Proceedings of The National Conference
On Undergraduate Research (NCUR) 2019
Kennesaw State University
Kennesaw, Georgia
April 11-13, 2019

# Driver Interfaces: Safety and Usability

Ekim Koca
University of Michigan Transportation Research Institute
The University of Michigan
2901 Baxter Road
Ann Arbor, MI 48109

Faculty Advisor: Paul Green

## Abstract

Driver distraction is increasingly prevalent in modern society with the introduction of new tasks into vehicles such as texting and manual navigation entry. However, vehicle interfaces for these tasks are a controllable aspect of driver distraction. Therefore, automakers must determine if their interface designs will be overtly distracting as per U.S. Department of Transportation guidelines. This can be done by testing in a driving simulator or, in the future, calculating task times for interface designs per SAE (Society of Automotive Engineerings) Recommended Practice J2365, which can be done much more efficiently. The calculation involves adding up the times for the task elements (press a button, move the hand, etc.) of which each task consists. Unfortunately, this protocol was created before the introduction of touch screen interfaces and needs to be updated. Accordingly, the mean and standard deviation of the duration for in-vehicle task elements (pinch, zoom, tap, drag, etc.) need to be determined for touch screens. To begin, literature was reviewed to identify published estimates for the task elements of interest. There were three categories of literature to review: previous protocols and guidelines, time calculation methods, and direct time estimates. After adequate research was gathered on those topics and organized, the literature was synthesized to create a final report containing recommendations for time estimates for certain tasks as well as methods that could be used to calculate task times (e.g., Pettitt's Method, Purucker's Method). The next steps will be to conduct human experiments in a driver simulator in order to determine the accuracy of the time estimates and build the updated dataset for the interface designers. This research can help decrease driver distraction while conducting tasks on the interface and improve driver safety.

**Keywords: Driver Distraction, Human Factors, Task Time**

## 1. Background – What is the Problem

Driver distraction is an important issue in many countries, but, in the United States due to the number of car crashes and subsequent fatalities are caused by driver distraction every year. [1, 2] Contemporary driver interfaces (shown in Figure 1) can be quite complex, require long times to complete tasks which can be distracting and time consuming to operate while driving, potentially comprising driver safety. [3,4]As part of the design of motor vehicles, manufacturers collect usability data, which includes task completion times. In addition, they can also use calculation procedures such as those described in SAE Recommended Practice J2365 to estimate those times. Unfortunately, the data in J2365 is from the pre-touchscreen era, so reliably estimating task times using J2365 is a challenge.

### 1.1. Quantifying Driver Distraction

Driver distraction is directly connected to the usability of a driver interface. Usability is defined as the "extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." [5] According a meta-analysis performed by Hornbaek and Law [6], the most effective method of analyzing usability is through the total task time. However, it is too costly and time consuming to measure the task time of every design of a driver interface. Therefore, systems were developed to estimate the total task time, but these systems were developed before touchscreens were included in vehicles and need to be updated accordingly. The basic idea is to divide tasks into simple elements (or steps) with correlated times and the existing systems will be covered more in depth later.

As shown in Figure 1, Consumer Reports ranked the Tesla interface as one of the most distracting and the Chrysler as one of the least distracting. For the Tesla, they discussed that having all controls be on the touchscreen causes more distraction than typical system that is split between touchscreens and physical controls. The Chrysler system benefitted from having larger text and icons while incorporating traditional knobs.


Figure 1. Examples of Driver Interfaces from Tesla [7] (left) and Chrysler [8] (right)

Given this context, how can the time to complete tasks associated with in-vehicle systems be estimated? How can the outcome of the NHTSA (National Highway and Transportation Safety Administration) occlusion test be predicted? Through the new equations and data, designers will be able to predict compliance with the government test procedure during the design process. Ideally, these predications will be coded directly into an automakers interface design system and give immediate feedback if the current system is distracting according to the existing guidelines set out by the U.S. Department of Transportation. Their guidelines describe two test methods.

### *1.1.1 test method 1 – eyes-off-road time*

To begin, subjects practice a car-following task, which involves the drivers keeping a consistent time gap between their vehicle and a leading vehicle. The speed of the lead vehicle varies. They also practice the in-vehicle tasks of interest for which distraction is a concern. Subsequently, the car-following test is repeated while subjects complete the in-vehicle tasks. The statistic of interest is the total-eyes-off-road time while driving, data collect by an eye-fixation recording system.

### *1.1.2 test method 2 - occlusion*

In NHTSA's most popular testing method a participant wears goggles which open and close periodically to simulate looking at the road (closed) and looking at the navigation system (open). All tasks must be completed within 12 seconds or 8 intervals of goggles open time. [9,10] The opening and closing of the goggles attempt to simulate looking back and forth between the in-vehicle interface and the road. The advantage of this method is that it does not require a driving simulator or eye fixation system and can be completed more quickly than the first method described. At this point, SAE J2365 does not contain a method to predict compliance with the NHTSA occlusion method.

## 2. Definition of Gestures

The actions that drivers make to operate knobs, buttons, and touchscreen can be broadly defined as gestures. Knowing the time for each gesture, the total task time, the time for a sequence of gestures, can be determined. A gesture is defined as "any physical movement that a digital system can sense and respond to without the aid of traditional pointing device such as a mouse or stylus." [11]

To update the current time prediction systems to accommodate for touchscreen driver interfaces, the gestures that are the most common and useful for driver interfaces had to be determined. Wroblewski [12] created a touch gesture guide which described the most basic and core gestures for a touchscreen. The first page of this guide is shown in Figure 2 which contains the core gestures. Outside of these core gestures, vehicles also utilize some specific operators such as handwriting which also have to be accounted for. There are also some mental processing operations that must be included as they are an essential part of some tasks. For example, if a driver is choosing a song from a list, they will have to search the list each page before continuing to scroll. Most of the relevant prediction systems have created operators for searching, reading, and related mental processes.

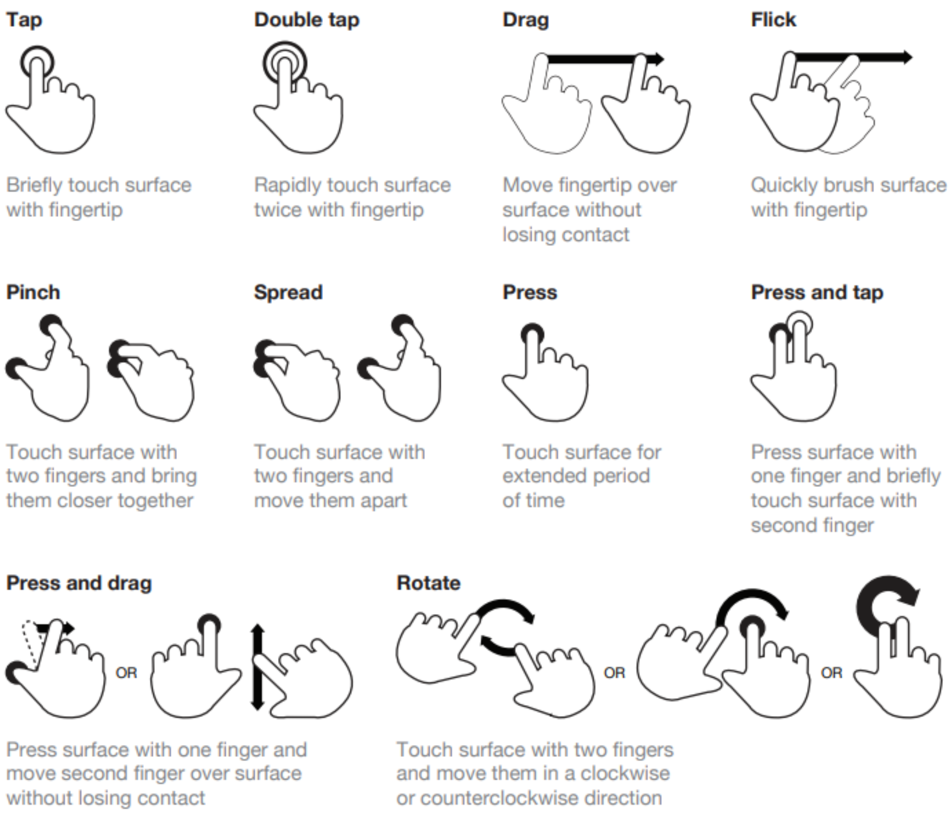


Figure 2. Wroblewski core touchscreen gestures with definitions and diagrams.

## 3. Predicting Task Time and Distraction

There are many methods to predict driver distraction caused by in-vehicle tasks. The first category are task time prediction methods which will analyze the steps and overall time it takes to complete the task. The second category are predicting the time it will take to complete a task during an occlusion test or the total time a driver's eyes were off the road.

## 3.1. Task time prediction methods

Task time prediction methods were initially used to predict the time it would take a typical factory worker to complete their task. These systems work by determining the mean time for each element or movement associated with typical tasks. These times are then put into multiple tables and used to create a step-by-step analysis of a task. For example, the reach element which is present in most systems is listed as one single time in one system but listed in a table organized by reach distance with multiple times for each distance depending upon the complexity or difficulty of the reach. The systems can be very simple or complex. The more complex a system is the more accurate the prediction is, however the complexity of time systems also increase the amount of time it takes to calculate the predictions. Some systems come from Industrial Engineering (Work Factor [13], Methods Time Measurement [14], and MODAPTS [15]) and some are from Human-Computer Interaction (Keystroke-Level Model [16] and Model Human Processor [17]). One system (SAE J2365 [18]) was developed from the mentioned systems specifically for in-vehicle tasks. An example calculation from this system is shown in Figure 3 below. The systems most relevant and easily adaptable to in-vehicle tasks are covered in the following sections.

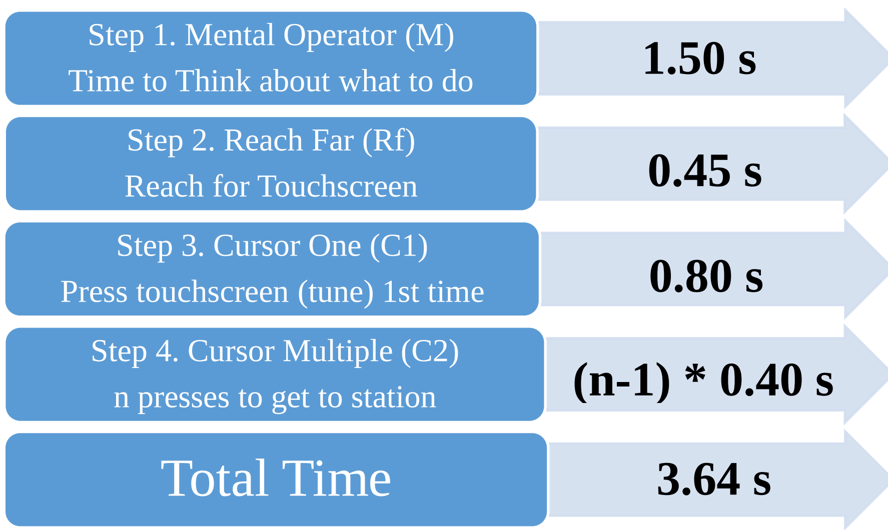


Figure 3. Example calculation to tune a radio.

This reach value was one of two available and involved reaching to anywhere further than near the steering wheel. Here, the radio tuning control is assumed to be in the center console, not a switch on the steering wheel yoke. It is also assumed that the turning function is immediately accessible, that one does not need to go through a series of menus to get to it. The time for step 4 depends on the number of total presses in the task. Here, it is assumed to be 2. These times are for young drivers (18-30).

## 3.2. Distraction Prediction Methods

Distraction can be predicted by determining either (1) eyes off road time or (2) total shutter open time from the total static task time predicted by the methods shown above. These predictions will also indicate how well the design will perform in the government occlusion test. There are two current methods to determine these values.

For the eyes off road time, Purucker [19] created an equation (1) which requires the user to count all the Keystroke-Level Model elements in a task to calculate eyes off road time. Purucker's method does make accommodations for age but acknowledged that there are some issues. Since it is a linear regression equation, it accounts for the variability of eyes-off-road time from task to task and has high accuracy. This value can also be used to calculate the occlusion time.

$$\log(TEORT) = 0.08 * n_k + 0.3*n_p + 0.37*n_u + 0.17*n_{knob} + 0.003* Age \quad (1)$$

where $n_k$ = # of keystrokes

$n_p$ = # of predictable lists (menus)

$n_u$ = # of unpredictable lists

$n_{knob}$ = # of knob actions

Age = participant age (years)

Total shutter open time can be determined through Pettitt's method, [20] illustrated in Figure 4. This method first determines the total static time to perform a task from SAE J2365 or the Keystroke-Level Model. Then, one simulates what would occur in an occlusion test considering the three assumptions shown in the figure. Pettitt's method needs to be adjusted to fit the NHTSA occlusion approach as Pettitt assumed an occlusion time of 2 s and un-occluded time of 1.5 s, whereas NHTSA sets both times as 1.5 s. Resulting from the analysis is a decision, is the calculated total occluded task time less than the 12-second total-occluded-task time standard set by the U.S. Department of Transportation [21,22] . As shown in the figure below, some actions can be continued throughout the occlusion. For example, the mental processes continue as they do not require visual or physical interaction with the interface. The figure also shows that the navigation task is considered safe under the government guidelines.

Time and distraction prediction methods are important in determining driver safety and usability. Therefore, updating the time prediction methods will automatically update the distraction prediction methods as they are directly linked since distraction predication methods depend on the total predicted task time.

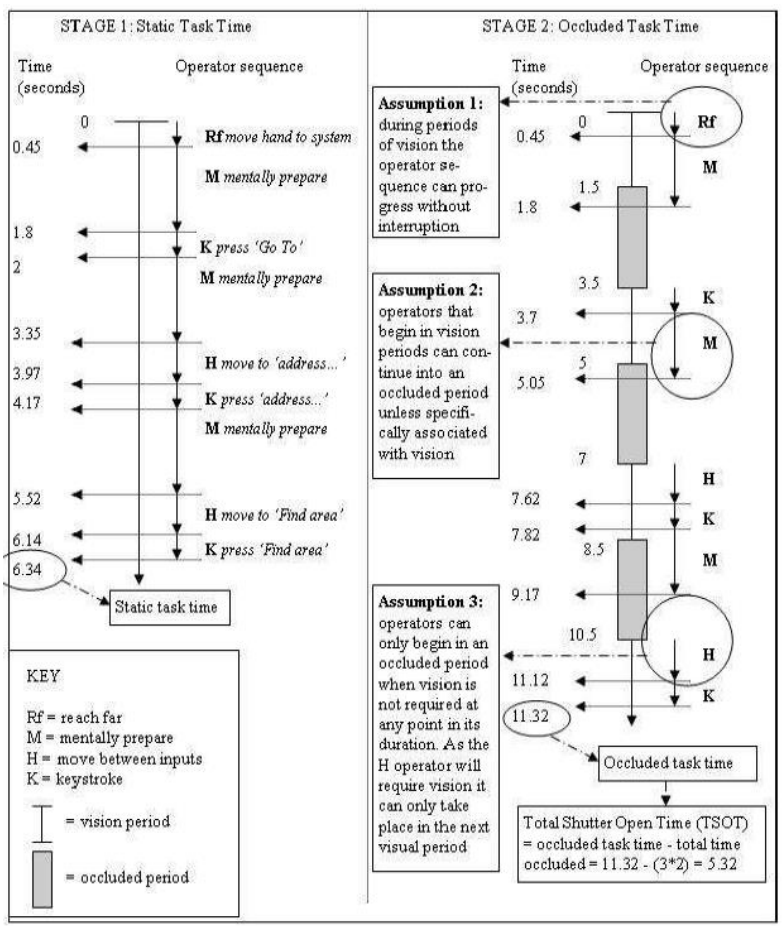


Figure 4. Example of Pettitt's method [17] for the beginning of a navigation task.
Source: Pettitt (2008), page 153

## 4. Next Steps and Lessons Learned

The project so far has mainly involved gathering all the literature available in order to learn the most effective method to determine total task time and predict driver distraction during the design process. There are an enormous number of references on this topic. The challenges are understanding how to search an enormous body of literature while being both comprehensive and emphasizing the most important sources.

The next steps are to validate the predictions based on the literature, to create an experiment to validate them, to conduct that experiment, and then improve the predictions based on the experiment. The specific gestures of interest including those that involve touchscreens. After the data has been collected, the mean time and statistical distribution for each gesture will be determined and equations to predict task time and compliance with the government distraction protocol will be developed. Then, the equations and data will be implemented into driver interface design software to help driver interfaces designers determine the usability and safety of their current design. Just as there have been many education lessons learned from the literature review, there are likely to be many lessons learned about creating an experimental design, submitting those materials to the board that approves human subject testing, how to interact with people when conducting an experiment, and how to reduce and analyze the substantial amount of data to be collected.

## 5. References


1. U.S. Department of Transportation (2010). *Distracted Driving 2009* (technical report DOT HS 811379)., Washington, D.C.: U.S. Department of Transportation, National Highway Traffic Safety Administration.
2. U.S. Department of Transportation (2018). *Distracted Driving 2016* (technical report DOT HS 812517).,
3. Olsen, P. (n.d.). High-Tech Features Distract Drivers for Dangerously Long Periods, AAA Study Finds. Retrieved from https://www.consumerreports.org/car-safety/high-tech-car-features-distract-drivers-aaa-study/
4. Strayer, D. L., Cooper, J. M., Goethe, R. M., McCarthy, M. M., Getty, D., & Biondi, F. (2017, September). Visual and Cognitive Demands of Using In-Vehicle Infotainment Systems. Retrieved June 1, 2019, from https://publicaffairsresources.aaa.biz/wp-content/uploads/2017/09/CDST_Final_Report.pdf
5. International Standards Organization (2018). *Ergonomics of Human-System Interaction — Part 11: Usability: Definitions and Concepts* (ISO 9241-11:2018(en)), Geneva, Switzerland: International Standards Organization
6. Hornbaek, K. & Law, E. L-C (2007). Meta-analysis of correlations among usability measures, *CHI 2007 Proceedings*, 617-626.
7. Bantick, M. (2016, May 03). Infotainment Review: Tesla Model S. Retrieved May 17, 2019, from http://www.motoring.com.au/infotainment-review-tesla-model-s-102248/.
8. Consumer Reports. (n.d.). The Most and Least Distracting Infotainment Systems. Retrieved from https://www.consumerreports.org/car-safety/most-and-least-distracting-infotainment-systems/
9. Washington, D.C.: U.S. Department of Transportation, National Highway Traffic Safety Administration.
10. U.S. Department of Transportation (2013, April 26). *Visual-Manual NHTSA Driver Distraction Guidelines for In- Vehicle Electronic Devices* (78 CFR 24817, Docket NHTSA-2010-053), https://www.federalregister.gov/documents/2013/04/26/2013-09883/visual-manual-nhtsa-driver-distraction-guidelines-for-in-vehicle-electronic-devices.
11. Saffer, D. (2008). *Designing gestural interfaces: touchscreens and interactive devices*. " O'Reilly Media, Inc.".
12. Wroblewski, L. (2010). *Touch Gesture Reference Guide*. https://www.lukew.com/ff/entry.asp?1071
13. Quick, J. H., Duncan, J.H., and Malcolm, J.A. (1962). *Work-factor Time Standards: Measurement of Manual and Mental Work*. New York, NY: McGraw-Hill.
14. Karger, D. W., & Bayha, F. H. (1987). *Engineered Work Measurement* (3rd ed.*)*. New York, NY: Industrial Press.
15. Carey, P., Farrell, J., Hui, M., and Sullivan, B (2001). *Heyde's MODAPTS*, Australia: Heyde Dynamics.
16. Card, S. K., Moran, T. P., & Newell, A. (1980). The keystroke-level model for user performance time with interactive systems. *Communications of the ACM*, *23*(7), 396-410.
17. Card, S.K; Moran, T. P; & Newell, A. (1986). *The Model Human Processor: An Engineering Model of Human Performance.* In K. R. Boff, L. Kaufman, & J. P. Thomas (Eds.), *Handbook of Perception and Human Performance. Vol. 2: Cognitive Processes and Performance*, 1–35.

18. Society of Automotive Engineers (2016). *Calculation and Measurement of the Time to Complete In-Vehicle Navigation and Route Guidance Tasks* (SAE Recommended Practice J2365), Warrendale, PA: Society of Automotive Engineers.
19. Purucker, C., Naujoks, F., Prill, A., and Neukum, A. (2017). Evaluating distraction of in-vehicle information systems while driving by predicting total eyes-off-road times with keystroke level modeling. *Applied Ergonomics*, *58*, 543-554.
20. Pettitt, M. A. (2008). *Visual Demand Evaluation Methods for In-Vehicle Interfaces* (doctoral dissertation). Nottingham, UK: University of Nottingham.
21. U.S. Department of Transportation (2013, April 26). *Visual-Manual NHTSA Driver Distraction Guidelines for In- Vehicle Electronic Devices* (78 CFR 24817, Docket NHTSA-2010-053), https://www.federalregister.gov/documents/2013/04/26/2013-09883/visual-manual-nhtsa-driver-distraction-guidelines-for-in-vehicle-electronic-devices.
22. U.S. Department of Transportation (2014, September 16). *Visual-Manual NHTSA Driver Distraction Guidelines for In- Vehicle Electronic Devices* (79 CFR 55530, Docket NHTSA-2014-088), https://www.gpo.gov/fdsys/pkg/FR-2014-09-16/pdf/2014-21991.pdf)