

An Empirically Based Suggestion for Reformulating the Glance Duration Criteria in NHTSA's Visual-Manual Interaction Guidelines

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ABSTRACT

NHTSA recently proposed performance guidelines for visual-manual interaction with non-driving related in-vehicle systems. While a commendable effort to reduce distraction related crashes, in part they seem overly strict. In particular, NHTSA proposes that for each driver performing a secondary task, no more than 15 % of the off-road eye glances can be longer than 2.0 s, and 21 in 24 drivers must meet this criterion.

The applicability of this criterion was assessed in a study using data from two eye-tracker based studies, involving 35 subjects performing a range of secondary tasks on normal roads.

Results showed that over tasks, the average off-road glance duration lengths were quite robust within drivers but varied widely between drivers. Off-road glance duration length thus seems more to reflect individual driver attention allocation strategy than in-vehicle task complexity.

Also, several drivers failed to meet the suggested criterion. Assuming that their relative prevalence can be generalized to the general driver population, then as many as one in six drivers may display the type of naturally long off-road glances that will make them fail to meet the criterion. It follows that any task tested by a group of randomly selected drivers likely will fail, since the suggested performance criterion does not allow for this natural driver variability.

As currently written, the proposed compliance testing thus risks disqualifying many in-vehicle systems independently of how well they are designed. The criterion therefore needs to be reformulated, e.g., by measuring compliance on a group level rather than on an individual level.

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INTRODUCTION

In the vehicle design domain, the topic of driver distraction has come into focus in recent years. There are three reasons for this development. First, there are the results from recent naturalistic driving studies, which based on video recordings of crash and near crash involved drivers have concluded that visual distraction (i.e. looking away from the forward roadway for more than a certain period of time) is a key crash contributing factor. In the first study of the eye glance data set from the 100-Car Naturalistic Driving Study [1], Klauer et. al. found that when the total off-road glance duration exceeded 2 s in the 5 s before and 1 s after the onset of the precipitating event, the risk of crashes and near-crashes approximately doubled [2]. In two recent studies [3-4], where the same data set was re-examined with a larger set of prediction algorithms, both studies found that algorithms

based solely on instantaneous off-road glance duration predicted crash risk even better than algorithms based on glance history, such as the one in [2]. This corresponds well with another recent study based on test track data from the Crash Avoidance Metrics Partnership Driver Workload Metrics project, showing that the length of single glances to secondary tasks influenced event detection more than total eyes-off-road time. In fact, the latter was best viewed as a separate and orthogonal source of variance in the data [5].

These results have led to an increased interest in the extent to which distraction can be identified as a crash contributing factor in various crash databases. Starting in 2010, NHTSA has both improved the way data in the Fatality Analysis Reporting System (FARS) is encoded and adopted a more precise terminology regarding whether distraction was contributing to a crash or not in the National Automotive Sampling System (NASS) [6]. In this updated framework,



according to NHTSA in 2010 9% of fatal crashes and 18% of injury crashes were reported as distraction-affected [6]. The actual numbers are 3,092 people killed in crashes involving distracted drivers and an estimated additional 416,000 injured in motor vehicle crashes involving distracted drivers [6].

The third reason why driver distraction has come to the foreground in vehicle design is the societal transition towards ubiquitous use of information technology. From a vehicle design point of view, many of the currently identified sources of distraction, e.g., eating, drinking, interacting with passengers and putting on make-up, are outside the manufacturers influence. However, one thing OEMs can control is the design of in-vehicle systems that involve visual-manual interaction. Now, it is often assumed that people increasingly expect to stay connected and remain interactive even while in transit, be it on a bus, bicycle or behind the wheel of a car. This means that even though use of vehicle based technologies today are quite far down on the list of non-driving related activities, it may be conjectured that visual distraction could increase in the future, if people spend an increasing amount of time on interaction with display-based technologies in their vehicles.

Given these developments, it follows that the current time might be an appropriate one to set up new, or revise previously existing, recommendations and guidelines for how and when drivers are to interact with display-based technologies in the vehicle. Hence, NHTSA has proposed a set of guidelines for visual-manual interaction with in-vehicle systems [7]. The purpose of the NHTSA Guidelines is to limit potential driver distraction associated with secondary, non-driving-related, visual-manual tasks (e.g., information, navigation, communication and entertainment tasks) performed using integrated electronic devices.

Of course, the fear that distraction might compromise safety has been around for quite some time, even if not has been as central to the discussion as it is today. Extensive research on driver distraction and its effects on safety has been conducted. One way in which this work has been incorporated in the vehicle design process is through the development of guidelines similar to those now being proposed by NHTSA, i.e. guidelines that give recommendations for how to minimize the potential for driver distraction during visual-manual interactions while the vehicle is in motion. Currently published guidelines include the European Statement of Principles [8], the “Guideline for In-Vehicle Display Systems, Version 3.0” [9] and the “Statement of Principles, Criteria and Verification Procedures on Driver-Interactions with Advanced In-Vehicle Information and Communication Systems” [10]. The NHTSA guidelines therefore are not written from scratch; rather they draw heavily on in particular the AAM guidelines.

NHTSA approaches visual distraction in a two step procedure. First, they list certain tasks that which they believe inherently interferes with a driver's ability to safely control the vehicle, and hence should be unavailable while the vehicle is in motion (including e.g., internet browsing and

social media browsing). For all other tasks, the proposed guidelines specify test methods for assessing whether a task interferes too much with driver attention to be suitable to perform while driving.

While there are many aspects to the suggested testing, the one of particular interest for this study is the proposition for how to measure how visually distracting an in-vehicle device is. The guidelines focus on the amount of time the driver's eyes are drawn away from the roadway during the performance of a task. NHTSA proposes the following acceptance criteria for compliance testing [7]:

1. For at least 21 of the 24 test participants, the mean duration of all individual eye glances away from the forward road scene should be less than 2.0 s while performing the secondary task
2. For at least 21 of the 24 test participants, no more than 15 percent (rounded up) of the total number of eye glances away from the forward road scene should have durations of greater than 2.0 s while performing the secondary task¹.
3. For at least 21 of the 24 test participants, the sum of the durations of each individual participant's eye glances away from the forward road scene should be less than, or equal to, 12.0 s while performing the secondary task one time.

Of these, the first criterion is perhaps the one which has the most solid empirical foundation, as it follows directly from the studies of visual behavior in relation to event detection and crash risk discussed here. The third criterion is more of an unknown. The Alliance guidelines [10] specified a maximum total eyes-off-road time of 20 s, which NHTSA in turn has lowered to a maximum of 12 s [7]. Now, while total eyes-off-road time performs less well than instantaneous eyes-off-road duration as crash predictor [3, 4], and in fact might represent a source of driver performance data variance that is unrelated to event detection [5], viewed as a general principle designed to prevent continuous interaction with secondary tasks, the basic concept seems sound. Some version of it is likely to be contained in future guidelines as well.

The second criterion however is less straightforward. To explain why, a short discussion of visual attention sharing when multitasking is required. Attention sharing between the forward roadway and the secondary task can be portrayed as an iterative cycle. The drivers first look at the road to check their safety margins, then at the display to do the next step in the task, then back at the road again to check the safety margins, and so forth (See Figure 1).

Now, it is well known that human performance normally is associated with certain variability between and within individuals. It is therefore unlikely that drivers will be completely uniform in terms of how they perform this cycle. Rather, it is quite conceivable that some drivers may prefer a faster cycle pace (i.e. a short glance on the display, a short glance on the road, a short glance on the display, etc.) while

others can be considered “long glancers”, i.e. they prefer longer visual dwell times in each step.

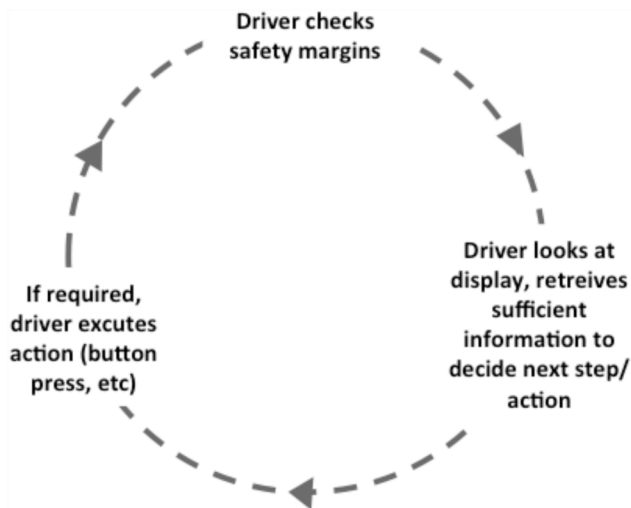


Figure 1. Typical interaction cycle when multitasking.
Note that not each cycle will require an action; some cycles will be for information gathering only.

The potential problem implied by this in relation to the second criterion is that as currently written, the second criterion brings the pass/fail measurement of off-road eye glance durations down to an individual level. According to criterion two, each individual should first be assessed in terms of whether they meet an 85th percentile off-road glance duration criteria. In other words, for each driver, 85 % or more of the off-road glance durations observed during a task must be shorter than 2.0 s, and if more than 3 in 24 drivers fail in this regard, the secondary task is considered as non-compliant with the guidelines.

Now, if we assume that cycle times in visual attention sharing are not uniform but instead display a certain natural variability between drivers, it is possible both that more than 3 in 24 drivers are natural “long glancers”, and that the cycle times they prefer might be long enough to fail on criterion 2. If this would turn out to be true, it follows that the random sampling of 24 drivers for compliance testing according to the guidelines from time to time would result in a failure to meet criterion 2 due to normal variability in the driver population, independently of how well or poor the tested task is designed. As that is not the intent of the proposed guidelines, it becomes very important to investigate whether such “long glancers” exist, and if so how common they are in the normal driver population. If they indeed are common, then criterion 2 would need to be adapted to this property of the normal driver population, for example by assessing the off-road-glance duration on a group level rather than on the individual level.

The research questions that follow from the reasoning presented here are whether cycle times do vary between drivers, and if so; how large the proportion of “long glancers” can be expected to be in a normal driving population. The

present study aimed to address these two issues through analysis of drivers' off-road glance patterns while performing secondary tasks on normal roads in a variety of normal production vehicles.

METHOD AND DATA SOURCES

The current study is based on data from two studies involving a total of 35 subjects that were carried out in response to the findings in the 100 car study [1], but *before* the proposed guidelines were published. The study designs therefore do not follow the recommendations in the proposed guidelines other than by sheer coincidence, as the guidelines were unknown at the time of study design. For example, all test subjects were Volvo Car employees. The potential bias and implications of this for the results are elaborated on in the discussion section.

Each subject performed a total of five different secondary tasks, including MP3 song selection from a music library, manual radio tuning to a specified frequency, address input in navigation system, dial a 10 digit phone number and adjusting treble and base in the sound settings. For each subject and vehicle, these five tasks were repeated four times. In the first study (18 subjects), the tasks were implemented as generic (i.e. non-vehicle specific) tasks (Table 1 below). A more detailed description of the implementation of these tasks can be found in [11].

The tasks were carried out on a height adjustable touch screen mounted in the center stack of the vehicle. Between repetitions, the screen was moved between a higher and a lower position. The lower position corresponds to the lower limit for display position as defined in the AAM guidelines [10] while the higher corresponded to a position approximately 10 degrees above that. Each participant drove the vehicle once.

In the second study (17 subjects), tasks were instead vehicle-specific, i.e. carried out using available in-vehicle systems in five cars of different make and model, including Volvo, BMW, VW and Audi vehicles. The study was designed as a within group study but for practical reasons this design turned out not to be feasible. In the end, a total of 51 drives were performed, with each driver driving at least two of the different vehicles. As task HMI's were vehicle-specific, for each vehicle the closest equivalents to the generic tasks in Table 1 were identified. For example, all vehicle models allowed for manual radio tuning to a predefined frequency, so this was used as the radio tuning task, and so forth.

Another difference between the studies is that in the first study, half the participants were directly involved in the design of visual-manual secondary task interfaces, while the other half was not. In the second study, only employees not involved in design were selected. This might also introduce a bias, and is further elaborated on in the discussion section.