A simulation approach for evaluating the relative safety impact of driver distraction during secondary tasks

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ABSTRACT

Any driver behavior that draws the driver's attention away from the roadway may increase the chance of a crash. This study developed a procedure to simulate safety impacts associated with driver distraction due to various secondary tasks. The simulation models a rear end hazard scenario where a lead vehicle suddenly decelerates while a driver is engaged in a secondary task. The simulation was tested with a sample set of data collected from drivers in test track and on-the-road trials. The outcomes of the simulation can be used to rank secondary tasks on a relative basis using measures that are uniform and safety-relevant.

INTRODUCTION

This paper documents a study performed by the U.S. Department of Transportation (USDOT) National Highway Traffic Safety Administration (NHTSA). The study addresses the question: "How can one measure the impact of visual distraction during performance of a secondary task on a driver's ability to drive safely?" Any driver behavior that draws the driver's visual attention from the road environment is likely to increase the risk of a crash. Driver distraction is the term commonly used to describe a decrement in driving performance due to the shift of attention from the primary task of driving. Data from the NHTSA Fatality Analysis Reporting System (FARS) indicate that driver distraction was a contributing factor in 11 percent of fatal crashes, while the National Automotive Sampling System General Estimates System (GES) estimates that various forms of driver distraction contribute to between 25 and 30 percent of injury and property-damage-only crashes (1). Secondary tasks performed by a driver are defined as activities unrelated to controlling and monitoring vehicle movement, such as inserting a cassette into the audio system, reading a map, or listening to a book-on-tape.

The key source of data for the study was the Crash Avoidance Metrics Partnership (CAMP) Driver Workload Metrics (DWM) project (2) funded by the USDOT Intelligent Vehicle Initiative (IVI). However the DWM project design was not intended to provide direct measurement of safety effects. Therefore NHTSA created a simulation model using the DWM data to enable comparison, on a relative basis, of the likelihood of a rear-end collision [0]associated with various secondary tasks. The simulation links the driver glance behavior (duration and frequency) and vehicle performance characteristics during secondary tasks to a safety-relevant metric.

The first section of this paper describes the DWM project protocol and the data collected. The second section presents the NHTSA simulation approach and methodology. The third section discusses the simulation results, and the final three sections present simulation issues, conclusions, and suggestions for further research.

DESCRIPTION OF THE DRIVER WORKLOAD METRICS STUDY

The Crash Avoidance Metrics Partnership provides a mechanism for the USDOT and automotive industry partners (in this case Ford, General Motors, Toyota, and Nissan) to work cooperatively to study fundamental pre-competitive issues. The CAMP study goal was to measure driver workload associated with secondary tasks. Participants performed a series of specified tasks while operating a driving simulator in a lab, driving on a test track, or driving on actual highways in the Detroit, Michigan area. While some tasks were common to all venues (laboratory, on-the-road and test track) a few tasks were not performed on public roadways because of safety concerns of executing the more difficult tasks while driving. Participating drivers were categorized by gender and by age (20-39, 40-59, or 60-79).

Experiment protocol

The types of tasks performed by the participants included:

- Tasks that were primarily visual-manual in nature and were usually completed quickly (less than 30 seconds), including adjusting the radio, retrieving coins from a change tray, or manually dialing a cell phone;
- More complex visual-manual tasks lasting about a minute, including map reading and navigation destination entry, performed only on the test track to minimize safety concerns for on-the-road driving;
- Tasks that were primarily auditory-verbal and typically lasted for one to two minutes including listening to a book on tape, summarizing its contents, and performing mental travel computations; and
- A "Just Drive" task, providing a measure of driver behavior during a two-minute stretch of driving without any secondary tasks.

During the on-the-road (public roadways) and test track portions of the study, the drivers performed each task while traveling in a three-car platoon. The participant was instructed to follow a confederate lead vehicle (LV) at a safe speed and distance. In turn, the subject vehicle (SV) was followed by a second confederate vehicle, providing an additional margin of safety.

In addition to driving safely and performing the specified secondary tasks, drivers were instructed to be alert for a coast-down without braking by the lead vehicle, illumination of an additional center high-mounted stop lamp (CHMSL) on the LV without braking, or illumination of a turn signal by the following vehicle. Watching for the turn signal activation required frequent glances to the rear-view and/or side mirrors. These object and event detection measures were present as a background for all tasks, including Just Drive.

Kinematic data were collected during the driving trials, including vehicle speed, forward range, forward range-rate, steering angle, brake and gas pedal position, and lateral lane position. Video cameras captured images inside and outside the vehicle. The images captured inside the car included views of the driver's face; these images were later used to determine where the driver was looking at each point in time during the secondary tasks. All data values were collected and recorded by CAMP staff during the course of the experiment.

Eye-glance behavior

Eye glance behavior has long been accepted as a fundamental measure of driver visual attention, or, conversely, distraction. Driving strongly depends on visual attentiveness. Any time the driver is not looking at the forward scene he or she may miss a critical change in the driving environment that leads to an increase in risk (3).

CAMP used a multi-rater procedure recommended by NHTSA (4) to capture eye glance data by manually reducing the video data files. Reduced eye glance data files for thirty-six drivers were available for this study. CAMP selected six drivers for each combination of gender and age based on the clarity of the video views of the drivers' eyes and completeness of collected data. Trained analysts watched the videos showing the drivers' faces and coded where each driver was looking at each point in time during the tasks. The coding procedure identified ten areas to categorize where the driver was looking: forward, up (visor area), instrument panel, down, left mirror, rear-view mirror, right mirror, center stack, missing (obscured), and other. At the same time, glances were rated as related or not related to a secondary task.

DESCRIPTION OF THE MONTE CARLO SIMULATION

Simulation motivation

Table 1 presents statistics from GES crash data (5,6,7), focusing on pre-crash driving movements that are similar to the driving scenario in the CAMP DWM experiments. These pre-crash scenarios included those resulting in rear-end collisions with lead vehicle decelerating, moving at constant speed, or stopped; lane-change or drifting collisions; road-departure collisions; and certain intersection collisions. Rear-end collisions with the lead vehicle decelerating account for approximately one-half of the pre-crash scenarios with a longitudinal crash component. Lateral movement crashes related to distraction accounted for a much smaller magnitude of distraction-related crashes, less than 10% of the total.

Although not all driving distractions result in collisions, many real-world crashes do occur when a lead vehicle decelerates suddenly and the following driver does not have sufficient time to react because he or she was looking away from the road when the lead vehicle began to decelerate. Rear-end collisions with decelerating lead vehicles are the predominant form of distraction-related crashes in these scenarios. Therefore NHTSA used the CAMP DWM data to study the distraction effect of secondary tasks on these types of collisions.

The CAMP DWM protocol was designed to minimize the potential for collisions. This protocol eliminated situations where prompt driver detection and reaction to external stimuli were required to avoid crashes or conflicts. Therefore a simulation approach was devised to generate scenarios where distraction associated with various secondary tasks could be related to the potential for rear end collisions. NHTSA used data from the DWM project to study the question "*if a rapid lead vehicle deceleration had occurred at a random time during a DWM secondary task, what would the result have been?*" The simulation allowed measurement of the results of various behaviors without

Table 1: Distraction as the "Primary" Factor in Selected Pre-Crash Scenarios

Crash Types	Pre-Crash Scenarios	Total Annual Crashes	Distraction as the "Primary" Factor	Estimated Annual Crashes Due to Distraction	Proportion of Selected Pre-Crash Scenarios
Longitudinal:					
Rear End	Lead Vehicle Decelerating	864,000	36%	**311,000**	42%
	Lead Vehicle Stopped	432,000	37%	160,000	21%
	Lead Vehicle Moving	144,000	23%	33,000	4%
Road Departure	Departure on Curved Road	110,000	24%	26,000	4%
Intersection	Red Light Violation	203,000	43%	87,000	12%
	Stop Sign Violation	187,000	33%	61,000	8%
Lateral:					
Lane Change	Drifting	60,000	13%	8,000	1%
Road Departure	Departure on Straight Road	282,000	22%	62,000	8%

running the risk of any actual collisions. The simulation approach focuses on the relative hazard associated with different tasks in the specific lead vehicle deceleration scenario.

A Monte Carlo simulation derives its name from the games of chance at a Monte Carlo casino, which make extensive use of random numbers. Monte Carlo simulations are run hundreds or thousands of times with input numbers randomly drawn from specified distributions. The strength of a Monte Carlo simulation is that the full range of behavior in a complex system can be studied, not just the average or most likely outcome. In the case of a response to lead vehicle deceleration during secondary tasks, it is true that the vast majority of such events do not cause crashes because the inter-vehicle headway is sufficient for the following driver to react in time. However, occasionally short headway, high lead vehicle deceleration rate, long following driver distraction time, and long reaction time combine so that a collision or near-collision results. Using thousands of repetitions, the relative frequencies of rare outcomes can be compared across the different input conditions representing different secondary tasks.

It should be noted that NHTSA engaged in the development of a Monte Carlo simulation tool in the 1970's called DRIVEM (8) which attempted to estimate crash risks based on driver performance models. However, the simulation described in this paper substantially differs from DRIVEM in its approach. While DRIVEM attempted to perform a comprehensive and highly accurate rendition of situational outcomes in many scenarios, this analysis focuses upon a specific scenario and single response. It is able to do so primarily because the goals involve relative measurement of impacts between specified tasks, rather than an absolute prediction of crash statistics. By capturing the influence of several key factors, this approach maintains a tractable solution and focuses on inputs such as eye glance data which are thought to be of critical importance.

Simulation assumptions and definitions

The simulation scenario assumes the following:

- A Lead Vehicle Deceleration (LVD) occurs at a random point during the execution of a secondary task.
- The lead vehicle decelerates at a constant rate of 0.39 g. This rate has been used in some previous CAMP "surprise trials" and last-second maneuver studies (9,10), and is significant enough to require prompt reaction by the following driver.
- The following driver may or may not be looking at the road when the LVD event begins. If the driver is looking away from the road or is engaged in a glance related to the secondary task, reaction to the LVD event cannot begin until the driver's glance returns to the forward scene (i.e. detection of LVD events by peripheral vision is not considered).
- The subject vehicle continues at a constant speed until the simulated driver begins to apply the brake. The model simulates braking only without steering maneuvers.
- The ranges and range-rates between lead and subject vehicles during execution of a secondary task during the DWM trials are representative of naturalistic driving. Experiment protocol attempted to standardize the range and range-rate at which subject drivers began the secondary task, but after that point subject drivers chose the range and range-rate during execution of the secondary task.
- Cognitive distraction is not considered in this analysis; the auditory-verbal tasks are excluded (see discussion below)

On-road and off-road glances

For the Monte Carlo simulation, a simple on-road or off-road classification of glances was used. All off-road glances were treated as equivalent, whether they were strictly task-related or looking at something else such as a mirror, the speedometer, or the passenger. If the driver's eyes were directed forward but the driver was looking at a task-related item (e.g., a cell phone), the glance was coded as eyes forward/task related and considered off-road to reflect the probability that attention was not on the road environment.

Reaction time

If the driver is looking away from the forward scene at the time the LVD begins, the time that passes from the beginning of the LVD event to when the driver's glance returns to the forward scene is called the visual distraction time (VDT). If the driver is looking forward at the time LVD event begins, the VDT is zero.

This study defines Eyes Forward Reaction Time (EFRT) to an LVD event as starting when the driver's eyes are on the road/forward view and ending at the driver's physical response (touching the brake). This differs from the common definition of reaction time as starting with the onset of LVD. We do this because any driver response to a driving event such as a LVD cannot begin until it is perceived, and full perception requires the driver to be looking in the direction of the event. If the driver is already looking forward, EFRT is from LVD initiation to first driver response. However if the driver is not looking forward, the EFRT starts from the point at which the visual attention has returned to the forward view and ends at the first driver response.

Reaction times may be adversely impacted by tasks that require significant cognitive resources. If a driver is "lost in thought," the ability to react may not be fairly represented by the EFRT corresponding to an undistracted situation, even though the driver's eyes may be gazing forward. The ability to detect and adjust for this "cognitive stare" may be enhanced by the use of eye tracking devices or other methods to capture more detailed eye glance information. However, since such detailed eye tracking data were not available, the study excluded all secondary tasks categorized as auditory-verbal, which are assumed to involve significant cognitive activity.

Simulation scenario and methodology

For each driver, for each visual-manual secondary task and the Just Drive task in the CAMP DWM project, one thousand iterations of the simulation were performed. At the start of each iteration, a point was randomly selected during the execution of the given secondary task by the given driver. If the driver had performed that secondary task more than once, the random choice could be drawn from any of the repetitions of the task. Instants occurring during an actual lead vehicle coast-down were not included in the simulation because the range and range-rate between vehicles had already been affected. For each of the thousand iterations, the simulation:

1. Determined the subject vehicle's speed, range to the lead vehicle, and range-rate with respect to the lead vehicle at that time from the engineering data.
2. Determined whether the driver was looking at the forward scene at the selected time, based on the eye glance data for that instant in time. If yes, the simulation skipped directly to step 3 (the VDT was zero). If the driver was not looking forward when the simulated deceleration began, it determined the actual VDT (i.e., how much time elapsed before the driver's glance returned to the forward scene during the actual driving trials). As long as the driver is looking away from the forward scene or is looking at a task-related object, it is assumed that the driver does not see

the LV decelerate, and therefore there is no reaction to the event. After the VDT has passed, the EFRT can begin.

3. Drew a random EFRT from a lognormal distribution with mean of 1.25 seconds and standard deviation of 0.46 seconds. True reaction times to a lead vehicle braking are not available from the CAMP DWM trials since there were no lead vehicle braking events with the lead vehicle's brake lights visible. Therefore the distribution for reaction times used by the simulation was based on trials in the literature (11,12,13) where braking was required. Past research has suggested that such reaction times are skewed toward longer values (11) and are consistent with a lognormal distribution (14, 15). At the end of the EFRT, the "simulated driver" began to apply the brakes.
4. Computed the projected range and range rate between the LV and SV at the time the simulated driver applied the brakes. These values are based on the initial range and range-rate, the constant 0.39g deceleration rate of the lead vehicle, and the assumption that the SV does not take any action until the simulated driver begins to apply the brake.

In summary, the result of each simulation iteration was determined by three primary factors: the range and range-rate at the starting instant of the LVD, the remaining duration of the driver's glance away from the forward scene (if any), and the assigned eyes-forward reaction time. These factors combined to simulate the range and range-rate when the driver begins pressing the brake. Two random draws are involved for each iteration. First, a random point is chosen during the execution of the given task by the given driver. The speed, range, range-rate, and VDT (if any) are taken directly from the DWM data at that randomly-chosen point in time. Second, the EFRT is drawn from a lognormal (therefore non-negative) probability distribution.

Simulation outcome – conflict state

Each iteration of the simulation for a given driver and secondary task produced a range and range-rate at the time of SV braking. A previous NHTSA study (16) defined four conflict states (low risk, conflict, near crash, or crash imminent) on the basis of range and range-rate at the time of first braking while approaching a stopping lead vehicle. The simulation outcome can be directly mapped to one of these four conflict states for a LVD scenario. The thousand repetitions produced a thousand conflict states. The percentage of "crash imminent" (i.e. SV braking is insufficient to avoid a crash) results is presented as the Hazard Index. The Hazard Index is an indicator of relative safety effects of distraction caused by the secondary task.

DISCUSSION OF SIMULATION RESULTS

Six secondary tasks considered to have a high workload were performed only on the test track. This study focused on test track data so these tasks could be included. Of the 18 eye glance data files available for test track subject drivers, a usable set of eye glance data for all 13 visual-manual tasks and the Just Drive task were available for 12 subject drivers. For this presentation we labeled the visual-manual tasks as Vis-A through Vis-M.

Compensatory behavior

While engaged in secondary tasks, drivers have the potential to make adjustments to their car-following behavior, either consciously or unconsciously. These adjustments may influence the distribution of initial conditions for lead vehicle deceleration events, which in turn influence the outcomes. For example, if a driver increases the following distance while engaged in a particular

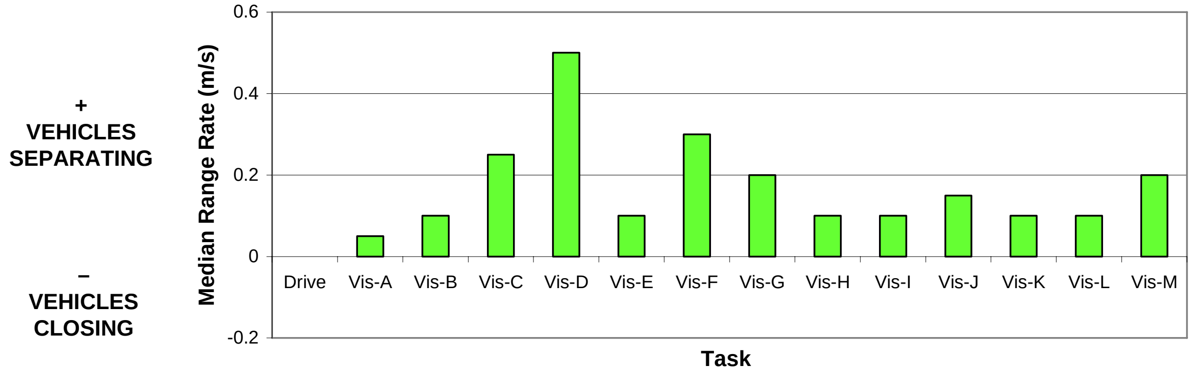

Figure 1. Median Range-Rate (Rdot) During Task Performance

task, the chance of a crash may be reduced by this increase in the following distance. On the other hand, if a driver unconsciously gets closer to the lead vehicle when engaged in the secondary task, the chance of a crash is likely to be higher.

The experimental protocol directed drivers to be approximately 35 meters behind the lead vehicle when the tasks were initiated. However, subsequent car-following distance (during the task) was under the driver's control. The median range-rate to the lead vehicle during the performance of different tasks is shown in Figure 1. The observed tendency toward a positive range-rate (distance between LV and SV increasing) suggests that drivers compensate for secondary task performance by "falling back." Since the simulation framework presented here includes the actual range and range-rates that drivers elected to maintain during the tasks, the simulation explicitly incorporates this compensatory behavior exhibited during the driving trials.

Conflict states

Figure 2 shows the range and range-rate at initial SV braking point for each iteration for one driver and one task. It also overlays the dividing lines between driving conflict states to illustrate the classification of the simulated outcomes into different levels of risk. The range and range-rate at initial SV braking determine the conflict state into which each iteration result falls. The number of trials in each conflict state is then counted and divided by the total number of iterations to yield the percentage of iterations in each conflict state. Since the lead vehicle decelerations are distributed randomly across the task performance time, the percentages may be interpreted as the probability of a lead vehicle deceleration event resulting in each conflict state.

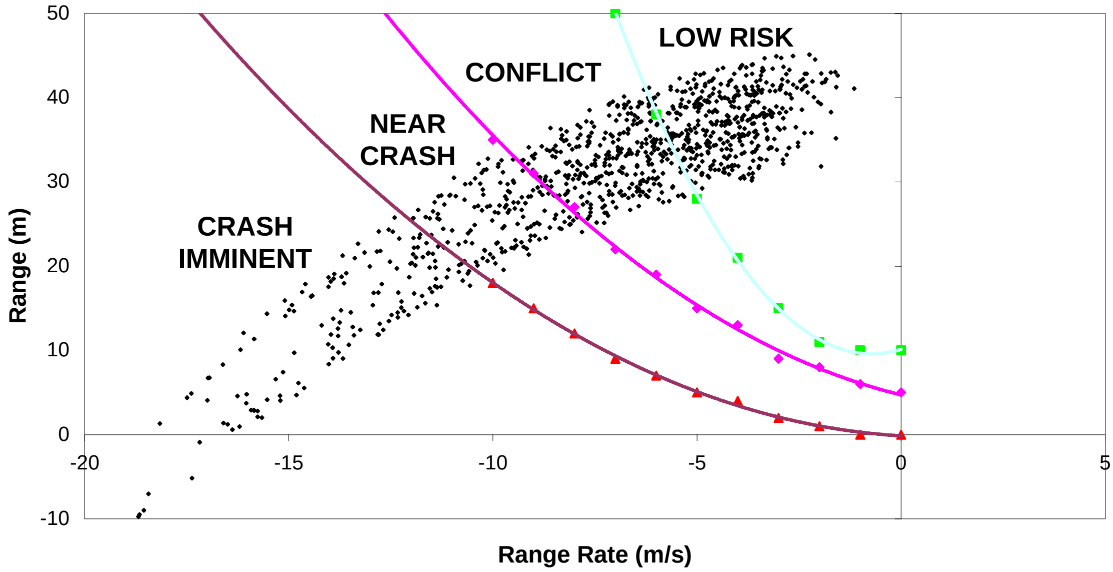

Figure 2. Simulated Outcomes (Range and Range-rate at Initial Brake Response)

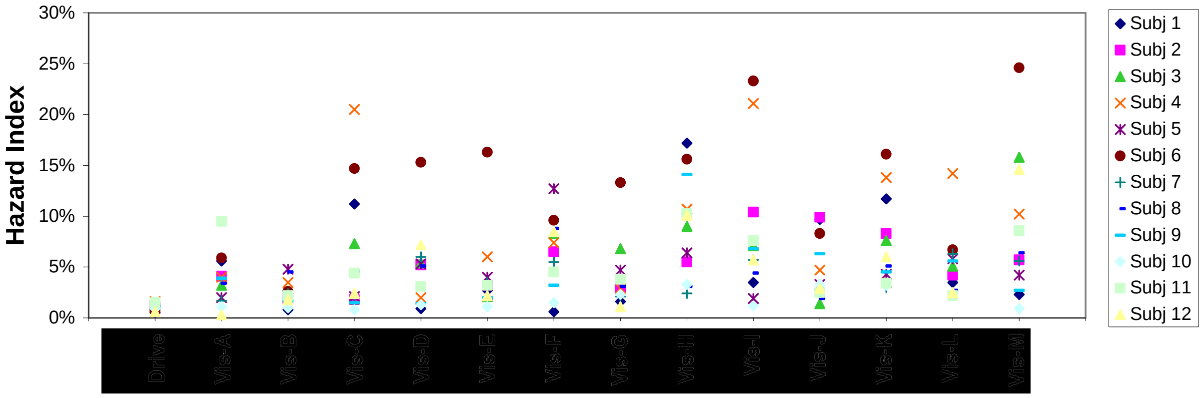

Figure 3. Hazard Index Scores for Visual-Manual Tasks for 12 Subjects

Statistical comparison of the hazard index across secondary tasks

The simulation permits the calculation of a "Hazard Index" for each driver and secondary task. The hazard index reflects the potential for collision caused by the driver distraction associated with the performance of a secondary task. Figure 3 shows the hazard index results for the 12 participants analyzed; a considerable amount of variation between subjects is seen for many tasks.

A Levene's test for equal variances (17) found that the variances of the tasks were not the same at the 5% significance level ($F=32.4 > F_{crit}=1.83$). Since the variances were not the same, a two-way nonparametric Friedman's test (18) was conducted to compare the results across the various secondary tasks. This method uses ranks to control for variation and to determine if there are significant differences between the tasks. The results of the Friedman's test indicate that the tasks are not all the same at the 5% significance level ($F=64.6 > F_{crit}=5.89$). In other words, we can say with 95% certainty that for the available data, there is a significant difference among the task rankings. There is less than a 5% chance that the tasks had basically the same hazard index, and the observed differences arose by chance.

Since the secondary tasks were designed to range from easy to difficult, the result reported above is a confirmation of the experimental design. The Friedman test itself cannot say which task should be ranked higher or lower than any other particular task. For that goal, the multiple comparison procedure described in Conover (18) was used as a follow-up to the Friedman test.

For the Conover test, a threshold value is calculated based on the number of subjects, number of observations per subject, and the desired confidence level. The rank sum scores derived for the Friedman test are compared between a pair of tasks. If the difference in the rank sum scores exceeds the threshold, then there is a statistically significant difference between the ranks of the two tasks; otherwise the difference is not statistically significant. For this set of data, the threshold level of statistical significance was 32.4.

At the low end of the hazard index scale was the Just Drive task. It was expected that most or all of the secondary tasks would have a hazard index that ranked higher than that of Just Drive, and that expectation was confirmed. The ranks of all 13 of the other tasks were higher than that of Just Drive at the 95% confidence level (i.e. the rank sum for those tasks exceeded that of Just Drive by more than 32.4).

Five tasks stood out at the high end of difficulty. These tasks had rank sums that were statistically higher than most of the other tasks. Four of the five tasks in this group were tasks that were performed only on the test track. The experimenters' judgment that these tasks were likely to cause more visual distraction was confirmed.

The remaining eight tasks had intermediate rank sums, which were not separated by an amount great enough to show statistical significance

Figure 4 shows the rank sum scores for the 13 secondary tasks and Just Drive. At the left of the figure are the five tasks ranked near the top of list, and which have a statistically higher ranking than most of the other tasks. In the middle are the eight tasks which are statistically indistinguishable from each other, but still statistically higher than the Just Drive task, which is shown at the far right.

SIMULATION ISSUES

Interpretation of simulation results

To illustrate the application of the simulation model, usable data were available from twelve subjects. The results presented here, therefore, are intended to provide an example, and may not be representative of the general driving population.

Alternate methods of ranking tasks include:

- Rankings based on the total percentage in both near-crash or crash-imminent categories rather than only the crash-imminent.
- Ranking based on deceleration required to avoid a collision, given range, range-rate, and LV deceleration level at the instant of first braking.

It should be noted that comparing tasks does not have to be done using only a single metric. Rankings may ultimately be based on multiple dimensions of performance.

Task duration

The visual-manual tasks examined in this study lasted until they were completed, typically requiring less than thirty seconds to perform. A few, such as Navigation Destination Entry, required significantly longer to complete. In contrast, the Just Drive task duration was fixed at two minutes.

The different task durations posed a major impediment to the comparison of workload and safety effects for different secondary tasks. The eye glance literature (19) clearly indicate that longer eye glances away from the forward scene increase the risk of a crash, but the relative risk of a short task

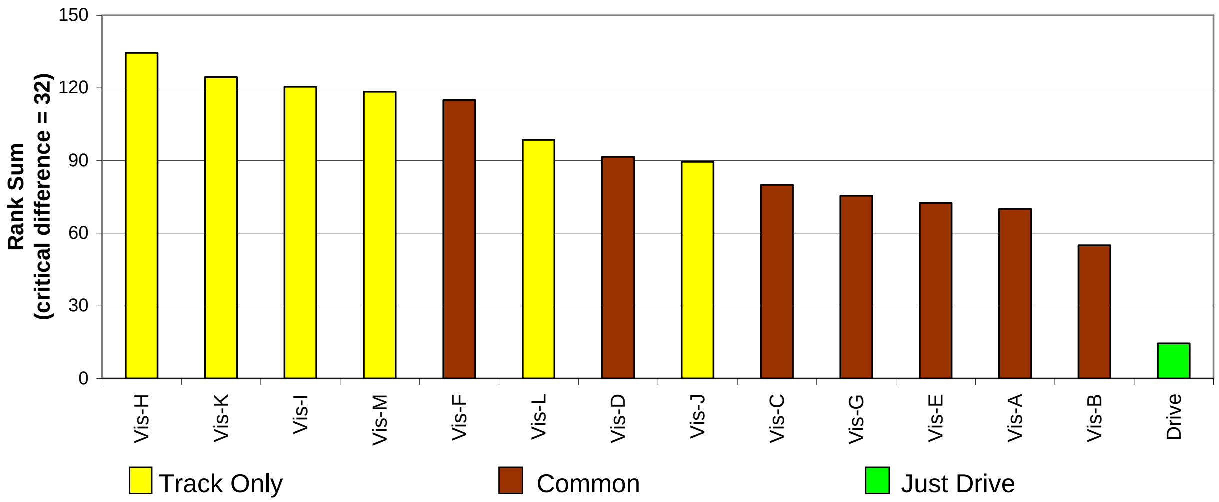

Figure 4. Hazard Index Rank Sums for 13 Tasks and Just Drive (12 Subjects)

with a high amount of visual distraction to a longer task with a lower amount of visual distraction has not been determined.

If two secondary tasks have identical eye glance patterns, the longer task imposes the greater safety risk. The risk is greater because the chance of an external event requiring a response is directly proportional to exposure. The tradeoff and relative strength between task duration and hazard index/distraction level is by no means evident.

Observed reaction time to visual stimuli

Since the CAMP DWM trials included three types of test for response to external visual stimuli (the lead vehicle coast-down, the lead vehicle CHMSL illumination, and the following vehicle turn signal indicator), it would be possible to use driver reactions to those events as a measure of driver situational awareness. However, there are two fundamental problems with doing so.

First, if the external event is of brief duration, the effect of visual distraction is not so much a lengthening of the reaction time as it is the increased chance of missing the event altogether. If the event is missed, the concept of reaction time is meaningless. A missed reaction cannot be compared to a reaction in response to a significant lead vehicle deceleration.

Second, given the protocol of the trials, even when the driver noticed the external event, there was no need for an urgent response. In the case of the lead vehicle coast-down, as well as the cases of CHMSL illumination and turn signal activation, the subject driver knew there was no danger. Such a lack of urgency means that drivers' reactions times cannot be compared to the reaction time realized in an actual sudden braking scenario. That is why the simulation used reaction times documented in other studies where sudden braking was required.

Non-uniform distraction levels

The visual and/or mental workload imposed by a secondary task can vary during the task. Periods of high distraction may alternate with periods of attentiveness. The analysis can either concentrate on the periods of high distraction or attempt to handle duration.

The approach used by the simulation uses distraction levels drawn uniformly from all times when the task was being performed. With this method, periods of high and low distraction will be weighted with the same frequency as that observed over the long run for multiple performances of the task.

An alternate approach involves selecting a short time period (e.g., 10 seconds) and then looking for the period of that length exhibiting the greatest impact on driving performance during each secondary task. Utilizing this selected period for the simulation yields results that reflect a "worst case" scenario for each task.

CONCLUSIONS

The analyses presented here illustrate a Monte Carlo Simulation approach to assess relative rear-end collision risk associated with secondary tasks. The structure of the simulation follows directly from a chronology of a lead vehicle braking event. Elements of visual distraction have been incorporated into the structure as well as the potential for compensatory behavior through the use of actual range and range-rates from secondary task performances. The simulation utilizes data generated during the CAMP DWM on-the-road and test track trials.

The simulation approach:

1. Captures key factors in the lead vehicle decelerating scenario;
2. Results in a metric that permits the comparison of secondary tasks;
3. Produces reasonable initial results; Just Drive is the lowest risk task, while the test-track-only tasks originally judged to have the highest visual demands generally resulted in the highest hazard indexes and the highest ranked level of risk; and
4. Establishes a methodology with direct relevance to safety.

RECOMMENDATIONS FOR FUTURE STUDY AND RESEARCH

Brake reaction times

Since the CAMP DWM data set does not include the participant braking in response to a sudden lead vehicle deceleration, more realistic brake reaction times could be obtained from naturalistic driving studies, such as the 100 Car Naturalistic Driving Study (20) conducted by the Virginia Tech Transportation Institute (VTTI) for USDOT.

Cognitive reaction times

While there is good research evidence that cognitive distraction does exist (21), there is no <u>direct</u> measure of cognitive distraction available in this data set. Measurement is further confounded in this data set by task duration being artificially set on the tasks that are most likely to have a cognitive component, i.e., the auditory-verbal tasks. Cognitive reaction time might be measured using reliable eye-tracking systems rather than eye glance reduction from low-frequency video.

Other factors

Among factors not already discussed, several areas offer high potential for useful future research. A better understanding of drivers' task engagement decisions and the ability to accurately assess potential risks would enable other aspects of compensatory behavior (i.e. choice not to engage at a given time) to be incorporated, perhaps with the assistance of naturalistic driving data. The specific nature of tasks with respect to generating and affording interruptions and active (e.g. phone ringing) vs. passive (e.g. read a display) qualities may also play a significant role in performance. Other promising areas of study include investigation of drivers' familiarity with tasks, peripheral vision, and perception of changes in the road scene.

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