

Driver Distraction/Overload Research and Engineering: Problems and Solutions

2010-01-2331

Published
10/19/2010

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ABSTRACT

Driver distraction is a topic of considerable interest, with the public debate centering on the use of cell phones and texting while driving. However, the driver distraction/overload issue is really much larger. It concerns specific tasks such as entering destinations on navigation systems, retrieving songs on MP3 players, accessing web pages, checking stocks, editing spreadsheets, and performing other tasks on smart phones, as well as, more generally, using in-vehicle information systems.

Five major problems related to distraction/overload research and engineering and their solutions are addressed in this paper. Problems include (1) the misuse of the term distraction (and possible misdirection of effort), (2) driving performance measures and statistics that are either undefined or poorly defined (to be resolved by an SAE practice), (3) the workload of the driving task is not quantified (for which an equation is proposed), (4) the demand characteristics of in-vehicle tasks are not quantified (for which a scheme is proposed), and (5) too often, standards specify only measurement methods, not compliance criteria (which must be developed).

INTRODUCTION

Driver distraction/overload/workload is now the topic of considerable scientific and public debate. For the public, this debate has led to the passage of laws in cities and states restricting the use of cell phones and other devices while driving. Most recently, the province of Ontario, in Bill 118, took this step, becoming effective at the end of 2009 ([Legislative Assembly of Ontario \(2008\)](#)). However, this topic has been one of scientific inquiry for some time (e.g., [Brown, Tickner, and Simmonds, 1969](#)).

Cell phones are but one example of nomadic devices that provide a wide range of features that are carried into motor vehicles. They supplement information and driver assistance systems now becoming commonplace. Each of these systems and their features is being provided for a valid reason, and collectively, they increase complexity of vehicle operation. With many more tasks for the driver to do, these systems could also collectively diminish usability and safety. This is particularly a concern for the carried in equipment, especially phones, which are rarely tested for use while driving, even though use while driving is expected.

Some perspective of how the current situation has arisen is useful. Consider the top- five selling vehicles in the U.S. in January 2010 per the *Wall Street Journal* (http://online.wsj.com/mdc/public/page/2_3022-autosales.html#autosalesC, retrieved February 25, 2010) ([Table 1](#)).

Table 1. Top Five Vehicles Sold in the U.S., January 2010

Rank	Vehicle	Sales
1	Ford F series	27,630
2	Chevrolet Silverado	22,772
3	Honda Accord	19,022
4	Nissan Altima	18,636
5	Toyota Corolla/Matrix	17,121

These vehicles are all reasonably well equipped. Among them, the 2010 Nissan Altima 2.5 with the SL package, a typical contemporary sedan, was selected as an example for which technical details are readily available. How does the current vehicle differ from the 2000 model? The 2.5S with the SL package and the technology option includes a navigation system with a 6.5-inch, touch-screen unit, traction control, and vehicle stability control.

includes speed limit advisories, Zagat restaurant guide, XM traffic and weather data, a DVD player, and provides for several ways to accept auxiliary audio/video input. The Altima does not have adaptive cruise control, yet. Nothing like this was available on the 2000 model Altima, or for many other vehicles of that time period. The operation of these added systems is something drivers must now learn and will use while driving. If improperly designed, these systems can be distracting and their use overwhelming. Further, for any of the other vehicles in this list or a larger list, the same trend of increasing functionality should be apparent.

Each of the systems just mentioned, at least if it was developed by an automaker, was probably subjected to some sort of human factors analysis or evaluation. However, those doing the work are sometimes so close to those evaluations that they may not be aware of the larger problem of increasing total vehicle complexity. Moreover, because of the focus on very specific interface issues, engineers are not aware of the larger shortcomings of current work, which may fall below the quality of research and engineering being done in other industries. The author does not have any statistical evidence to support this assertion, though many human factors professionals will agree that the problems identified in the sections that follow are real.

Specifically, five major problems and their solutions are addressed in this paper. Those problems include (1) the misuse of the term distraction (and potential misdirection of effort), (2) driving performance measures and statistics that are either undefined or poorly defined (to be resolved by an SAE practice), (3) the workload of the driving task is not quantified (for which an equation is proposed), (4) the demand characteristics of in-vehicle tasks are not quantified (for which a scheme is proposed), and (5) too often, standards only specify measurement methods, not compliance criteria (that must be developed).

PROBLEM 1: MISUSE OF THE TERM DISTRACTION

Driver distraction and workload are often used interchangeably, but are not the same. Part of the problem is defining what is the problem. As has been stated before (Oberholtzer, Yee, Green, Eoh, Nguyen, and Schweitzer, 2007; Green, 2008), in the popular press but also in the scientific literature, the term “distraction” is often used to describe the topic addressed here. Two examples are the well-done series in the New York Times, “Driven to Distraction,” (http://topics.nytimes.com/top/news/technology/series/driven_to_distraction/index.html, retrieved March 2, 2010) and the most comprehensive book on the topic, *Driver Distraction* (Regan, Lee, and Young, 2009). Distraction generally refers to something that attracts and retains attention, whereas workload or overload refer to the individual and aggregate demands of the tasks a driver

performs. In practice, sometimes the consequences of both are the same, but nonetheless distraction persists as the label for both phenomena, probably because it is easier to get attention and funding.

The naming/identification of the problem is important because of its implications for what one thinks the problem is and which performance measures should be collected. Keep in mind that there is just something compelling about answering a ringing phone, keeping a phone conversation going, responding to a text message, or completing an in-vehicle task such as entering a destination. When these tasks are conducted while driving, they become a safety issue.

PROBLEM 2: DRIVING PERFORMANCE MEASURES AND STATISTICS ARE EITHER UNDEFINED OR POORLY DEFINED.

Contemporary practice is to establish knowledge, such as how distraction/overload affects driving, based on the scientific method, a method that has existed for centuries. Richard P. Feynman, the Nobel prize-winning physicist at Caltech, in his well-known textbook *Feynman Lectures on Physics* (volume 1, page 2-1), said, “Observation, reason, and experimentation make up what we call the scientific method.” Following the scientific method involves creating a hypothesis to explain a phenomenon, collecting observable, quantifiable data in experiments to test the hypothesis, and using reasoning to interpret the results.

Those quantifiable data, measurements, must be repeatable and reliable. The lack of such measures has been a major problem for driving research and engineering, especially for work on distraction/overload. A few examples from Savino (2009), his master's thesis, make the point. Savino reviewed the refereed human factors literature relating to driving, with the goals of determining the names used to identify common driving performance measures and statistics and how they were defined. He examined every issue of *Human Factors* and *Ergonomics* from 2000 to 2005, as well as the *HFES* and *Driving Assessment Conference Proceedings*, and other references. He did not examine SAE or ISO standards, as those interested in the research were familiar with their content. Overall, Savino examined 498 references, of which 111 were relevant to his research. Three examples of problem measures and statistics follow.

EXAMPLE 1: LANE DEPARTURES

The number of lane departures per unit of time or trial is a very common safety statistic. If drivers are distracted, they are more likely to depart the lane (Zhang and Smith, 2004). Table 2, from Savino's research, shows how often various names for this statistic appear in the literature. Notice that the

most common name is used only one-third of the time, and it is not the preferred name.

Table 2. Names Used for Lane Departure in the Literature

Measure name	Frequency
lane deviation	5
out of lane	4
lane departure	3
lane exceedence	2
lane keeping	1
lane violations	1
crossing white sidelines	1
major lane deviations	1
Total	18

However, what is most critical is that this measure was rarely defined and when it was, the definition was imprecise. Contrast the definition of [Jenness, Lattanzio, O'Toole, and Taylor, 2002](#) (page 594) of a lane departure beginning when “the automobile crossed the white sidelines on the roadway,” with that of [Blanco, Hankey, and Chestnut, 2005](#) (page 1977) as beginning “when the vehicle's tire came into contact with the lane marker.”

So, what then is a lane departure? There are two aspects that need to be defined, what part of the lane is considered the boundary and what part of the vehicle is considered to have departed. In the U.S., as defined by the Manual of Uniform Traffic Control Devices ([U.S. Department of Transportation, 2009](#)), a lane marking is typically four inches wide. Depending upon whether the boundary is the inside edge of the line in the lane in question or the midline of the line is a two-inch difference. Further, the question is if departing is relative to any part of the vehicle, for example the outside edge of the mirror, or the outside of a front tire ([Figure 1](#)). For passenger cars and pick up trucks, the outside edge of the mirror is three to six inches farther outboard than the edge of the tire patch.

Thus, there are at least two candidate criteria for a lane departure, (1) the outer edge of the exterior mirror passes over the midline of the lane marking, and (2) the front tire touches the inside edge of the lane marking.

The first criterion is the most crash relevant. The second is easier to detect (when using a side-mounted camera). Simple math suggests there is a one to four inch difference between the two criteria. In reality, the difference is slightly less because most vehicles approach the lane marking at an angle. As a footnote, the definitions in [SAE J2808](#) (Society of Automotive Engineers, 2007) and [ISO 17631](#) (International

[Standards Organization, 2007](#)) refer to the tire contacting the lane marking.

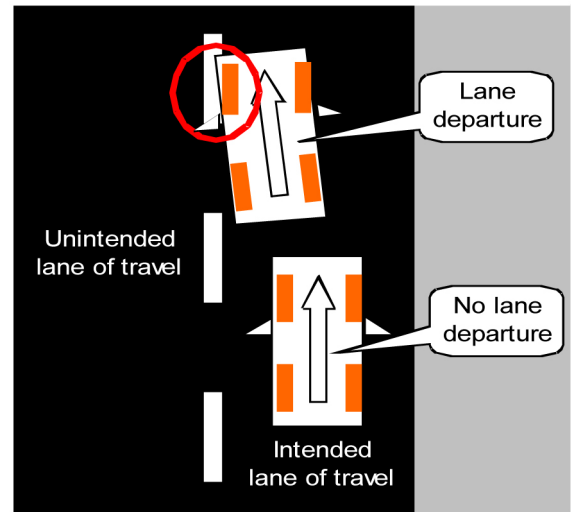


Figure 1. What is a Lane Departure? Source: [Savino, 2009, page 25.](#)

EXAMPLE 2: TIME-TO-LINE CROSSING

Time-to-line crossing, a key safety measure, reflects the safety margin for lateral control. When drivers are distracted, the minimum time-to-line crossing over a time window decreases ([Jamson, Westerman, Hockey, and Carsten, 2004](#)). Fortunately, this is a term for which only that name is used. At a superficial level, it seems simple to define, basically how long it takes the vehicle to reach the lane boundary. Time-to-line crossing is defined in standards associated with lane departure warning systems, [SAE J2808](#) (Society of Automotive Engineers, 2007) and [ISO 17631](#) ([International Standards Organization, 2007](#)), but papers on lane departure rarely reference those standards or their definitions as well.

There are actually at least three different ways time-to-line crossing can be defined: (1) as lateral distance divided by lateral velocity, (2) as an expression that includes lateral acceleration, and (3) as the complete trigonometric solution that considers the radius of curvature of the vehicle's path and the radius of curvature of the road. Of the values provided by the three expressions, the first two of which are approximations, and all three can differ considerably. (See [Godthelp, 1984](#); Van Winsum, Brookhuis, and de Waard, 2000).

Further, as with lane departure, there is the issue of what is considered a departure. For time-to-line crossing, it is typically when the tire touches the lane boundary, but it does not have to be.

EXAMPLE 3: HEADWAY

The more closely one follows a vehicle ahead, the more likely a crash ([Ervin, Sayer, LeBlanc, Bogard, Mefford, Hagan, Bareket, and Winkler, 2005](#)). Of the various types of crashes, rear-end collisions are much more likely when drivers are distracted ([Wang, Knipling, Goodman, 1996](#)).

In the civil engineering literature, for example, the Highway Capacity Manual ([Transportation Research Board, 2010](#)), headway refers to the time difference between when two successive vehicles pass by the same point on a road. Generally, it is the front bumper to front bumper difference ([Figure 2](#)). Civil engineers are interested in measuring traffic volume, how many vehicles/lane/hour occur on a road. The inverse of the interarrival time of successive vehicles is a measure of traffic volume.

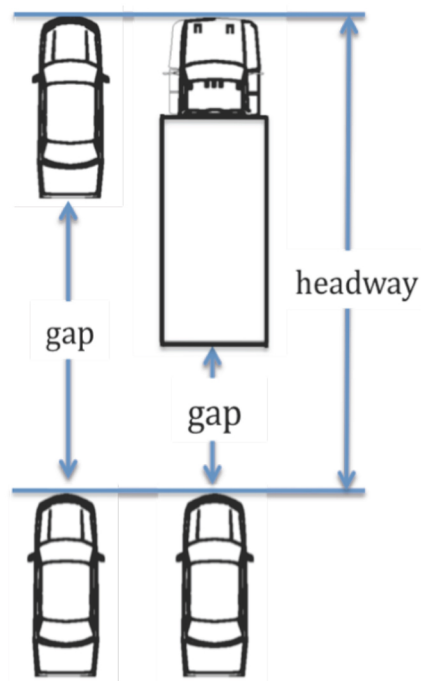


Figure 2. Gap vs. Headway

However, human factors engineers are interested in the space between vehicles, the stopping distance available to avoid a crash. They often call that distance (or time) “headway,” as shown in [Table 3](#), even though gap is the classically used and appropriate name (as in gap acceptance studies; [Farber, Landis, and Silver, 1968](#); [Chan, Ragland, Shladover, Misener, and Marco, 2005](#); [Hwang and Park, 2005](#); [Farah, Bekhor, Polus, Toledo, 2009](#)). Strangely, SAE and ISO documents refer to gap as clearance, a name no one seems to use in the literature.

Table 3. Terms Used for Distance Gap in the Literature

Measure name	Frequency
distance headway	6
following distance	3
space headway	1
vehicle headway	1
gap	1
gap distance	1
min, following distance	1
Total	14

However, the problem is not just that the name headway is inconsistently used, but the intended use is uncertain because it is not defined. [Savino \(2009\)](#) found 10 definitions for distance headway and 18 definitions for time headway in the literature. The definition of [Strayer, Drews & Crouch, 2003](#), page 27, is typical. Following distance as “the distance between the pace car and the participant’s car.” Not specifying the points on the vehicle leads to ambiguity. In a simulator, it is sometimes easiest to give the distance from center of gravity (CG) to center of gravity, since CG related measures are often computed. However, the difference between gap and headway, as defined here, depends on the length of the lead vehicle. The difference in length between and car and a tractor-trailer is close to 40 ft (12 m), quite substantial. Further, it would be awkward to define several gap values, each for a different length lead vehicle or relative to a different part of the vehicle. (The CG-to-CG distance is not equal to either gap or headway, but some weighted combination that depends upon the length of the lead vehicle, an undesired complication.)

So, what is the solution to this problem? The first step was [Savino's \(2009\)](#) review that provided data to show the lack of consistency and provided a basis for defining terms. Using that information, a subcommittee of the Society of Automotive Engineers Safety and Human Factors Committee is developing a set of standard term names and operational definitions for driving performance measures and statistics (SAE Recommended Practice [J2499](#)). The terms initially being considered are: accelerator response time, accelerator to brake transition time, brake response time, steering wheel reversal, distance gap, time gap, headway time, headway distance, time to collision, lane departure, lane change, lateral lane position, and time to line crossing.

There are several key points to be made about these definitions and the process to develop them. First, the SAE subcommittee is being diligent to make sure the definitions are based on current practice and the research literature, as well as criteria for good definitions, not mere opinions. Second, to document how and why particular terms and specific definitions were selected, a rationale document is being written. Third, in several situations, such as for lane