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# HUMAN SYSTEM ENGINEERING APPLICATIONS FROM DISTRACTED DRIVING SIMULATIONS

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## Abstract
Most of the studies to explore the impact of distracted driving have been descriptive in nature; i.e. the research is conducted in naturalistic settings to evaluate the performance of the driver with and without distracters. However simulation models can also be used that predict the workload for driving tasks. Using concepts from process modeling, baseline models of driving tasks can be created for different driving sequences that include the associated fine motor, visual and cognitive human resources. These models can then be used to evaluate incidents of workload overload caused by different distracters, from both the internal and external vehicle environment. Identifying specific overloaded resources can lead to mitigation strategies to reduce workload and minimize distracted driving. Lessons learned from distracted driving research can then be applied to evaluation other types of manual, visual, and cognitive intensive tasks. Identifying combinations of tasks that contribute to peak workload of operators, and then simulating the impact of multi-tasking using personal devices (i.e. cell phones) can lead to management insights for other types of work environments. Additionally, iterative modeling can also include the impact of sensors and alerts, as well as enhanced workstation displays. Individual component overload can help understand causes for performance detriments during different task sequences, and the impact of additional types of technologies and activities. Using the simulation analysis, the impact on overall workload, identification of peak workload occurrences, and specific overloaded resources can lead to mitigation strategies to reduce workload and improve operator performance.

## Keywords
Human System Engineering, Workload Modeling, Distracted Driving

## Introduction
The National Highway Transportation Safety Administration has identified three types of driving distracters: manual (hands off the wheel), visual (eyes off the road), and cognitive (mind off driving) (NHTSA, 2012). "People do about as much while driving their cars as they do while sitting in their living rooms - eating, reading, talking on the phone" (Truelove, 2012, para 1). Studies at Virginia Tech that focused on the use of cell phones while driving have found that the risk of having an accident increases by a level of magnitude. These researchers observed that the most dangerous tasks are visual-manual in nature. "You have to take your eyes off of the road to do something and most of the tasks required multiple steps to complete and multiple glances away from the road" (Ibid, 2012, para 7). The researchers concluded that additions to the driving environment, such as sensors and cell phones, should focus on minimizing visual-manual interaction with devices and thereby minimizing eyes-off road time. However their research, using naturalistic methods collecting data from video cameras placed inside the car, found that total cell phone bans that included true hands-free voice input-output devices are unwarranted.

Interestingly, another set of researchers at the University of Utah investigating the difference between talking to a passenger versus talking on the cell phone in a driving simulator did not support that conclusion: They found that all of the drivers [involved in accidents] were using hands-free handsets, debunking the idea that it's safer to talk on the phone if the driver is not holding a handset (Drews, 2008). These conflicting hypotheses can be further explored by using a model of driver workload to identify what types of distracters contribute to overloaded, and hence distracted drivers. These same models can also be used to identify implications of distracted operators in performing tasks in other types of work processes in organizational environments.

Researchers can predict the mental workload associated with different typs of tasks using the Improved Performance Research Integration Tool (IMPRINT). IMPRINT is a human performance modeling tool developed by the US Army Research Labs to help system developers predict the impact of operator attributes on system performance (Mitchell, 2005). Task-level information is used to construct work processes representing the temporal flow of tasks; underlying human performance algorithms are then employed to perform simulations. An important feature of IMPRINT is the capability to model mental workload demands. Workload theory is based on the idea that every task a human performs requires resource demands, such as visual, auditory, cognitive, fine motor, gross motor, and speech. IMPRINT is structured to help assign values representing the amount of effort that must be expended in each resource in order to perform each task. The descriptors correspond to increasing levels of human information processing activity within each resource channel (Wojciechowski, 2004).

Using IMPRINT, sequences of driving tasks can be modeled and combinations of tasks that contribute to the peak workload of the driver can be identified. A model containing common sequences of driving tasks can be simulated to achieve a baseline workload value. Iterative modeling can then include different types of sensor and alerts (i.e., back up cameras), personal devices (i.e., cell phones), and enhanced dashboard displays (i.e., real-time GPS displays) to the driving sequences. IMPRINT will allow researchers to predict the mental workload used in the different task combinations. Individual component overload can help understand causes for distracted driving based on the impact of additional types of sensors and distracters to driving sequences, especially for the visual, fine motor and cognitive components identified in distracted driving studies. Using the IMPRINT analysis, the identification of peak workload occurrences and specific overloaded resources can lead to mitigation strategies to reduce workload and minimize distracted driving.

The modeling methodology developed in this study can then be applied to other areas of workplace distractions to identify the impact on performance, as well as to develop mitagation strategies. A study at Michigan State Univeristy idenfied the impact of even small distractions on productivity. Researchers found that interruptions of roughly three seconds doubled the error rate of work tasks, while interruptions of four-and-a-half seconds tripled the number of errors (Altmann, Trafton & Hambrick, 2014). Based on the results of the IMPRINT study, different types of work processes can be modeled and the impact of distractions, such as phone calls, texting, and emails can be assessed. Especially in environments where it is necessary to be as error-free as possible, distractions go beyond detriments to productivity and may impact safety. When workers shift attention from one task to another during a process that takes considerable thought, even momentary interuptions can cause delays and errors.

## Method

The research approach for this exploratory project closely followed the Task Analysis Workload Methodology (TAWL) (Bierbaum & Hamilton, 1990). The TAWL method can be used to conduct a task analysis, produce workload predictions, and compare the workload across baseline and enhanced task process sequences. This method advocates decomposing a typical scenario into segments, functions, and tasks. This yields a description of the sequence of tasks and the interface associated with each task. The workload analysis of each task is based on the multiple resources theory of human attention and yields independent estimates of the cognitive, psychomotor, and sensory components of workload using predefined scales. The TAWL methodology treats each of the workload components independently, in order to determine ways to reduce workload or to redistribute workload among the operators. The outcomes of the task analysis and workload estimates can be used as inputs into the simulation environment to evaluate the behavior of the driver during different driving segments. By completing a post simulation analysis of the reported workload values over different segments, “toxic” combinations of tasks, and their impact on different resource components can be identified. Exhibit 1 summarizes the methodology for the project.

Exhibit 1. Project Methodology

| |
|---|
| 1. Identify short segments of tasks. |
| 2. Create a network diagram of the segment in IMPRINT. |
| 3. Include resource demand information for the tasks in the network model; verify from past ARL task models. |
| 4. Execute the baseline model to determine predicted workload for |

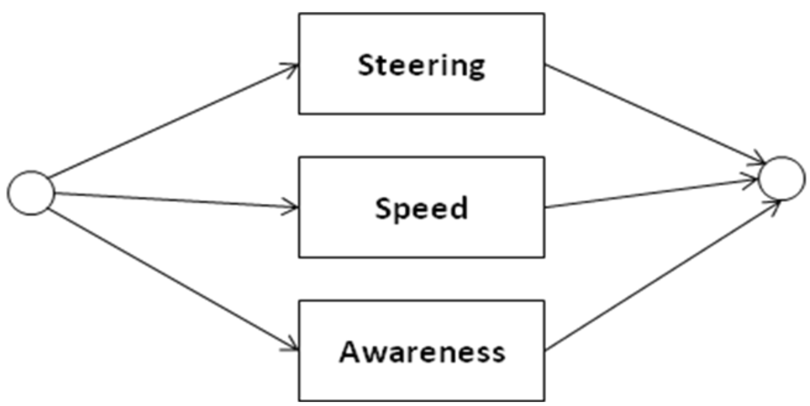
| |
|---|
| modeled segments. |
| 5. Enhance baseline models with distracters and simulate to evaluate the impact on operator resources. |

**Identify short segments of tasks**
The initial models were based on videos from the University of Utah's driving lab (Applied Cognition Lab, 2012). These short videos show the actions of a driver in the driving simulator. The first video, *Driving,* was chosen as the baseline video and the fourth video, *Text Messaging,* was chosen as the distracter. From these videos the following functions and tasks can be defined for the driving sequences:

- Steering Tasks:
  - Steering Straight, Steering Regular, Steering Hard
- Accelerator Tasks
  - Driving Steady, Driving Accelerating, Accelerating Hard, Driving Breaking, Breaking Hard
- Situation Awareness Tasks:
  - Looking Forward, Looking Instruments, Looking Right Mirror, Looking Left Mirror, Looking Rear Mirror

**Create a network diagram in IMPRINT**
From the task decomposition, a general high-level functional network was determined, as shown in Exhibit 2. This network can then be customized by populating the high level functions with different tasks for different segments. For example, in a "clear highway driving segment" the steering function would be composed of "steer straight" and the speed function would be "maintain speed." In an "overtaking (passing) segment" both steering and speed would require adjustments.

Exhibit 2. High Level Functional Network




The scenario used in the simulation model is composed of four parts: Drive Straight, Turn Left, Drive Straight Again, and Change Lane. Each segment of the scenario replicates the functional network shown in Exhibit 2, with cusomized tasks to represent the specific functionality. Exhibit 3 depicts the breakout of functions and tasks for each segment of the scenario.

Exhibit 3. Scenario Segment Functions and Tasks

| Scenario Segment | Higher Level Functions | Tasks |
|---|---|---|
| Drive Straight (DS) | Steer | Steer Straight (SS) |
| | Speed | Accelerate Normal (AN) |
| | | Maintain Speed (MS) |
| | Situation Awareness | Look Forward (LF) |
| | | Look Instruments (LI) |
| Turn Left (TL) | Steer | Steer Left Normal (SLN) |
| | Speed | Slow Down Slowly (SDS) |
| | Situation Awareness | Look Forward (LF) |
| | | Look Instruments (LI) |
| | Signal | Left Signal (LS) |
| Drive Straight Again (DSA) | Steer | Steer Right Normal (SRN) |
| | | Steer Straight (SS) |
| | Speed | Accelerate Normal (AN) |
| | | Maintain Speed (MS) |
| | | Slow Down Slowly (SDS) |
| | | Accelerate Normal (AN) |
| | | Maintain Speed (MS) |
| | Situation Awareness | Look Forward (LF) |
| | | Look Instruments (LI) |
| Change Lane (CL) | Steer | Steer Left Slowly (SLS) |
| | | Steer Straight (SS) |
| | Speed | Slow Down Slowly (SDS) |
| | | Maintain Speed (MS) |
| | Situation Awareness | Look Forward (LF) |
| | | Look Instruments (LI) |

## Results

Model task durations were determined based on the simulator videos - the modeled tasks occur for the same length of time as the simulator tasks. Workload for each task was first estimated based on the IMPRINT workload scales. These values were then verified using data from previous analysis of soldier driving tasks (Mitchell, 2009). The values of the workload components for each task are shown in Exhibit 4.

**Execute the Baseline Model**

The IMPRINT workload contains several different aspects that can be analyzed to understand the baseline workload over the different segments:

*Operator Workload.* The total workload value (sum of the component values) for an operator completing a task over an interval of time.

*Component Overload.* A component overload occurs when the total workload for a single component reaches or exceeds a threshold value during a simulation interval. In the IMPRINT output data, the Operator Workload Summary data set can be used, and the number of times each individual component is overloaded can be tallied. This will indicate which components are highly taxed during the scenario (Handley, 2010).

*Overload Condition.* An overload condition is a variable length period that contains at least one component overload. The time sequences where the operator is taxed can be identified from the Operator Workload Summary data set by looking across each row and noting how many components are greater than the threshold. Note that there may be occurrences where one or two of the components are overloaded, but the overall workload does not indicate an overloaded condition.

Exhibit 4. Task Workload Components

| Function | Tasks | Time (sec.) | Resources | | |
|---|---|---|---|---|---|
| | | | **Visual** | **Cognitive** | **Fine Motor** |
| Steer | SS (DS) | 10 | | 4.6 | 2.6 |
| Steer | SS (DSA) | 29 | | 4.6 | 2.6 |
| Steer | SS (CL) | 4 | | 4.6 | 2.6 |
| Steer | SRN (DSA) | 3 | | 4.6 | 2.6 |
| Steer | SLN (TL) | 5 | | 4.6 | 2.6 |
| Steer | SLS (CL) | 3 | | 4.6 | 2.6 |
| Speed | AN (DS) | 3 | 5.1 | 1.2 | 2.2 |
| Speed | AN (DSA) | 2 | 5.1 | 1.2 | 2.2 |
| Speed | AN (DSA) 2 | 3 | 5.1 | 1.2 | 2.2 |
| Speed | SDS (DSA) | 5 | 5.1 | 1.2 | 2.2 |
| Speed | SDS (TL) | 5 | 5.1 | 1.2 | 2.2 |
| Speed | SDS (CL) | 3 | 5.1 | 1.2 | 2.2 |
| Speed | MS (DS) | 7 | 5.1 | 1.2 | 2.2 |
| Speed | MS (DSA) | 7 | 5.1 | 1.2 | 2.2 |
| Speed | MS (DSA) 2 | 15 | 5.1 | 1.2 | 2.2 |
| Speed | MS (CL) | 4 | 5.1 | 1.2 | 2.2 |
| Signal | LS (TL) | 5 | | 1.0 | 2.2 |
| Signal | LS (CL) | 6 | | 1.0 | 2.2 |
| Situation Aware | LF (DS) | 10 | 6 | 6.8 | |
| Situation Aware | LF (TL) | 5 | 6 | 6.8 | |
| Situation Aware | LF (DSA) | 32 | 6 | 6.8 | |
| Situation Aware | LF (CL) | 7 | 6 | 6.8 | |
| Situation Aware | LI (DS) | 10 | 6 | 13.6 | |
| Situation Aware | LI (TL) | 5 | 6 | 13.6 | |
| Situation Aware | LI (DSA) | 32 | 6 | 13.6 | |
| Situation Aware | LI (CL) | 7 | 6 | 13.6 | |
| Scheduled Function | Reading | 6 | 5 | 6.8 | |
| Scheduled Function | Texting | 11 | 5 | 4.6 | 2.2 |
| Scheduled Function | Continue Texting | 15 | 5 | 4.6 | 2.2 |

**Enhance baseline models with distracters**

A summary of the total Operator Workload for a time period within the baseline driving scenario is shown in Exhibit 5. Once the baseline model was used to establish the driving segment workload, additional events representing distracters could be included in the model to evaluate the impact on operator workload. Events are included in the model as "scheduled tasks" and can represent external occurrences such as road hazards or unexpected traffic actions, or internal actions such as the use the GPS, radio, or cell phones. For this initial modeling evaluation, the use of text messaging was included in the baseline scenario. The texting event represented reading the text message and then typing a reply. The results from the workload simulation of the texting scenario, for a time period within the driving segment, are shown in Exhibit 6. Comparing the overall workload values from Exhibits 5 and 6 illustrates the change in workload from the baseline driving segment with the addition of texting. A workload threshold of 60 is the default value within the IMPRINT simulation environment (Mitchell, 2005). While the overall workload for each of the timestamps in the baseline model are comfortably under that limit, the addition of texting pushes the workload over the limit at time 10:00, and at the limit for the other timestamps.

Exhibit 5. Task Workload Components (Time 10:00 - 18:00)

| **Clock** | **Task Name** | **Overall Workload** |
|---|---|---|
| 00:00:10.00 | Left Signal (TL) | 51.30 |
| | Look Forward (TL) | |
| | Look Instruments (TL) | |
| | Slow Down (slowly) (TL) | |
| | Steer Left (normal) (TL) | |
| 00:00:15.00 | Accelerate Normal (DSA) | 48.10 |
| | Look Forward (DSA) | |
| | Look Instruments (DSA) | |
| | Steer Right (normal) (DSA) | |
| 00:00:17.00 | Look Forward (DSA) | 48.10 |
| | Look Instruments (DSA) | |
| | Maintain Speed (DSA) 1 | |
| | Steer Right (normal) (DSA) | |
| 00:00:18.00 | Look Forward (DSA) | 48.10 |
| | Look Instruments (DSA) | |
| | Maintain Speed (DSA) 1 | |
| | Steer Straight (DSA) | |

Exhibit 6. Task Workload Components with Texting (Time 10:00 - 18:00)

| **Clock** | **Task Name** | **Overall Workload** |
|---|---|---|
| 00:00:10.00 | Left Signal (TL) | 61.10 |
| | Look Forward (TL) | |
| | Look Instruments (TL) | |
| | Reading | |
| | Slow Down (slowly) (TL) | |
| | Steer Left (normal) (TL) | |
| 00:00:15.00 | Accelerate Normal (DSA) | 59.90 |
| | Look Forward (DSA) | |
| | Look Instruments (DSA) | |
| | Steer Right (normal) (DSA) | |
| | Texting | |
| 00:00:17.00 | Look Forward (DSA) | 59.90 |
| | Look Instruments (DSA) | |
| | Maintain Speed (DSA) 1 | |
| | Steer Right (normal) (DSA) | |
| | Texting | |
| 00:00:18.00 | Look Forward (DSA) | 59.90 |
| | Look Instruments (DSA) | |
| | Maintain Speed (DSA) 1 | |
| | Steer Straight (DSA) | |
| | Texting | |

## Discussion

The outcomes of the IMPRINT simulations can identify problematic areas of workload under certain combination of driving tasks and inputs. Operators who are overloaded tend to employ task shedding (i.e., performing situation assessment less frequently) and poor decision making (i.e., estimating breaking distance). Results from the baseline scenario show that situation awareness, especially looking at instruments, uses the greatest amount of cognitive resources. Comparison of the baseline scenario workload with texting scenario workload indicates that cell phone usage results in an overload condition by increasing the use of cognitive, visual and fine motor resources.

The driving segments identified with IMPRINT as being problematic can be further explored using a subject experiment or simulator. Additionally, the IMPRINT simulation can also suggest ways to ameliorate the high workload segments (i.e., delay use of an interface until an appropriate driving segment) which can also then be tested experimentally. In the example shown in Exhibit 6, the model simulates the operator reading the text during a turning segment, which is of higher workload than the drive straight segment. Both the model and the simulator can be used to evaluate the delay of texting from the turning to the drive straight segment.

## Implications for Engineering Managers

Cell phones are a great tool when used properly; when used to talk or text while driving, they can be deadly. The National Safety Council estimates than an accident related to this practice occurs every 24 seconds ( NSC, 2012). Although cell phones are responsible for a large percentage of distracted-driving accidents, they are not the only contributory factor. For companies that have mobile workforces with in-truck terminals or on-board tablets or other devices that help make work more efficient, managers and employees must take care to recognize the hazard of these potential distractions as well. While the example presented only illustrates the impact of texting on driving, the planned program research includes predicting task workload of key driving tasks with and without a variety of distracters, including sensors and warning devices. This information may allow system designers to reduce workload or redistribute workload over time or system interfaces. If a particular interface is difficult to use or if it interferes with other driving tasks, then the operators workload may increase. Increased workload, in turn, may result in decreased performance. Like all hazards, if the hazard of texting or talking when operating a vehicle goes unrecognized, the risk cannot be mitigated.

Not only while driving, distractions in the workplace are the leading cause for accidents and injuries. When people stop paying attention to what they are doing, they are more likely to make a mistake or to experience a safety related incident. In safety critical situations, even short distractions make mistakes much more likely. Interruptions of just 2.8 seconds long double the likelihood that an employee will make an error; when the length of the distraction is increased to 4.4 seconds, and the number of mistakes triples. (Altmann, Trafton & Hambrick, 2014). When an employee is momentarily disrupted and then returns to their task, there is an increased chance of resuming at a different point in their cognitve thought process. Being taken out of the moment and landing back in a slightly different place may mean even short disruptions can impact the worker.

Using the same methodology as shown in Exhitbit 1, organizational work processess can be created and the workload levels on the operators determined. The simulation model can objectively evaluate the impact from different types of distractions on the operator performance. The quantative results can then provide the data managers need to make informed policy decisions on workplace distractions. While most managers have been aware of the danger of increasing types of disruptions that workers face, the methodology described in this paper provides a tool to evaluate the impact of the potential hazard. Although some workplace distractions and interruptions are unavoidable, others, if not properly controlled or regulated, have the potential to cause errors, and even perhaps, injury.

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