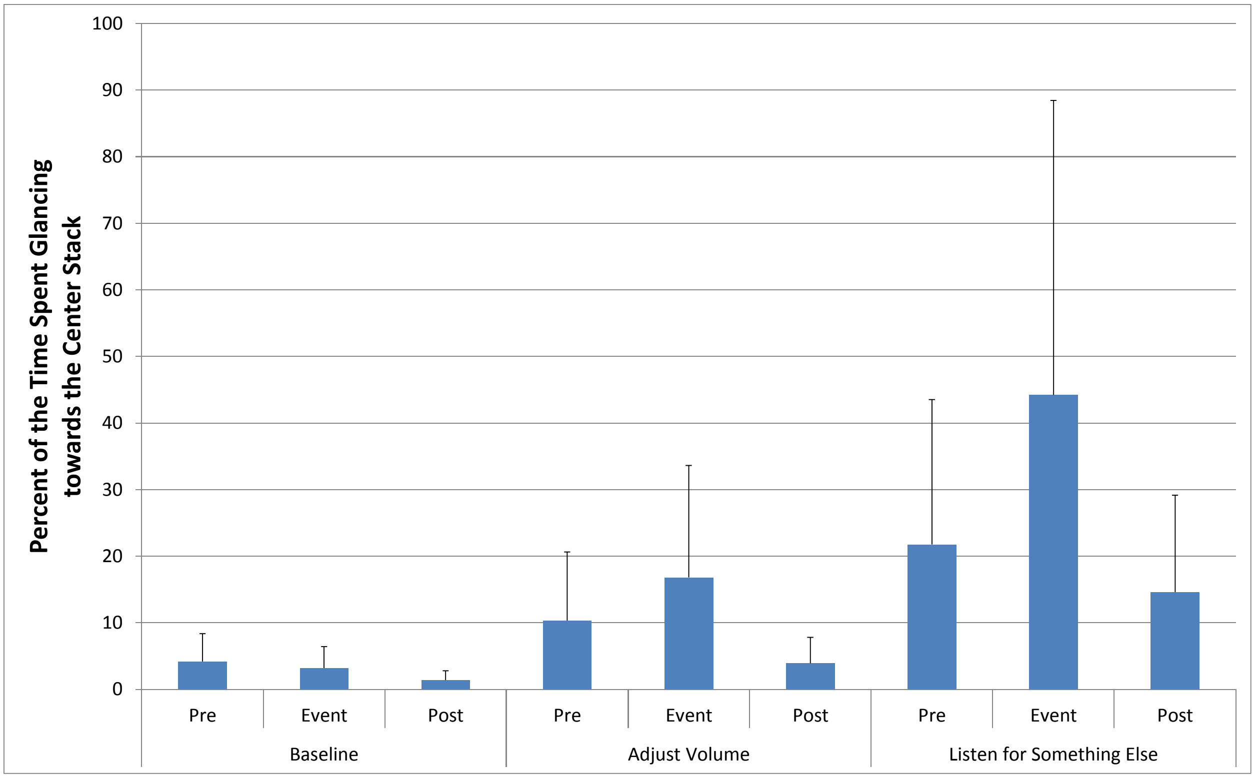

Figure 7. Chart. Percent of glances directed to the infotainment system as a function of the Type of interaction and the Timing of the sample with respect to the actual interaction.

The type of interaction was the only factor with a statistically significant effect on the percent of the number of glances to the infotainment system that were over 2 sec in duration. Post hoc tests showed that the difference was mainly present for the Listen for Something Else condition and the Baseline condition (Figure 8), and the significance level was right at the Type I error threshold.

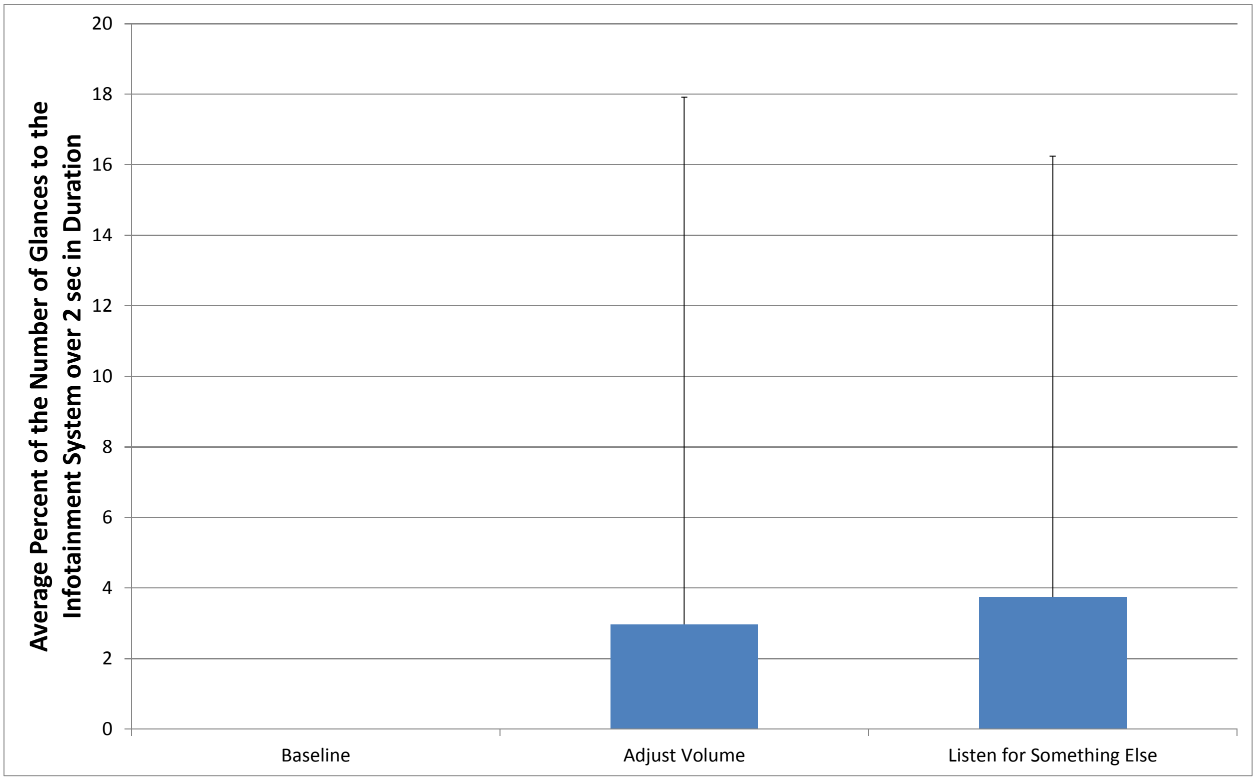

Figure 8. Chart. Percent of glances directed to the infotainment system as a function of the Type of interaction and the Timing of the sample with respect to the actual interaction.

CHAPTER 4. DISCUSSION AND CONCLUSIONS

The data set yielded no crashes and a limited number of near-crashes. While this limits the strength of the conclusions that can be gleaned from the data, it is not surprising given the relatively rare nature of these types of events. The "yield" of valid events from the triggers identified was also very low (~3% overall) but in line with previous observations.[12, 14] Future efforts should be directed towards developing event detection tools that are more sensitive and specific than those currently available. The use of artificial intelligence techniques (e.g., artificial neural networks) may aid in such efforts in the future.

Infotainment system or cell phone use was observed in about 10% of the validated near-crash events in the data set. While low, the number is not trivial, since the percentage of time that participants spent manipulating system controls across the entire data set was approximately 2%. Therefore, there seems to be a nominal over-representation of infotainment system manipulations in near-crash events. Larger data sets are needed to assess the actual presence and magnitude of this effect. Even if such an over-representation does not exist, there were observable adjustments in eye glance patterns that could place drivers at increased crash risk when operating these devices. An over-representation of infotainment system use in crashes and near-crashes would yield hypothetical ties between these adjustments and crash risk. The opposite finding may be indicative of driver self-regulation in the use of these devices (e.g., choosing to use them in low-traffic-density situations). Nominally, infotainment system or cell phone use was also over-represented in "Single Vehicle" traffic conflicts (e.g., lane excursions). In comparison, Stutts et al.[15] reported drivers being distracted with radio adjustments on 11.4% of the cases they examined, but Wang et al.[16] reported a much lower percentage (1.2%) based on crash investigations.

The glance locations at the near-crash event onset are particularly interesting, because they provide a glimpse into the event detection area. Participants were glancing away from the forward roadway on ~28% of cases, but failed to see all the relevant events on ~35% of the near-crash events. Therefore, there is some potential (albeit small) evidence of "looking but not seeing" in ~7% of the near-crashes.

In terms of driver reaction to near-crash conditions, braking was the most common reaction to these near-crash events (~84%), either by itself or in combination with steering. While the reaction times were not significantly different between cases where infotainment use was present and those for which it was absent, it is interesting that drivers' responses were nominally faster when infotainment system use was present. While there was no attempt to assess the severity of near-crash events, perhaps the fact that a nominally quicker response was exhibited in those near-crashes in which infotainment system use was present provides an indirect indication that these situations were more severe (or last-second) and required a quicker response.

Statistically significant results were observed in only a small number of eye glance metrics for the near-crash data set. Seen as a whole, the data suggest that there was definitely some visual demand placed on the participants when they interacted with infotainment systems. This demand was met at the expense of peripheral glances that arguably improve the participants' situation awareness (e.g., glances to the rearview mirror) and of longer glance durations to the forward roadway.

The expanded data set with different types of infotainment usage events similarly identified different eye glance patterns between different types of usage and baseline conditions. These conditions also differed based on the number of observed lane deviations. However, these lane-keeping effects disappeared when the results were controlled for different condition durations. This suggests that, in the context of the types of tasks examined here, lane deviations due to infotainment system usage (if any) occur at rates that are lower than those attributable to other factors (e.g., type of road, road characteristics, type of vehicle) and to individual driver differences.

Potentially hazardous events would be expected to be observed uniformly across the sample if there were no biases in sample selection, and that was indeed the observation made from the data. While no significant differences were observed for the presence or absence of a driver response during an event, it was interesting that attentive drivers in the baseline conditions always exhibited a response. Since the events that were identified were of low severity, lack of response did not necessarily imply a crash or near-crash situation (e.g., a pedestrian that is about to cross stops appropriately at the end of the sidewalk). The problem occurs when the causal factor for the event occurs *unexpectedly* (e.g., instead of stopping, a pedestrian crosses in front of the vehicle). In those situations, it seems that the drivers not using the infotainment system would be less likely to be involved in a crash or near-crash because they have already initiated a preventive avoidance maneuver. Unfortunately, given the limited size of the data set, it is impossible to determine if the lack of significance for this particular factor was due to insufficient power or lack of an actual effect.

Response times also failed to reliably relate to the different types of interactions and their durations. There was, however, a trend that suggested a potential effect of the duration (longer infotainment system interactions were associated with longer event response times) and the type of interaction (the more complex interactions requiring longer response times). Once again, a larger data set would be necessary to determine whether these effects are indeed present.

Another notable trend was the decreased response frequency to potentially hazardous events as a function of their location within the forward scene (i.e., whether they were centrally located on the forward scene, as in lead vehicle braking; or peripheral to the forward scene, e.g., a pedestrian attempting to cross the road). As expected, peripheral events tended to be responded to less than central events. If supported by future research, this would encourage the development of active safety systems that detect and highlight potentially hazardous events on the vehicle's periphery.

Returning to the eye glance analysis, both the Adjust Volume and Listen for Something Else conditions exhibited different eye glance patterns than the Baseline conditions. These differences fluctuated based on the measure. Overall, it appears that conditions on the Lower duration tier exhibited high glance rates, but this is mainly a function of the short duration of the condition itself (which was the denominator in the rate). Lower duration conditions also resulted in higher glance durations, which suggest that drivers may have strategized their glances in terms of duration and frequency. It would seem that drivers performing Lower duration tasks were willing to trade off the use of a single glance to accomplish the task at the expense of a longer duration for that glance. In situations where drivers were aware that multiple glances would be required, they were content with using shorter glances.

These multiple glances add up, even when they have low durations. Long eyes-off-road time was observed when the interactions persisted for longer durations (i.e., in the “Higher” duration conditions). For the Listen for Something Else interactions, when the drivers’ searches persisted beyond 44 sec in length (the Higher duration condition), the average TEORT exceeded 20 sec, which is the limit currently recommended by the Alliance of Automobile Manufacturers for visual-manual tasks.[2] In general, however, TEORT rarely exceeded 10 sec for interactions with the infotainment system, which is much less than the Alliance threshold and in line with observations of radio-tuning interactions in much more controlled environments (based on unpublished existing data). TEORT was used by Klauer et al.[4] in developing crash risk curves based on the 100-Car data.[12] Overlaying the current results on those data on the basis of percentage of event duration is informative (Figure 9). Both of the infotainment system usage conditions are at nominally higher risk levels than is the Baseline condition; however, they avoid the upper part of the curve, where risk appears to increase exponentially as a function of percent of the event duration. Their placement is also compatible with the complexity associated with each of those types of tasks.

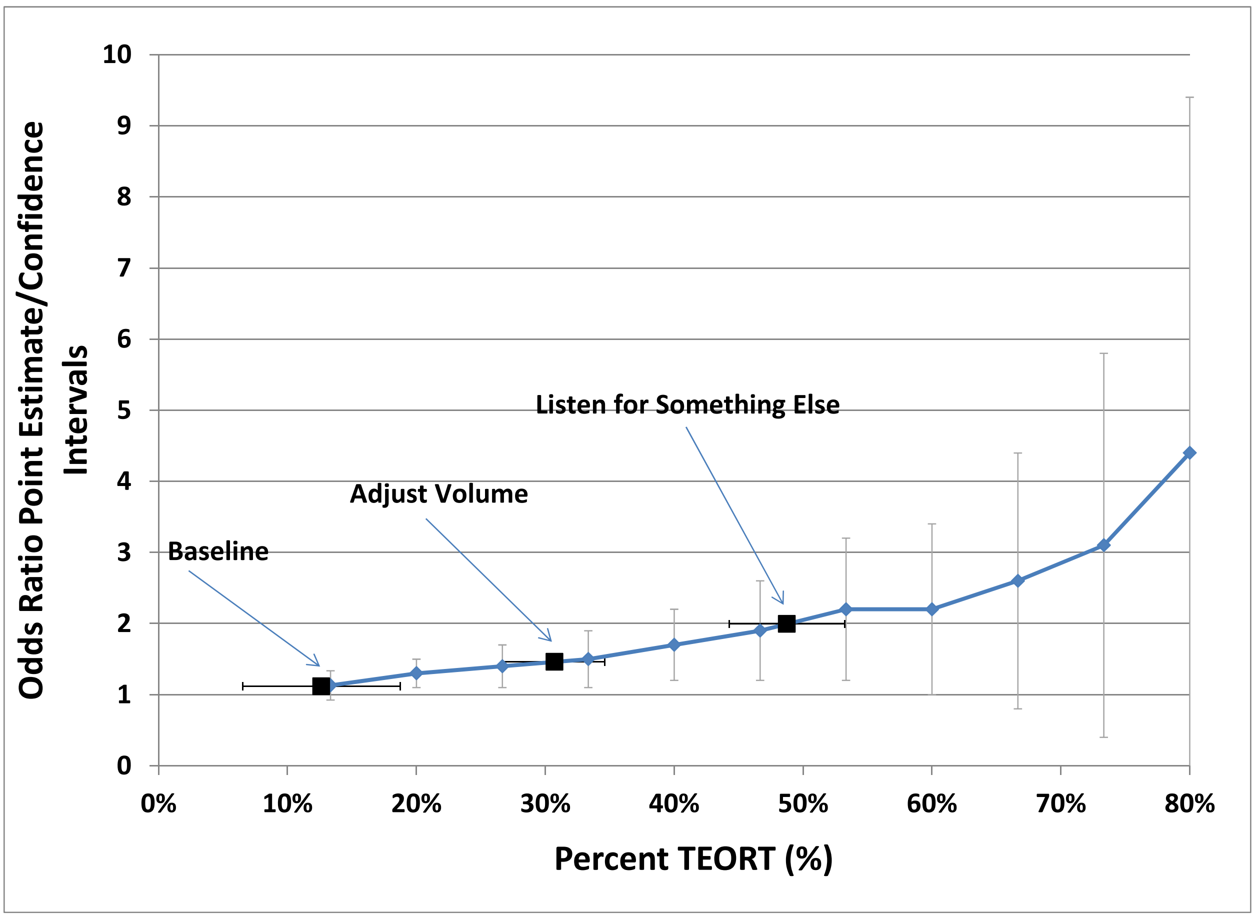

Figure 9. Chart. Infotainment use conditions overlaid on an empirically defined crash/near-crash risk curve.[4]

The percentage of time spent glancing towards the infotainment system provided the most reliable differentiation between types of interactions and the timing of the sample. More complex interactions required that a larger percentage of the available visual "capacity" be dedicated to the infotainment system. This variable also showed differences between the Pre, Event, and Post periods, suggesting the presence of anticipatory glances (Pre) and verification glances (Post). The duration of these anticipatory and confirmatory glances is not trivial according to the results. These glances should be incorporated in tests that assess the visual demand of visual-manual control systems, which would make the results of these tests more applicable to the real world.

Recent research has suggested that crash risk in distracted driving is more directly associated with the presence of long glances than with other glance measures.[(17)] In this study, there was a significant difference in the percentage of glances lasting over 2 sec between the Listen for Something Else and Baseline conditions, suggesting that this task imposes some visual load on the driver. Some long glances were observed for Adjust Volume as well. This suggests that these activities do place the driver at an increased risk of a crash. However, these percentages are often higher for other, more complex visual-manual tasks that are sometimes performed concurrently with driving. For example, Perez et al.[(18)] reported percentages of glances lasting over 2 sec of up to 5.3% for visual-manual control navigation devices and up to 0.7% for voice-controlled systems during destination entry tasks. The values for the visual-manual control devices are higher than the values observed here for radio tuning, which were about 3.0% for Adjust Volume conditions and 3.7% for Listen for Something Else conditions.

CONCLUSIONS

The data set, while relatively small, yielded a number of interesting findings. In most cases, these findings are not powerful enough to be conclusive, but show interesting and potentially meaningful trends. In general:

- Infotainment system or cell phone use were present on about 10% of the validated near-crashes, compared to the 2% of the driving time during which infotainment systems were used.
- Use of infotainment systems had measurable demands on the driver's visual resources.
- Use of infotainment systems had limited or no measurable effect on the control of the vehicle.
- Infotainment systems showed trends towards a reduced propensity of response to unexpected events on the forward roadway, especially when those events were peripheral to the visual field.
- The estimates of crash risk derived from some of these measures place infotainment system use risk at a level higher than "normal" driving, but lower than other visual-manual control tasks that are often performed while driving. These estimates are consistent with the presence of radio tasks in the crash record at very low levels.

Finally, the analytic approach that was taken in analyzing this study would provide an appropriate basis from which to derive a distraction index, if applied to data in which more distracting activities were undertaken by drivers. While it was not anticipated in advance that drivers would manage their attention to the road as effectively as they did during most infotainment tasks, the metrics and analysis methods which were applied to this study have established a foundation upon which to build further efforts toward a distraction index that could quantify crash risk on the basis of task attributes, driving kinematics, and driving behaviors. In particular, the addition of methods for evaluating attention to events occurring on the road (both centrally and peripherally) in conjunction with glance metrics appears to be a fruitful new development worth pursuing in future work.

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