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Visual, Auditory, Cognitive, and Psychomotor Demands of Real In-Vehicle Tasks

SAfety VEhicles using adaptive Interface Technology (SAVE-IT Project)
Task 3C: Performance

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16. Abstract

Two analysts rated the visual, auditory, cognitive, and psychomotor demands of 68 subtasks (e.g., prepare to eat/drink, converse on the cell phone) performed while driving. Ratings were relative to anchors from the U.S. Army IMPRINT modeling tool (0-to-7 scale). Video clips of those subtasks were sampled from the advanced collision avoidance system (ACAS) field operational test (FOT) database, a naturalistic study of driving previously performed by UMTRI.

Key findings were:

1. The most demanding tasks were dialing a phone, answering a phone, lighting a cigar or cigarette, dealing with pet and insect distractions, dealing with spilled drinks and food, typing with 2 thumbs, and drinking from a cup, in that order.
2. Demand levels within subtasks were moderately correlated (visual-cognitive=0.68, visual-psychomotor=0.48, cognitive-auditory=0.42, cognitive-psychomotor=0.34) or close to 0.
3. In terms of these ratings, cognitive demands, both per unit time and when weighted by exposure, were consistently double the value of others.
4. Demands varied to a limited degree among road types.
5. There were consistent differences in demand due to driver age and sex.

Researchers are encouraged to use the demand ratings provided and extend them to other tasks so tasks can be compared across experiments.

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VISUAL, AUDITORY, COGNITIVE, AND PSYCHOMOTOR DEMANDS OF REAL IN-VEHICLE TASKS

UMTRI Technical Report 2006-20 **March 2007**	**University of Michigan** **Transportation Research Institute**
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1 Primary Issues

1. What are the visual, auditory, cognitive, psychomotor, and total demands of real subtasks? Which subtasks are most and least demanding?
2. What is the relationship between demands for various resources within subtasks?
3. Using the Pass 2 sample of the advanced collision avoidance system (ACAS) field operational test data, how often were drivers exposed to each rating of demand? How often did each rating occur?
4. Does the demand drivers typically experience (per unit time, ignoring exposure duration) vary with the road type driven and the driver's age and sex?
5. In the complete ACAS dataset, what is the aggregate exposure to each demand type and total demand?

2 Methods

Using data from ACAS (a naturalistic driving study involving 96 drivers and over 100,000 miles of driving), 2 analysts coded video clips of the face for:

Coded Items		**Tasks**	
1	Driving conditions	Use phone	Read
2	Where the driver was looking	Eat/drink	Write
3	Where the head was pointed	Smoke	Type
4	What the hands were doing	Chew tobacco	Use in-car system
5	Tasks and subtasks observed (3-12/task, such as: prepare to drink, converse on cell phone)	Chew gum	Internal distraction
		Groom	Converse

Examples from enhanced U.S. Army IMPRINT scales used for coding:

Demand	Rating	Definition	Example
Visual	0.0	No visual activity	Self-explanatory
	3.7	Visually discriminate (detect visual difference)	Determine which traffic light is on
	7.0	Visually scan/search/ monitor (continuous)	Look through glove compartment
Auditory	0.0	No auditory activity	Self-explanatory
	4.9	Interpret semantic content (speech)	Understand speech (language is native to both speakers)
	7.0	Interpret sound pattern (pulse rate, etc.)	Determining how often or loudly an engine cylinder is clunking
Cognitive	0.0	No cognitive activity	Self-explanatory
	3.7	Sign/signal recognition	Recognize a stop sign
	7.0	Estimation, calculation, conversion	Mentally convert speed from mi/hr to km/h
Psycho-motor	0.0	No psychomotor activity	Self-explanatory
	4.6	Manipulative	Adjust center mirror
	7.0	Serial discrete manipulation (keyboard entries)	Type on a full keyboard

3 Results and Conclusions

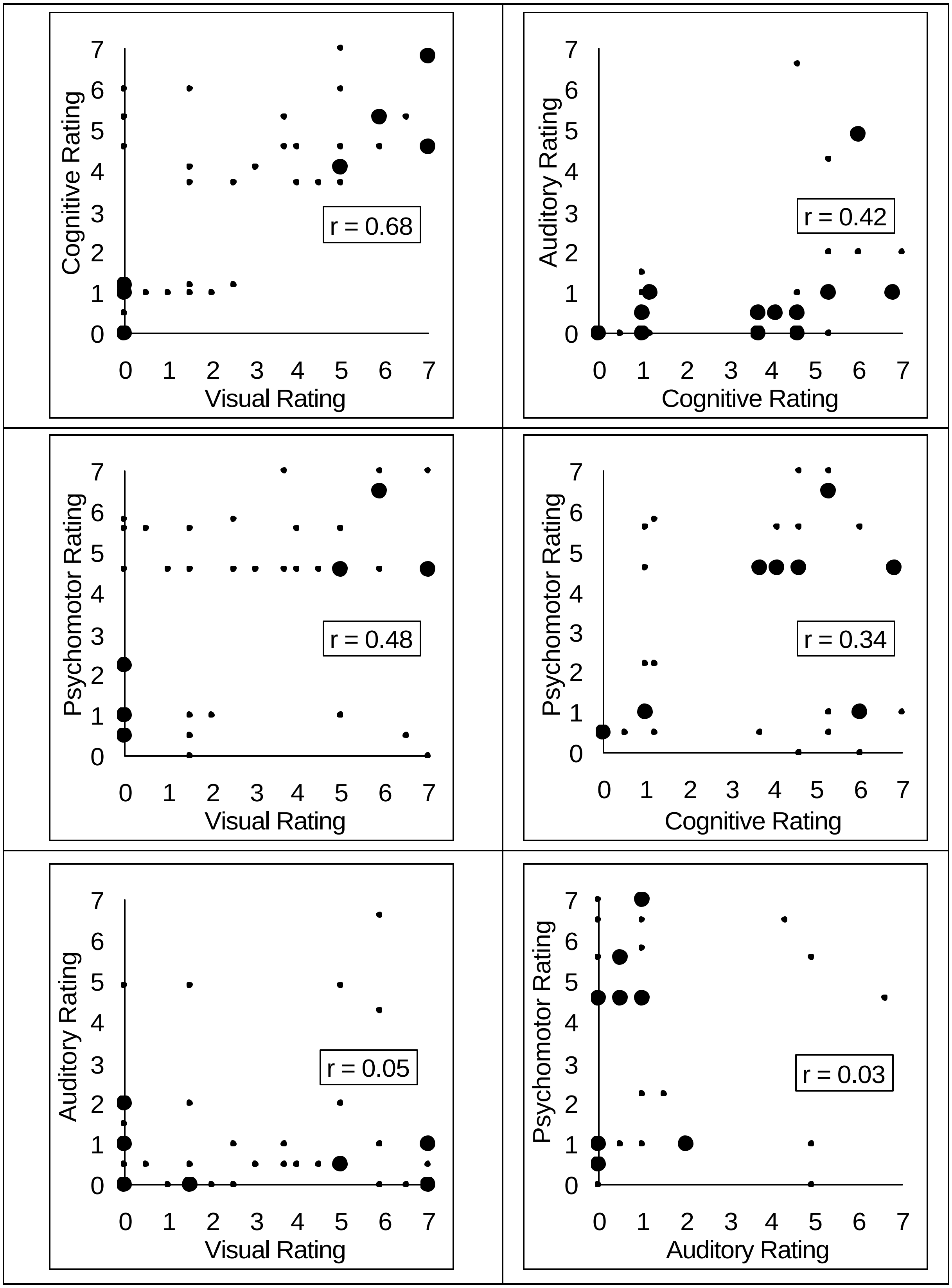
Subtask Demands, Phone As an Example

Description	Begins When:	Ends When:	Ratings			
			V	**A**	**C**	**P**
1.1 Prepare to use phone	Driver moves hand to reach for phone	Driver initiates another subtask with the phone	5.0	0.5	4.1	4.6
1.2 Dial phone – Hand-held	Driver presses first button	Driver initiates another subtask with the phone	5.9	4.3	5.3	6.5
1.3 Dial phone – Hands-free	Driver speaks first word	Driver initiates another subtask with the phone	0	2.0	5.3	1.0
1.4 Converse on phone (talk, listen)	Driver waits for a response (# is already dialed, phone is at ear)	Driver presses "End" button or closes phone	0	4.9	6.0	5.6
1.5 Hold phone	Driver holds phone in hand (no activity is taking place with the cell phone)	Driver initiates another subtask with the phone	0	0	0	0.5

Description	Begins When:	Ends When:	Ratings			
			V	A	C	P
1,6 Hang up phone /end call	Driver takes phone from ear (to put down or press "End" button)	Driver returns hand to a resting position or initiates another subtask	5.0	0.5	3.7	4.6
1.7 Answer phone	Driver reaches for phone upon hearing it ring	Driver holds phone in hand and answers call or initiates another subtask	5.9	6.6	4.6	4.6

Subtasks with the Greatest Total Demand

Rank	Subtask	Subtask Name	V	A	C	P	Total
1	1.2	Dial phone – Hand-held	5.9	4.3	5.3	6.5	22.0
2	1.7	Answer cell phone	5.9	6.6	4.6	4.6	21.7
3	3.2	Light cigar or cigarette	7.0	1.0	4.6	7.0	19.6
4	11.3	Pet-related distraction	7.0	1.0	6.8	4.6	19.4
5	11.2	Insect-related distraction	7.0	1.0	6.8	4.6	19.4
6	11.1	Catch falling object/ prevent object from moving, reach/lean/pick up	7.0	1.0	6.8	4.6	19.4
7	2.11	Spill/drop drink	7.0	1.0	6.8	4.6	19.4
8	2.10	Spill/drop food	7.0	1.0	6.8	4.6	19.4
9	9.3	Type with 2 thumbs	5.9	1.0	5.3	7.0	19.2
10	2.7	Drink from open cup	7.0	0	4.6	7.5	19.1



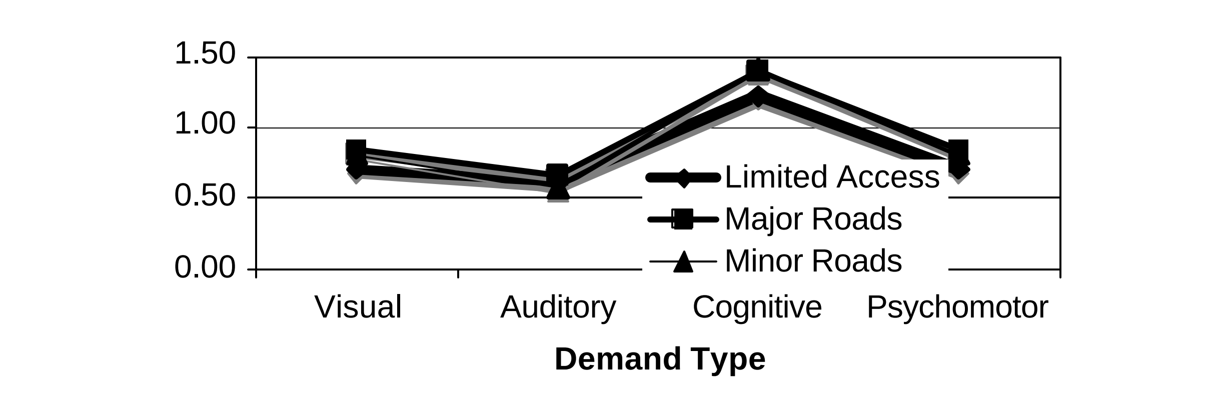
Demand Type Correlation Charts (by Subtask)

Mean Demand/Clip Frame by Age, Sex, and Road SuperClass

Demand	Age	Sex	Limited Access	Major Roads	Minor Roads
Visual	Young	Female	0.14	0.34	0.34
		Male	0.40	0.44	0.26
	Middle	Female	0.19	0.10	0.43
		Male	0.53	0.55	0.15
	Old	Female	0.12	0.14	0.06
		Male	0.30	0.48	0.70
Auditory	Young	Female	0.62	0.94	0.93
		Male	0.65	1.22	0.88
	Middle	Female	0.37	0.60	0.48
		Male	0.97	0.48	0.35
	Old	Female	0.49	0.40	0.52
		Male	0.61	0.34	0.29
Cognitive	Young	Female	1.36	1.57	2.12
		Male	1.13	1.87	1.66
	Middle	Female	0.86	1.40	1.25
		Male	1.86	1.19	0.78
	Old	Female	1.28	1.18	1.49
		Male	1.30	1.20	1.15
Psychomotor	Young	Female	0.60	1.18	1.12
		Male	0.92	1.63	1.03
	Middle	Female	0.36	0.71	0.56
		Male	1.35	0.69	0.36
	Old	Female	0.31	0.34	0.35
		Male	0.69	0.49	0.48
Total	Young	Female	2.71	4.03	4.51
		Male	3.10	5.16	3.82
	Middle	Female	1.77	2.81	2.72
		Male	4.71	2.91	1.64
	Old	Female	2.19	2.06	2.42
		Male	2.90	2.52	2.62

Aggregate Demand Using the Entire ACAS Dataset As Exposure

Demand	Age	Sex	Limited Access	Major Roads	Minor Roads
Visual	Young	Female	263.8	435.2	618.8
		Male	590.0	367.0	348.4
	Middle	Female	236.4	102.9	669.9
		Male	679.5	678.2	216.6
	Old	Female	155.6	106.3	69.8
		Male	430.8	471.4	887.6
Auditory	Young	Female	1168.1	1203.2	1692.6
		Male	958.8	1017.5	1179.2
	Middle	Female	460.3	617.4	747.8
		Male	1243.5	591.8	505.4
	Old	Female	635.5	303.6	605.3
		Male	876.0	333.9	367.7
Cognitive	Young	Female	2562.2	2009.6	3858.4
		Male	1666.8	1559.6	2224.4
	Middle	Female	1069.8	1440.6	1947.5
		Male	2384.5	1467.3	1126.3
	Old	Female	1660.2	895.6	1734.4
		Male	1866.8	1178.4	1458.2
Psychomotor	Young	Female	1130.4	1510.4	2038.4
		Male	1357.0	1359.4	1380.2
	Middle	Female	447.8	730.6	872.5
		Male	1730.7	850.8	519.8
	Old	Female	402.1	258.1	407.4
		Male	990.8	481.2	608.6
Total	Young	Female	5105.6	5158.4	8208.2
		Male	4572.5	4303.4	5118.8
	Middle	Female	2201.9	2891.5	4237.8
		Male	6038.2	3588.0	2368.2
	Old	Female	2840.4	1563.5	2816.9
		Male	4164.4	2474.6	3322.2
Sum			24923.1	19979.5	26072.0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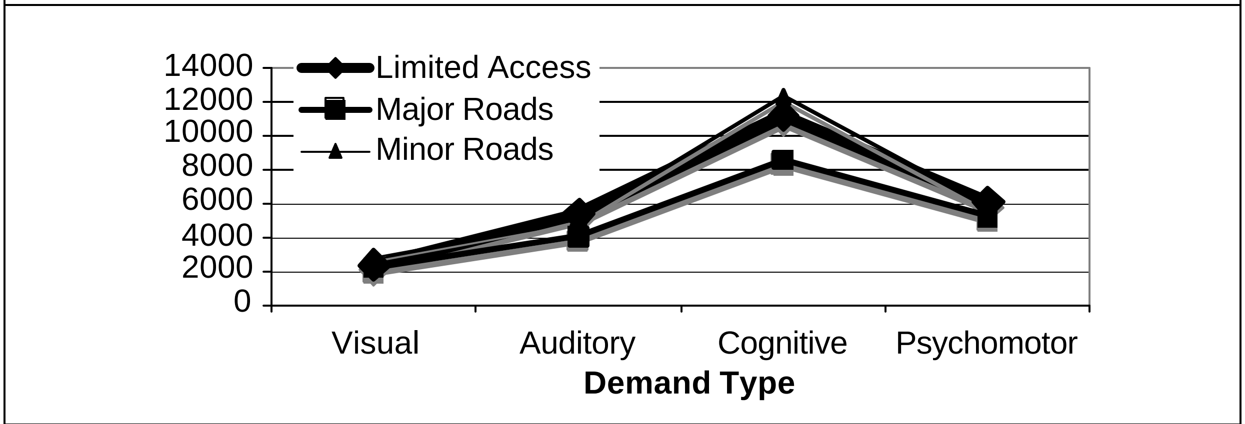
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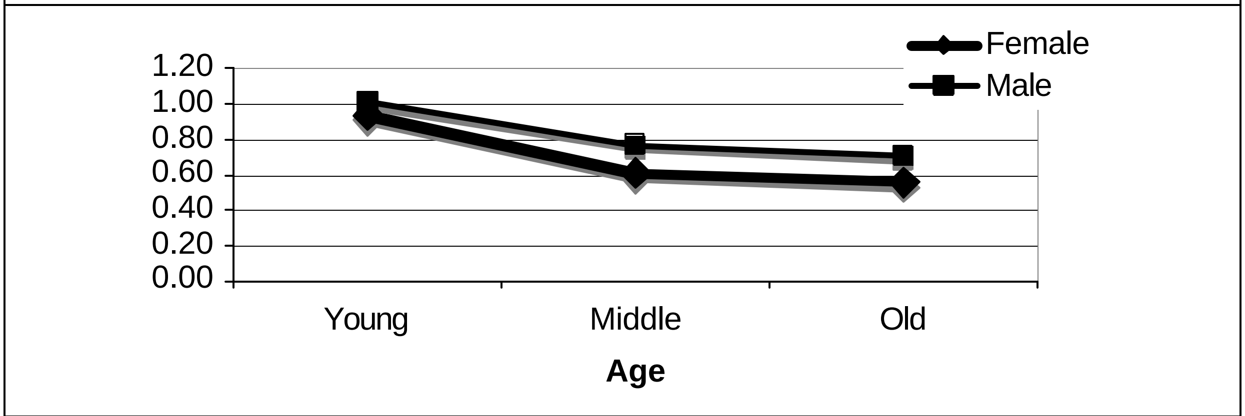
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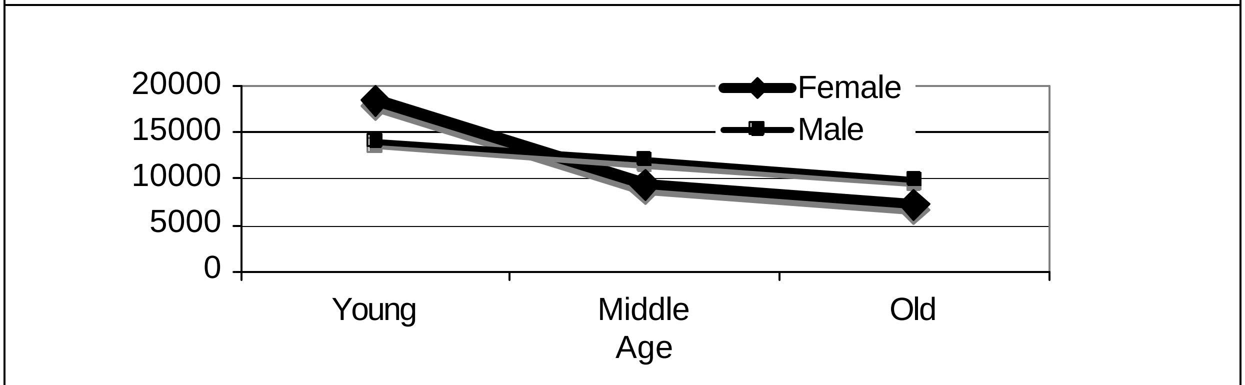
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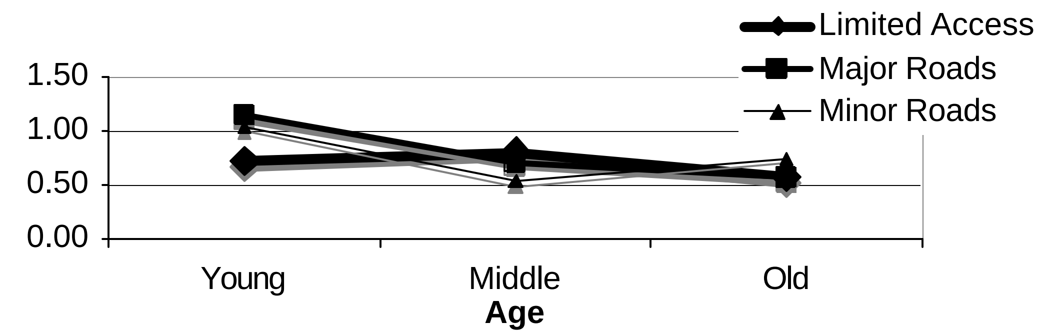
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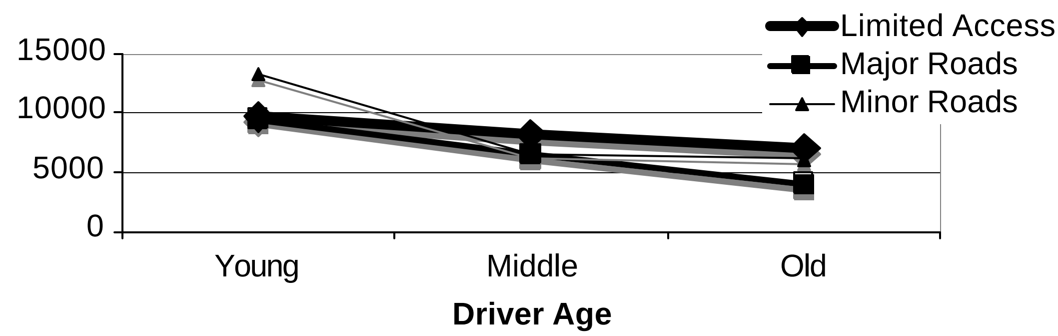
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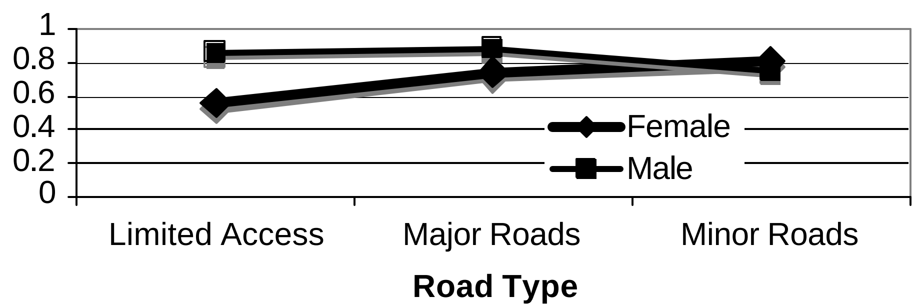
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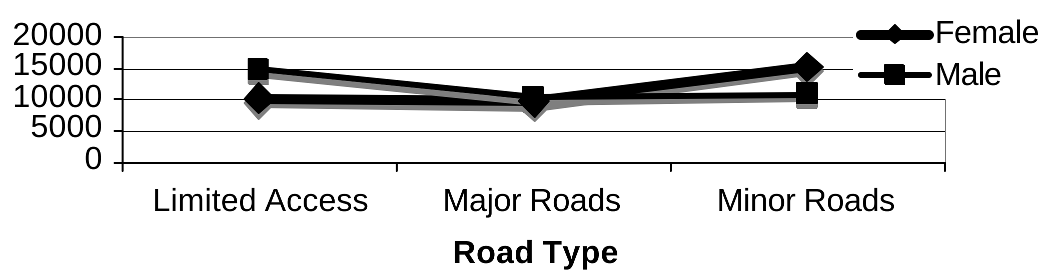
Major Roads
Minor Roads
Road Type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Road Type

PREFACE

This report is one of a series that describes the second phase of the University of Michigan Transportation Research Institute (UMTRI)'s work on the SAVE-IT project, a federally-funded project for which Delphi serves as the prime contractor and UMTRI as a subcontractor. The overall goal of this project is to collect and analyze data relevant to distracted driving, and to develop and test a workload manager. That workload manager should assess the demand of a variety of driving situations and in-vehicle tasks. Using that information, the workload manager would determine, for each driving/workload situation, what information should be presented to the driver (including warnings), how that information should be presented, and which tasks the driver should be allowed to perform. UMTRI's role is to collect and analyze the driving and task demand data that served as a basis for the workload manager, and to describe that research in a series of reports.

In the first phase, UMTRI completed literature reviews, developed equations that related some road geometry characteristics to visual demand (using visual occlusion methods), and determined the demands of reference tasks on the road and in a driving simulator.

The goals of this phase were to determine: (1) what constitutes normal driving performance, (2) where, when, and how secondary tasks occur while driving, (3) whether secondary tasks degrade driving and by how much, (4) which elements of those tasks produce the most interference, (5) how road geometry and traffic affect driving workload, (6) which tasks drivers should be able to perform while driving as a function of workload, and (7) what information a workload manager should sense and assess to determine when a driver may be overloaded.

In the first report of this phase (Yee, Green, Nguyen, Schweitzer, and Oberholtzer, 2006), UMTRI developed a second-generation scheme to code: (1) secondary driving tasks that may be distracting (eating, using a cell phone, etc.), (2) subtasks of those tasks (grooming, using a tool, etc.), (3) where drivers look while on the road, and (4) other aspects of driving. The scheme was then used to code video data consisting of face clips and forward scenes from the advanced collision avoidance system (ACAS) field operational test (FOT). The ACAS FOT was a major study in which instrumented vehicles collected a combined 100,000 miles of driving data for about 100 drivers, who used those vehicles for everyday use (Ervin, Sayer, LeBlanc, Bogard, Mefford, Hagan, Bareket, and Winkler, 2005).

Oberholtzer, Yee, Green, Nguyen, and Schweitzer (2006) used the second-generation UMTRI coding scheme to determine how often various secondary tasks and subtasks occur as a function of the type of road driven, driver age, driver sex, and other factors. In addition, Yee, Nguyen, Green, Oberholtzer, and Miller (2006), this report, performed an analysis to identify the visual, auditory, cognitive, and psychomotor (VACP) demands of all subtasks observed and determined how often those subtasks were performed. The goal of this analysis was to gain insight on how much, and to what degree, various aspects of subtask demand (VACP dimensions) affect driving.

In a subsequent study, Eoh, Green, Schweitzer, and Hegedus (2006), examined various combinations of measures (e.g., steering wheel angle and throttle) to analyze their joint distribution as a function of road type. This was done by pairing or grouping these measures to identify abnormal driving. By using the nonparametric distributions that describe these measures, pairs of thresholds were used to identify when particular maneuvers (e.g., lane changes) occurred on various road types. Success in this study was truly mixed, with high detection performance in some situations and poor detection in others. Nonetheless, some of these thresholds were descriptive enough to be used for a preliminary workload manager.

To support a more precise description of driving, Green, Wada, Oberholtzer, Green, Schweitzer, and Eoh (2006) developed distribution models that describe many of the driving performance measures examined.

Finally, to help characterize different driving situations and tasks, Schweitzer and Green (2006) asked subjects to rate clips of scenes from the ACAS FOT data relative to 2 anchor clips of expressway driving (1 of light and 1 of heavy traffic). Scenes of expressways, urban roads, and suburban driving were used for these ratings. Subjects also identified whether they would manually tune a radio, dial a cell phone, or enter a navigation destination in each of the clips. This data was used to determine the probability that each of the 3 tasks would be performed on each road type as a function of rated workload. In addition, the analysts used the ACAS driving performance data to develop equations that relate workload ratings to the driving situation (e.g., amount of traffic, headway to a lead vehicle).

The next task is for Delphi to use the findings from these reports to develop and test a workload manager.

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INTRODUCTION

For most of the 20th century, the motor vehicle driver's primary task has remained the same: to steer the vehicle in its path, control its speed, and not collide with other vehicles, pedestrians, or other objects. More recently, with the advent of telematics, the collection of tasks drivers perform has changed. Drivers must now divide their attention between the primary driving task and tasks related to a growing collection of telematics systems for navigation, collision warning, lane departure warning, entertainment, and so forth. Telematics systems are intended to make driving safer, easier, and more convenient but may actually end up putting the driver, their passengers, and those outside the vehicle at greater risk due to increased driver distraction.

So, what is distraction? The Merriam-Webster online dictionary (http://www.m-w.com) defines distraction as "1 : the act of distracting or the state of being distracted; *especially* : mental confusion, 2 : something that distracts; *especially* : AMUSEMENT." Furthermore, it defines distract as, "1a : to turn aside : DIVERT b : to draw or direct (as one's attention) to a different object or in different directions at the same time, 2 : to stir up or confuse with conflicting emotions or motives." Thus, in this context, a distraction is something that draws, diverts, or directs the driver's attention away from the primary task of controlling the vehicle.

A more detailed attempt to define driver distraction appears in the Tasca (2005) presentation at the International Conference on Distracted Driving (www.distracteddriving.ca/english/documents/ENGLISH-DDProceedingsandRecommendations.pdf) where the context of the problem is described and several definitions are provided. Interestingly Tasca does not directly define what a distraction is, but the definition can be inferred from the discussion of when a distraction occurs (Table 1).

Table 1. Definitions of Driver Distraction from Tosca (2005)

Source	**Definition as cited by Tasca (2005)**
Ranney, Garrott, and Goodman, 2000	"Driver distraction may be characterized as any activity that takes a driver's attention away from the task of driving. Any distraction from rolling down a window to using a cell phone can contribute to a crash. Four distinct categories of distraction: Visual (e.g., looking away from roadway) Auditory (e.g., responding to ringing cell phone) Biomechanical (e.g., adjusting CD player) Cognitive (e.g., being lost in thought)"
Stutts, Reinfurt, Staplin, and Rodgman, 2001	"Distraction occurs when a driver is delayed in recognition of information needed to safely accomplish the driving task because some event, activity, object or person (both inside and outside the vehicle) compelled or tended to induce the driver's shifting attention away from the driving task (citing Treat, 1980)."
Beirness, Simpson, and	"…Need to distinguish distraction from inattention…Distracted driving is part of the broader category of driver inattention…The presence of

Desmond, 2002	a triggering event or activity distinguishes driver distraction as a subcategory of driver inattention."
Green, 2004	"'Driver distraction'" is not a scientifically defined concept in the human factors literature. As used by the layperson, it refers to drawing attention to a different object, direction or task. A distraction grabs and retains the driver's attention."
Tasca, 2005	"Distraction occurs when there is…a voluntary or involuntary diversion of attention from primary driving tasks not related to impairment (from alcohol/drugs, fatigue or a medical condition). Diversion occurs because the driver is: performing an additional task (or tasks) or temporarily focusing on an object, event or person not related to primary driving tasks. Diversion reduces a driver's situational awareness, decision-making and/or performance resulting in any of the following outcomes—collision, near-miss, corrective action by the driver and/or another road user."

A second aspect of distraction is when the combined demands of the primary and secondary tasks overload the driver. How overload occurs and its consequences can be explained using the 2 most common mental workload theories: (1) bottleneck theory and (2) multiple resource theory.

According to the bottleneck theory, all demands on the person are treated equally, and when the total demand exceeds some maximum, performance degrades. Degradation may take the form of increased task time, increased errors, ignored or forgotten tasks, delayed start or completion of tasks, and so forth. According to bottleneck theory, when a person receives 2 simultaneous forms of stimulation, they will process the 2 sets of information in succession, not concurrently. In many situations, this simple approach to workload provides useful results. However, there are many cases where adding tasks may have no negative consequences, an outcome that does not fit with bottleneck theory. Nonetheless, bottleneck theory has a key advantage of simplicity, as it allows workload to be assessed on a continuous basis by subjectively assigning a single number for each moment.

A more complex approach to mental workload is multiple resource theory (Wickens, 1984). According to multiple resource theory, demands on a person are processed differently according to several perceptual and cognitive dimensions (visual or auditory modality, visual or spatial coding, etc.). Multiple resource theory asserts that people have separate attentional resources, each of which has a certain capacity and may be overloaded. A person can perform concurrent continuous tasks with little or no interference as long as those tasks use separate resources or the same resource but with different coding. However, when a person attempts to perform 2 concurrent continuous tasks that use the same resource and the same coding, interference is likely to occur and may negatively affect performance. Thus, overload may be of a single resource (visual, auditory, cognitive, or psychomotor (VACP)) or some combination of them. In fact, current research proposes a more complex model, dividing visual and auditory resources into focal and ambient versions, and distinguishing between speech and manual output (Horrey and Wickens, 2005).

For the purposes of the SAVE-IT project, multiple resource theory is a more appropriate model for workload as it provides a more comprehensive outlook of mental workload and resource demand, though in some instances, such as the clip workload rating task in Schweitzer and Green (2007), the use of a single rating dimension presumes bottleneck theory. However, the consequences of both theories are the same, performance of the primary and/or secondary task may decline, be delayed, not performed at all, etc. This performance decrement is especially dangerous in regards to driving, since declining performance of the primary driving task may have the dangerous effect of compromising driving safety.

Thus, distraction has at least 2 aspects (capturing and potentially holding attention) and overload (unmanageable task load, too much to do within resources). However, the way in which distraction is defined varies from source to source, as there is no one definition for either term that is standard throughout the literature. For the purposes of this report, the term distraction will be used to refer to both aspects, even though it is not technically correct, at least based on dictionary definitions.

How can distraction and the resulting crashes be reduced? Approaches proposed include implementing (1) regulations that prohibit performing distracting tasks (such as using a cell phone) while driving and (2) systems, such as a workload manager, to reduce distraction while driving (Green, 2004).

Both approaches have advantages and disadvantages. Affected suppliers and manufacturers often resist passage of new regulations. Furthermore, the burden of proof is on those proposing regulations, to show that something is unsafe, not on affected suppliers and manufacturers to show something is safe. The most convincing evidence to support motor vehicle regulation are crash statistics, especially fatalities, but it takes time for enough people to die and the evidence to accumulate. Given the rapid advances of telematics and the slow process of regulation, motor vehicle regulations are only developed well after they are needed, if at all. Finally, the focus of such regulations is often very narrow, for example focusing on cell phone use and ignoring other tasks of concern. Fortunately, once a regulation is passed, compliance is often very high.

The second approach, use of a workload manager, can occur more quickly. A workload manager makes a continual real-time assessment of the demands of the primary driving task, the demands of secondary tasks (e.g., using the phone), and, in some cases, the driver's capabilities so that it can determine when the driver is overloaded and suppress additional distractions. For example, if a driver is in heavy traffic, in the rain, on a curvy road, then an incoming phone call might be automatically routed to an answering machine instead of ringing as normal. Redirecting the call should reduce demand and eliminate an attention-grabbing task. Furthermore, a workload manager could be linked to a warning system to greatly enhance its effectiveness by reducing false alarms and presenting the warning only when needed (usually when the driver is distracted). Despite their possible benefits, drivers may feel that such safety systems (e.g., workload managers) are an invasion of privacy and may be unwilling to use them.

To design a workload manager that addresses overload, one needs to know: (1) the visual, auditory, cognitive, and psychomotor (VACP) resource capacities of a driver, (2) the VACP demands of the primary driving task in a wide range of situations, (3) the VACP demands of each secondary task, and (4) the resources required to coordinate primary and secondary tasks. This report focuses on the third aspect, the VACP demands of each task, and investigates the following questions:

1. What are the demand characteristics of real subtasks?

   More specifically, what are the visual, auditory, cognitive, psychomotor, and total demands of real subtasks? Which subtasks are most and least demanding?

2. What is the relationship between demands for various resources within subtasks?

3. Using the Pass 2 sample of the ACAS data, how often were drivers exposed to each rating of demand?

   More specifically, how often did each rating occur?

4. Does the demand drivers typically experience (per unit time, ignoring exposure duration) vary with the road type driven and the driver's age and sex?

5. In the complete ACAS dataset, what is the aggregate exposure to each demand type and total demand?

   In contrast to question 3 (a sample of ACAS) and question 4 (per unit time), this question considers all driving.

In addition to the theoretical reasons noted, understanding the nature of real task demands is also important for assessment. A significant number of studies relating to driver distraction use abstract distraction tasks (Recarte and Nunes, 2000, 2003; Harbluk, Noy, and Eizenman, 2002; Ostlund, Nilsson, Carsten, Merat, Jamson, Jamson, Murta, Varvalhais, Santos, Anttila, Sandbert, Luoma, DeWaard, Brookhius, Johansson, Engstrom, Victor, Harbluk, Janssen, and Brouwer, 2004). (See also Tijerina, Angell, Austria, Tan, and Kochhar, 2003, for an overview.) The studies make the point that because these artificial tasks can degrade driving, real-world secondary tasks that share the same demands should also be limited.

From time to time, authors assert that a particular task has some predominant demand (e.g., visual task). Often, at face value, the assertion seems reasonable. Further, when that task overloads a driver, it is asserted that problems related to the resource demanded by that task should be the primary concern (e.g., all visual tasks are bad), without considering the intensity of that demand. Such assertions are of particular concern when the task is abstract and has characteristics not found in real-world driving tasks. Further, what is needed is independent assessment of both real and abstract tasks against common standards for resource assessment.

These concerns are further arguments for the research described in this report.

METHOD

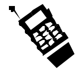
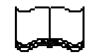
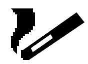
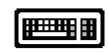
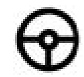
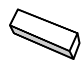
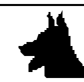
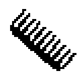
How the face clips were sampled and coded Initially

To distinguish between normal and distracted driving, driving performance data from the ACAS FOT (Ervin, Sayer, LeBlanc, Bogard, Mefford, Hagan, Bareket, Winkler, 2005) was examined in detail. This experiment assessed the combined effect of adaptive cruise control (ACC) and forward collision warning (FCW) systems on real-world driving performance. Data was collected using a fleet of 10 model year 2002 Buick LeSabre passenger cars equipped with custom ACC and FCW systems. Each car was also equipped with 2 monochrome cameras (for the forward scene and the driver's face) and additional instrumentation that recorded over 400 engineering variables (speed, steering wheel angle, etc.). Data was collected starting 5 minutes after the beginning of each trip, so in terms of exposure, local roads were underrepresented in the sample. The face video was recorded once every 5 minutes for 4 seconds at 5 Hz. The forward road scene was recorded at 1 Hz continuously and the engineering variables were recorded at 1 Hz. Road type descriptions and frequencies can be found in Appendix A.

A total of 96 subjects drove the test vehicles. Equal numbers of men and women, in 3 age groups (20s, 40s, and 60s) participated in the study. Fifteen of the subjects drove for 3 weeks, and 81 drove for 4 weeks. The first week of testing was for baseline, naturalistic data without the ACAS system in operation (the portion of the dataset examined here).

As is described in Yee, Green, Nguyen, Schweitzer, and Oberholtzer (2006), a coding scheme was developed to identify (1) driving conditions, (2) where the driver was looking, (3) where the head was pointed, and (4) what the hands were doing. Items (2) through (4) were analyzed to determine what secondary/distracting activities the driver was engaged in. These activities were parsed into 12 secondary tasks plus drowsiness. Those tasks and their associated symbols appear in Table 2. The task numbers are not consecutive because other items were coded for other phases of this project.

Table 2. Tasks, Drowsiness, and Their Associated Symbols

Task #	Task Name	Symbol	Task #	Task Name	Symbol
1	Use Cell Phone		7	Read	
2	Eat/Drink		8	Write	
3	Smoke		9	Type	
4	Chew Tobacco		10	Use In-Car System	
5	Chew Gum		11	Internal Distraction	
6	Groom		13	Converse	

Note: The symbols shown in this table are used in later tables to save space and improve understanding of the results.

Each task consisted of 3 to 12 subtasks, which were defined as phases or variations of task execution. A complete list of tasks and subtasks, along with descriptions and ratings, is shown in Appendix B. Based upon the ideas from the Maynard Operation Sequence Technique (MOST), a predetermined time system used in industrial engineering (Zandin, 2003), many tasks were divided into 3 phases: (1) prepare to do the task (e.g., get the parts in assembly tasks, prepare to eat here), (2) do the task (e.g., eat, bite, chew), and (3) finish the task (e.g., put the parts away in assembly tasks, wipe mouth with napkin).

More specifically, to assess the demands of driving and secondary tasks, approximately 3,000 clips were examined in 2 passes (Yee, Green, Nguyen, Schweitzer, and Oberholtzer, 2006). The original ACAS dataset contained codes for the age of each subject (3 levels), sex (male or female), and the type of road driven (6 types – interstate, expressway, arterial, minor arterial, collector, or local), but there was no information on the tasks performed or where the driver was looking.

The original plan was to draw from each of those 36 age*sex*road type cells equally. As enormous as the dataset was, there were not 83 clips (3,000/36) in some cases, so the road types were pooled into 3 superclasses (divided highways (interstates + expressways), major roads (arterials + minor arterials), and minor roads (collectors + local)) so roughly equal samples could be obtained. Examination of the original sample of 3,000 clips revealed that some were not usable for analysis because of poor image quality, misalignment, and so forth, so some re-sampling was done. However, there was a point at which re-sampling led to recoding the entire sample, which was very time consuming. Accordingly, after the last review, clips were not added, so the final sample was 2,914. This sampling strategy maximized the sensitivity of tests of task frequency due to age, sex, and road type. One disadvantage of this strategy was that the resulting overall frequencies were not a statistically representative sample of what an average driver would experience.

In the first pass, entire clips were coded to determine the tasks present in that clip, weather and road surface information, and so forth. In the second pass, the clips were examined frame by frame to identify the subtask performed, the direction of gaze, head orientation, and hand position. There were too many clips to code every frame within the project resources, so 831 clips were randomly selected, with roughly half involving distraction (the presence of a distracting task) and half involving normal driving. Since the resulting data was to be used to determine how normal and distracted driving differed (in terms of the driving data associated with each clip), equalizing the number of normal and distracted clips maximized the sensitivity of the analysis.

To provide consistent results, each clip was coded by 2 of the 3 analysts to determine which tasks were present. For both passes, the analysts coded independently. After each portion of the clips was coded, the analysts met and reconciled their differences. Often this meant they went back and recoded large numbers of clips. The analysts could simply have coded the entire set and used a computational scheme to combine their results, which would have provided a correlation for their level of agreement. However, the iterative approach led to a coding scheme that was consistent, handled all of the exceptions, and handled cases not thought of when the coding scheme was first developed. Most importantly, this iterative approach led to a very high quality dataset.

Assignment of VACP values to subtasks

All but 4 of the 72 subtasks in the UMTRI coding scheme were assigned values on a 0-to-7 scale for visual, auditory, cognitive, and psychomotor demand. Those 4 exceptions (chew gum-other, use in-car system-other, internal distraction-no task, and internal distraction-other) were not assigned demand values because the subtasks were insufficiently defined for that purpose.

The anchors for that coding (described In the following section) used in the "air" version of IMPRINT (http://www.arl.army.mil/ARL-Directorates/HRED/imb/imprint/Imprint7.htm), the most commonly used version. As background, there is a long history of VACP analyses using IMPRINT and other software to evaluate the operator workload of military weapons systems (Archer, Lewis, and Lockett, 1996; Pew and Mavor, 1998; Booher, 2003; Mitchell, Samms, Henthorn, and Wojciechowski, 2003) and for other complex systems. To facilitate coding, automotive specific examples to supplement the IMPRINT anchors were also defined.

Visual demand

Visual demand is defined as the complexity of visual stimuli requiring response (McCracken and Aldrich, 1984) with reference to the anchors shown in Table 3. For all 4 scales, the definition and rating columns were copied from IMPRINT, whereas the examples created by the authors were particularly helpful since the subtask definitions in the second-generation UMTRI coding scheme (Yee, Green, Nguyen, and Schweitzer, 2006) rarely specified glance behavior. Notice that the scale differentiates between visually tracking (following) an object, such as a moving car, and visually monitoring an object that is not moving. Visually scanning or monitoring involves search whereas inspection does not. Thus, the key visual demand scale characteristics are: 1) fixed versus moving object, 2) search versus scanning (an object or an area), and 3) basic detection versus complex processing (e.g., reading).

Table 3. Visual Demand Scale

Rating	Definition	Example
0.00	No visual activity	Self-explanatory
1.00	Visually register/detect image	Observe a warning light turn on
3.70	Visually discriminate (detect visual difference)	Determine which traffic light is on
4.00	Visually inspect/check (static inspection)	Check side mirror position while parked
5.00	Visually locate/align (selective orientation)	Change focus to a car
5.40	Visually track/follow (maintain orientation)	Watch a moving car
5.90	Visually read (symbol)	Read a native language
7.00	Visually scan/search/monitor (continuous)	Look through glove compartment

Auditory demand

As with visual demand, auditory demand is defined as the complexity of auditory stimuli requiring response as shown in Table 4. There is an important distinction between “orient to sound (general orientation),” where the focus is on 1 unique source with no other competing, similar sources and ”orient to sound (selective attention),” where several other competing, similar sources are present. Another important distinction is that between “discriminate sound characteristics,” which is qualitative, and “interpret sound pattern (pulse rate, etc.),” which is more quantitative.

Table 4. Auditory Demand Scale

Rating	Definition	Example
0.00	No auditory activity	Self-explanatory
1.00	Detect/register sound	Notice headlight chime
2.00	Orient to sound (general orientation)	Note that honking is occurring
4.20	Orient to sound (selective attention)	Focus on one specific source of honking (possibly out of several)
4.30	Verify auditory feedback	Listen to the engine rev up
4.90	Interpret semantic content (speech)	Understand speech (language is native to both speakers)
6.60	Discriminate sound characteristics	Determine if the engine sound is bad
7.00	Interpret sound pattern (pulse rate, etc.)	Determine how often or loudly an engine cylinder is clunking

Cognitive demand

Cognitive demand is defined as the level of thinking required by the driver as shown in Table 5. Cognitive demand was the most complex demand to rate because there are rarely visual indications of cognitive demand; there are only inferences. To a large degree, that was also true of auditory demand (as there was no soundtrack on the tapes), though auditory demand was easier to infer. Hence, in each scenario examined, cognitive demand was inferred from what the driver was probably thinking, or to what the driver was probably responding. Because making these inference required significant knowledge and experience in human factors engineering, the senior author was extensively engaged In reviewing the ratings.

Table 5. Cognitive Demand Scale

Rating	Definition	Example
0.00	No cognitive activity	Self-explanatory
1.00	Automatic (simple association)	Associate brake lights with braking
1.20	Alternative selection	Decide to turn left or right (at an empty T-intersection)
3.70	Sign/signal recognition	Recognize a stop sign
4.60	Evaluation/judgment (consider simple aspect)	Judge when to stop for a stop sign (on an empty, straight road)
5.30	Encoding/decoding, recall	Remember a license plate number
6.80	Evaluation/judgment (consider several aspects)	Weigh the pros and cons of taking a shortcut (given traffic, time, etc.)
7.00	Estimation, calculation, conversion	Mentally convert speed from mi/hr to km/h

Psychomotor demand

The Merriam-Webster online dictionary (http://www.m-w.com) defines *psychomotor* as "of or relating to motor action directly proceeding from mental activity." The psychomotor demand scale is shown in Table 6. Based on this scale, manipulating an object (such as moving a bag) is much more demanding than pushing a button or switch. Also, typing is more demanding than writing as it may involve parallel actions of 2 hands or multiple fingers of 1 hand.

Table 6. Psychomotor Demand Scale

Rating	Definition	Example
0.00	No psychomotor activity	Self-explanatory
1.00	Speech	Speak in a native language
2.20	Discrete actuation (button, toggle, trigger)	Activate turn signal
4.60	Manipulative	Adjust center mirror
5.80	Discrete adjustment (rotary, thumbwheel, lever)	Change windshield wiper speed
6.50	Symbolic production (writing)	Write in a native language
7.00	Serial discrete manipulation (keyboard entries)	Type on a full keyboard

To provide consistency, the ratings were assigned not by subtask, but so that all of those associated with a particular demand were grouped together, so similarities (and instances where the demand were the same) were readily identified. For example, if a group of tasks all involved holding something of the same size and shape, then they should probably all have the same psychomotor demand.

Psychomotor demands were considered first because they were the most visible of the demands (on the videotapes), facilitating the development of a consistent process by the evaluators. The visual, auditory, and cognitive dimensions were progressively more abstract, with some evidence of visual demand on the tape. But without sound, auditory demand was determined from expectations of what might have been heard and cognitive demands were determined by inferring what the driver was thinking about, which required some creative assessment by the evaluators.

The analysts assigned the demand ratings by first rating each subtask independently, then discussing and selecting a final rating by consensus. As with the prior 2-pass process of coding driver activity, this interactive approach probably led to a higher quality dataset than would have been obtained had the analysts identified the VACP values independently (John Lockett, 2006, personal communication).

More specifically, VACP values were assigned in several steps. The first step was to determine if a subtask description matched one of the IMPRINT scale anchors. This occurred most often for demands that involved speech. For example, listening to someone speak (a passenger, someone on the phone) corresponds to “interpret semantic content (speech)” on the auditory dimension. In most cases, for each dimension, a single VACP definition would apply to a subtask.

If a subtask involved either multiple steps or multiple contributing factors across which demand varied, then the second step was to determine a compromise value. For example, talking on a hand-held cell phone demands psychomotor resources from the driver’s mouth and hands. More specifically, a subtask that had elements of detection (1.0) and discrimination (3.7) at various times during that subtask might have a value of 2.5 (visually locate/align). Furthermore, it was recognized that demands would vary from trial to trial, depending on how it was executed. For example, a driver will not always look at a cigarette while smoking it, but rather shift attention to it occasionally. Thus, the demand value used was the weighted aggregate mean over the period of performance of the subtask and weighted with respect to how often different methods were expected to occur. Using this approach, each subtask was initially assigned a code value on the expanded scale. So, “drink from open-top container,” “spill/drop food,” and “light cigar/cigarette” were all coded as visually scan/search/monitor (rating 7.0). Information on the frequency of occurrence of various codes and subtasks appears in the Results section.

RESULTS

What are the demand characteristics of real subtasks?

More specifically, what are the visual, auditory, cognitive, psychomotor, and total demands of real subtasks? Which subtasks are most and least demanding? The purpose of this question is to determine which kinds of demands could compromise driving safety and which subtasks deserve further scrutiny.

Visual demand

Table 8 shows the number of subtasks assigned various ratings, ranging from 0.0 to 7.0. Averaging across subtasks, the visual demand was 3.1 with a standard deviation of 2.7. Most common was “visually locate/align-case a” (12 subtasks, rating=5.0). Some of the code names may seem a bit odd (e.g., “visually read”), but “visually” was included in every code name as an indicator of the type of demand. Many of the “prepare” subtasks were rated at or close to 5.0, as the driver often had to search for required objects. Many of the “finish” subtasks were rated lower than their corresponding “prepare” subtasks because discarding a used item rarely required visual search. Where a task could be performed using multiple methods, and it was expected that each method would be used equally often, the task demand was estimated as the mean of the ratings for the various methods. Subtask 7.2: “read” encompasses the reading of books, notes including directions, and other materials (visual demand of 5.9) as well as the “reading” of maps (visual demand of 7.0). Since both methods were expected to occur equally often, the visual demand was set at the mean of their ratings (6.5). (See Appendix B for details.)

Table 8. Number of Subtasks Having Various Visual Demands

Rating	Subtasks		Code Name
	#	%	
0.0	20	29	No visual activity
0.5	1	1	Visually register/detect image-case d
1.0	1	1	Visually register/detect image-case c
1.5	7	10	Visually register/detect image-case b
2.0	1	1	Visually register/detect image-case a
2.5	3	4	Visually locate/align
3.0	2	3	Visually discriminate-case b
3.7	2	3	Visually discriminate-case a
4.0	2	3	Visually inspect/check
4.5	1	1	Visually locate/align-case b
5.0	12	18	Visually locate/align-case a
5.9	5	7	Visually read-case b
6.5	1	1	Visually read-case a
7.0	10	15	Visually scan/search/monitor
	68	100	

Table 9 shows the 10 most visually demanding subtasks. They all require visual assessment of an unpredictable situation (e.g., how much food or drink will be spilled, what it spilled on, and where it will flow). Lighting a cigarette requires that the driver monitor the lighter to wait for ignition, and then bring the flame to the exact location it is needed. For a full list of the visual demand for all subtasks, see Appendix B.

Table 9. Top 10 Subtasks for Visual Demand

Subtask	Subtask Description	Rating	Coding Explanation
2.7	Drink from open-top container (cup)	7.0	**Visually scan/search/monitor**; subject must monitor fluid level on open-top container while driving to avoid spilling
2.10	Spill/drop food	7.0	**Visually monitor/scan/search**; subject must discern the extent, location, and severity of spill
2.11	Spill/drop drink	7.0	**Visually monitor/scan/search**; subject must discern the extent, location, and severity of spill
3.2	Light cigar/cigarette	7.0	**Visually scan/search/monitor**; driver must monitor the cigarette to determine how well it lights
8.1	Prepare to write	7.0	**Visually scan/search/monitor**; subject must find appropriate writing materials, which are unlikely to be readily found
10.6	Glance only - monitor in-car system	7.0	**Visually scan/search/monitor**; subject needs to assess the object
11.1	Catch falling object/prevent object from moving, reach/lean/pick up	7.0	**Visually scan/search/monitor**; task and result can be unpredictable
11.2	Insect-related distraction	7.0	**Visually scan/search/monitor**; task and result can be unpredictable
11.3	Pet-related distraction	7.0	**Visually scan/search/monitor**; task and result can be unpredictable
11.4	Glance only - monitor internal distraction	7.0	**Visually scan/search/monitor**; subject needs to assess the object

Table 10 contains the 5 subtasks with the lowest nonzero visual demand. In sharp contrast to lighting a cigarette, ashing it imposes very little visual demand, because ashing is often much less detailed (a well-practiced flicking motion is all that is needed to remove an approximate amount of ash). The 2 conversation subtasks also had very little visual demand because it was assumed that a driver does not maintain eye contact with the passenger. Subtask 9.5: "end typing" was assumed to involve devices that are typically clipped to the driver's belt or another static location; the driver would rarely have to search for where to put the device. Keep in mind that a few subtasks, such as "end typing," were never observed, so analysts estimated how they thought the subtask would be accomplished given other observations.

Table 10. Bottom 5 Subtasks for Visual Demand

Subtask	Subtask Description	Rating	Coding Explanation
9.5	End typing	1.5	More demanding than **Visually register/detect image (1.0)**; it is assumed the subject is most likely to use a Blackberry (or similar device), and the subject will have that clipped to his or her belt
13.2	Converse with passenger - speak	1.5	More demanding than **Visually register/detect image (1.0)**, as subject may occasionally focus on the passenger
13.3	Converse with passenger - listen	1.5	More demanding than **Visually register/detect image (1.0)**, as subject may occasionally focus on the passenger
3.6	Ash cigar/cigarette	1.0	**Visually register/detect image**; subject will merely detect that ash has been removed, very little detail required
2.3	Eat/bite food - not wrapped	0.5	Less demanding than **Visually register/detect image (1.0)**; food without wrappers often involved discrete pieces (candy, fries) requiring very little visual fixation

Auditory demand

As shown in Table 11, auditory demand codes used for subtasks ranged from 0.5 to 6.6 with a mean of 0.2 and standard deviation of 1.3. Codes for "detect/register sound" (38 instances for all 3 cases) were most common by far with values of 0.5 or 1.0.

Table 11. Number of Subtasks Having Various Auditory Demands

Rating	Subtasks		Code Name
	#	%	
0.0	20	29	
0.5	22	32	Detect/register sound-case c
1.0	15	22	Detect/register sound-case b
1.5	1	1	Detect/register sound-case a
2.0	5	7	Orient to sound (general orientation)
4.3	1	1	Verify auditory feedback
4.9	3	4	Interpret semantic content
6.6	1	1	Discriminate sound characteristics
	68	100	

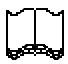
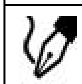
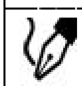
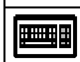
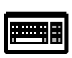
Table 12 lists the 10 subtasks with the highest auditory demand. The auditory demand for most tasks is low relative to the other demand types. Only 5 subtasks have an auditory demand greater than 2. Almost all subtasks in Table 12 entail conversation. The exception is 1.2: "dial phone – hand-held" where drivers presumably listen to the auditory feedback provided by the phone when buttons are pressed.

Table 12. Top 10 Subtasks for Auditory Demand

Subtask	Subtask Description	Rating	Coding Explanation
1.7	Answer cell phone	6.6	**Discriminate sound characteristics**; subject must determine if the ring tone belongs to the subject's phone
1.4	Converse on cell phone (talk, listen)	4.9	**Interpret semantic content**; subject has to understand speech
13.3	Converse with passenger - listen	4.9	**Interpret semantic content**; subject has to understand speech
13.5	Talk to someone outside vehicle (not by phone)	4.9	**Interpret semantic content**; subject has to understand speech
1.2	Dial phone – Hand-held	4.3	**Verify auditory feedback**; subject listens for the dial tone while entering numbers
1.3	Dial phone - Hands-free	2.0	**Orient to sound (general orientation)**; subject pays some attention to own voice
13.1	Converse with unknown	2.0	**Orient to sound (general orientation)**; subject pays some attention to own voice
13.2	Converse with passenger - speak	2.0	**Orient to sound (general orientation)**; subject pays some attention to own voice
13.4	Sing/talk to self	2.0	**Orient to sound (general orientation)**; subject pays some attention to own voice
13.6	Road rage	2.0	**Orient to sound (general orientation)**; subject pays some attention to own voice

Table 13 shows 5 subtasks with the lowest non-zero auditory demand. These subtasks, and others, were judged to generate a nontrivial amount of noise that serves as background static. Although such noise would not directly require auditory resources from the driver, it would interfere with sounds for other subtasks (e.g., those related to conversation). This interference had a greater impact on the auditory demand rating than any other demand because the driver cannot voluntarily stop the background noise without stopping the subtask.

Table 13. Bottom 5 Subtasks for Auditory Demand

Subtask	Subtask Description	Rating	Coding Explanation
 7.3	Put away/fold reading materials	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
 8.1	Prepare to write	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
 8.3	Put away writing materials	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
 9.1	Prepare to type	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
 9.5	End typing	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)

Auditory demand estimates for the full set of subtasks appear in Appendix C.

Cognitive demand

As shown in Table 14, subtask cognitive demands ranged from 0.0 to 7.0 with a mean of 3.7 and a standard deviation of 2.1. The cognitive demand levels most commonly associated with subtasks were 4.1 (12 subtasks, a compromise between sign/signal recognition (3.7) and evaluation/judgment (consider simple aspect) (4.6) (mean = 4.1), automatic (11 subtasks, simple association, 1.0), and evaluation/judgment (consider simple aspect) (4.1, 10 subtasks).

Table 14. Number of Subtasks Having Various Cognitive Demands

Rating	Subtasks		Code Name
	#	%	
0.0	3	4	No cognitive activity
0.5	2	3	Less demanding than Automatic (1.0)
1.0	11	16	Automatic (simple association)
1.2	5	7	Alternative selection
3.7	6	9	Comparable to Sign/signal recognition
4.1	12	18	Compromise between Sign/signal recognition (3.7) and Evaluation/judgment (consider simple aspect) (4.6)
4.6	10	15	Evaluation/judgment (consider simple aspect)
5.3	8	12	Encoding/decoding, recall
6.0	5	7	Encoding/decoding, recall
6.8	5	7	Evaluation/judgment (consider several aspects)
7.0	1	1	Estimation, evaluation, conversion
	68	100	

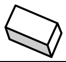
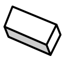
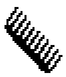
Table 15 lists the 10 subtasks with the highest cognitive demand. Five of the 6 most highly rated subtasks required response to an unpredictable situation; the rest of the highly rated subtasks were based on conversation. Most of these conversation subtasks were rated 6.0, but road rage (13.6) was rated 7.0 due to the implied loss of emotional control. The driver is assumed to concentrate heavily on the object of his or her anger. Therefore, road rage (13.6) was deemed to be comparable to a task involving estimation, calculation, or conversion, even though its nature is quite different from other tasks in the category.

Table 15. Top 10 Subtasks for Cognitive Demand

Subtask	Subtask Description	Rating	Coding Explanation
13.6	Road rage	7.0	**Estimation, evaluation, conversion**; high cognitive demand due to loss of emotional control, strong focus on object of anger
2.10	Spill/drop food	6.8	**Evaluation/judgment (consider several aspects)**; subject must consider the spill's location, extent, importance, etc.
2.11	Spill/drop drink	6.8	**Evaluation/judgment (consider several aspects)**; subject must consider the spill's location, extent, importance, etc.
11.1	Catch falling object/prevent object from moving, reach/lean/pick up	6.8	**Evaluation/judgment (consider several aspects)**; subject must consider the object's location, speed, importance, etc.
11.2	Insect-related distraction	6.8	**Evaluation/judgment (consider several aspects)**; subject must consider the object's location, speed, importance, etc.
11.3	Pet-related distraction	6.8	**Evaluation/judgment (consider several aspects)**; subject must consider the object's location, speed, importance, etc.
1.4	Converse on cell phone (talk, listen)	6.0	More demanding than **Encoding/decoding, recall**; context is often important to consider during conversation
13.1	Converse with unknown	6.0	More demanding than **Encoding/decoding, recall**; context is often important to consider during conversation
13.2	Converse with passenger - speak	6.0	More demanding than **Encoding/decoding, recall**; context is often important to consider during conversation
13.3	Converse with passenger - listen	6.0	More demanding than **Encoding/decoding, recall**; context is often important to consider during conversation

Subtasks that impose the lowest nonzero cognitive demand tended to be repetitive or static tasks. Table 16 has several examples, such as 5.6: bite/lick lips - chewing gum and 6.2: groom - hand only. These tasks are highly automated/practiced and therefore do not require special cognitive effort. Holding items that were not orientation-sensitive were rated 0.0 for cognitive demand, whereas subtasks such as hold food/drink (2.12) were rated as 0.5 because the item must be maintained at a certain orientation.

Table 16. Bottom 5 Subtasks for Cognitive Demand

Subtask	Subtask Description	Rating	Coding Explanation
 5.6	Bite/lick lips	1.0	**Automatic (simple association)**; biting or licking lips is an automatic action
 5.7	Tongue motion	1.0	**Automatic (simple association)**; tongue motion is an automatic action
 6.2	Groom - hand only	1.0	**Automatic (simple association)**; grooming with the hands (mainly itching, rubbing) is an automatic action
 2.12	Hold food/drink	0.5	Less demanding than **Automatic (1.0)**; holding food or drink is mostly static, and requires only maintaining a specific orientation (to avoid spilling)
 3.5	Hold cigar/ cigarette	0.5	Less demanding than **Automatic (1.0)**; holding a cigarette is mostly static, and requires only maintaining a specific orientation (to avoid burning)

As shown in Appendix D (where all of the subtask cognitive demand ratings appear), many of the “prepare” subtasks received ratings close to 4.1, which is more demanding than sign/signal recognition. Arguably, the “prepare” subtasks should be assigned a 4.6, which corresponds to an evaluation/judgment (consider simple aspect), because the driver must judge whether to undertake an activity. However, for these tasks the driver has already decided to perform a subtask before actually performing it. Further, the “prepare” subtasks are more similar to stopping at a stop sign than judging the stopping distance to that sign. On the other hand, most “prepare” subtasks were considered more demanding than sign/signal recognition because other subtasks depend on how well the “prepare” subtasks are carried out. Planning is still a factor when preparing to do something.

Psychomotor demand

As show in Table 17, psychomotor codes for subtasks ranged from 0.0 to 7.0 with a mean of 3.5 and a standard deviation of 2.6. Ratings of 4.6 (”manipulative,” 26 subtasks) and 1.0 (“speech,” 13 cases) were most common. Subtasks with very high psychomotor demands were rare.

Table 17. Number of Subtasks Having Various Psychomotor Demands

Rating	Subtasks		Code Name
	#	%	
0.0	3	4	No psychomotor activity
0.5	8	12	Less than speech
1	13	19	Speech
2.2	3	4	Discrete actuation
4.6	26	38	Manipulative
5.6	6	9	Manipulative + speech
5.8	2	3	Discrete adjustive
6.5	3	4	Symbolic production
7	3	4	Serial discrete manipulation
7	1	1	Symbolic production + speech
	68	100	

Table 18 shows the 10 subtasks with the highest psychomotor demand, all of which involve use of the hands. The psychomotor elements of “drink from open-top container (cup)” (subtask 2.7) summed to 7.5 but the subtask was given a rating of 7, as 7 is the upper bound of the scale.

Table 18. Top 10 Subtasks for Psychomotor Demand

Subtask	Subtask Description	Rating	Coding Explanation
2.7	Drink from open-top container (cup)	7.0	Cumulative demand from **Symbolic production (6.5)**, as the subject tilts cup to a specific angle (a precise, one-handed subtask), and **Speech (1.0)**, as the subject's drinking motions are comparable to speaking
3.2	Light cigar/cigarette	7.0	Comparable to **Serial discrete manipulation**; subject performs a subtask that requires precision (bringing flame to end of cigarette) with two hands
9.3	Type with 2 thumbs	7.0	**Serial discrete manipulation**; subject presses multiple keys in succession with both hands
9.4	Type on full keyboard	7.0	**Serial discrete manipulation**; subject presses multiple keys in succession with both hands
1.2	Dial phone – Hand-held	6.5	Comparable to **Symbolic production**; subject performs a subtask that requires precision (entering numbers) with one hand
8.2	Write	6.5	**Symbolic production**; subject is writing
9.2	Type with 1 thumb	6.5	**Symbolic production**; subject performs a subtask that requires precision (pressing keys) with one hand
10.3	Use stalk control	5.8	**Discrete adjustive**; it is assumed that the stalk control will have multiple, discrete settings
10.4	Use IP, column, or center console control	5.8	**Discrete adjustive**; it is assumed that the IP, column, or center console control will have multiple, discrete settings
1.4	Converse on cell phone (talk, listen)	5.6	Cumulative demand from **Manipulative (4.6)**, as the subject keeps the phone to the mouth and ear, and **Speech (1.0)**, as the subject is speaking

Table 19 shows the 5 subtasks with the lowest nonzero psychomotor demand (0.5). Holding subtasks were considered more demanding than those with no psychomotor activity (rating of 0.0), but less demanding than speech (rating of 1.0). Though subtasks 6.1: "prepare to groom" and 6.5: "finish grooming" are not strictly "holding" tasks, the majority of the task time is spent idly holding an object.

Table 19. Bottom 5 Subtasks for Psychomotor Demand

Subtask	Subtask Description	Rating	Coding Explanation
5.1	Hold gum in mouth	0.5	Less demanding than **Speech (1.0)**; though the subject's mouth is occupied, the subtask is static
6.1	Prepare to groom	0.5	Less demanding than **Speech (1.0)**; the subject will rarely need to handle a tool before grooming
6.4	Hold grooming tool	0.5	Less demanding than **Speech (1.0)**; though the subject's hand is occupied, the subtask is static
6.5	Finish grooming	0.5	Less demanding than **Speech (1.0)**; the subject will rarely need to handle a tool after grooming
7.2	Read	0.5	Less demanding than **Speech (1.0)**; though the subject's hand is occupied, the subtask is static

Many of the "prepare" and "finish" subtasks were considered an exact or approximate match to "manipulative" (demand=4.6). Chewing subtasks were considered to have demand similar to speech (demand=1.0), as many of the motions are similar if not identical, though obviously the cognitive demands are quite different. A deviation from the speech rating would occur if there was a nontrivial need to prevent choking, or food falling out of the mouth.

Psychomotor demand ratings for all subtasks appear in Appendix E.

Subtask total demand

Figure 1 shows the total demand for all subtasks, which ranged from 0.5 to 22.0 with a mean of 11.2 and a standard deviation of 6.1. Notice there is no particular shape to the distribution.

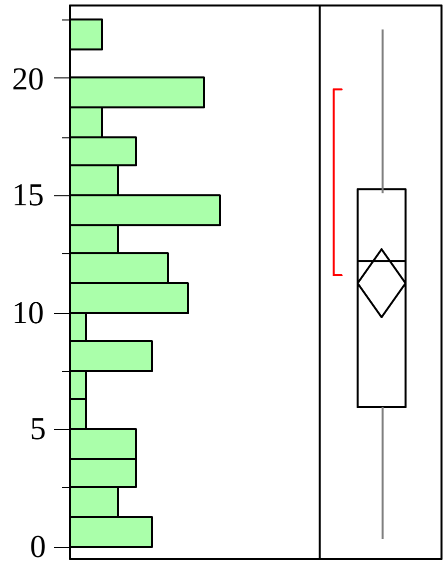


Figure 1. Distribution of Subtask Total Demands

The 10 subtasks with the greatest total demand are shown in Table 20. Notice that the top 2 most instantaneously demanding tasks are associated with cell phones and others are associated with spills and eating. (For the complete list, see Appendix G.)

Table 20. Subtasks with the Greatest Total Demand

Rank	Subtask	Subtask Name	V	A	C	P	Total
1	1.2	Dial phone – Hand-held	5.9	4.3	5.3	6.5	22.0
2	1.7	Answer cell phone	5.9	6.6	4.6	4.6	21.7
3	3.2	Light cigar or cigarette	7.0	1.0	4.6	7.0	19.6
4	11.3	Pet-related distraction	7.0	1.0	6.8	4.6	19.4
5	11.2	Insect-related distraction	7.0	1.0	6.8	4.6	19.4
6	11.1	Catch falling object/ prevent object from moving, reach/lean/pick up	7.0	1.0	6.8	4.6	19.4
7	2.11	Spill/drop drink	7.0	1.0	6.8	4.6	19.4
8	2.10	Spill/drop food	7.0	1.0	6.8	4.6	19.4
9	9.3	Type with 2 thumbs	5.9	1.0	5.3	7.0	19.2
10	2.7	Drink from open-top container (cup)	7.0	0	4.6	7.5	19.1

Table 20 shows the low demand subtasks, which are primarily associated with holding an object or chewing.

Table 20. Subtasks with the Least Total Demand

Rank	Subtask	Subtask Name	V	A	C	P	Total
1	1.5	Hold cell phone	0	0	0	0.5	0.5
2	5.1	Hold gum in mouth	0	0	0	0.5	0.5
3	2.12	Hold food/drink	0	0	0.5	0.5	0.5
4	2.12	Hold food/drink	0	0	0.5	0.5	1.0
5	3.5	Hold cigar or cigarette	0	0	0.5	0.5	1.0
6	4.2	Chew tobacco	0	0	1.0	1.0	2.0
7	5.6	Bite/lick lips	0	0	1.0	1.0	2.0
8	5.7	Tongue motion	0	0	1.0	1.0	2.0
9	2.5	Chew food	0	0.5	1.0	1.0	2.5
10	5.5	Chew gum	0	0.5	1.0	1.0	2.5

Recall that total demand is determined by adding the demands on the 4 dimensions. It could be that some other combination is appropriate, but that is the standard method for determining total demand.

What is the relationship between demands for various resources within subtasks?

As was noted earlier, an often-asked question is which single demand has the greatest effect on driving. If the demands are correlated, the answer to the single demand question could be complicated. Correlations were determined using the VACP values for each subtask. As shown in Table 21, none of the demand pairs were negatively correlated, and 4 correlations were positive. The strongest correlation exists between visual and cognitive demands (r=0.68), which makes sense because many cognitive tasks such as signal recognition, decoding, and evaluation/judgment require visual information as inputs. Visual and psychomotor demands were also related (r=0.48) because many psychomotor tasks require visual and produce visual feedback while the task is performed.

Table 21. Within Subtask Demand Type Correlations

Demand Type	r
Visual-Cognitive	0.68
Visual-Psychomotor	0.48
Cognitive-Auditory	0.42
Cognitive-Psychomotor	0.34
Visual-Auditory	0.05
Auditory-Psychomotor	0.03

Though most secondary tasks (and their subtasks) had low auditory demand, a nonzero correlation was observed between auditory and cognitive demand types because the few highly auditory tasks in the dataset were also highly cognitive. This is the nature of high demand auditory tasks—they are primarily interpretation and discrimination, both of which require cognitive resources. Cognitive and psychomotor demands were quite correlated because many complicated manipulation tasks require evaluation (such as how well a cigarette is lit) or encoding/decoding (such as writing). The importance of these relationships may depend on driver exposure to particular tasks, which is discussed later in this report.

Finally, as was noted earlier, many of the high demand visual tasks (and subtasks) involve a physical manipulation of something in the environment to control the unpredictable situation. Therefore, tasks and subtasks that have high visual demand may also have high psychomotor demand. Considering that driving is largely a visual and psychomotor task, this combination means the most visually demanding secondary tasks could overload the driver in a combined manner.

A graphic representation of the relationships between subtasks is represented in Figure 2. The small dots represent 1 or 2 subtasks and large dots represent 3 or more. One of the more interesting observations from that figure is that the distribution of the demands for several dimensions are not continuous as was suggested by tables provided earlier. For example, cognitive ratings were either very low (0.0 or 1.0) or moderate to high (mostly 4.0 or greater). There were no tasks with cognitive demands of 2.0 or 3.0. Similarly, there were no psychomotor demands of 3.0 or 4.0, and few auditory ratings greater than 2. It may be that these gaps in the range of values could be used to aid in the assessment of workload, by providing break points.

In aggregate, this data suggests that a test protocol that only assess a single demand will imperfectly assess that aggregate demand of a range of tasks and subtasks and their effect on driving safety.

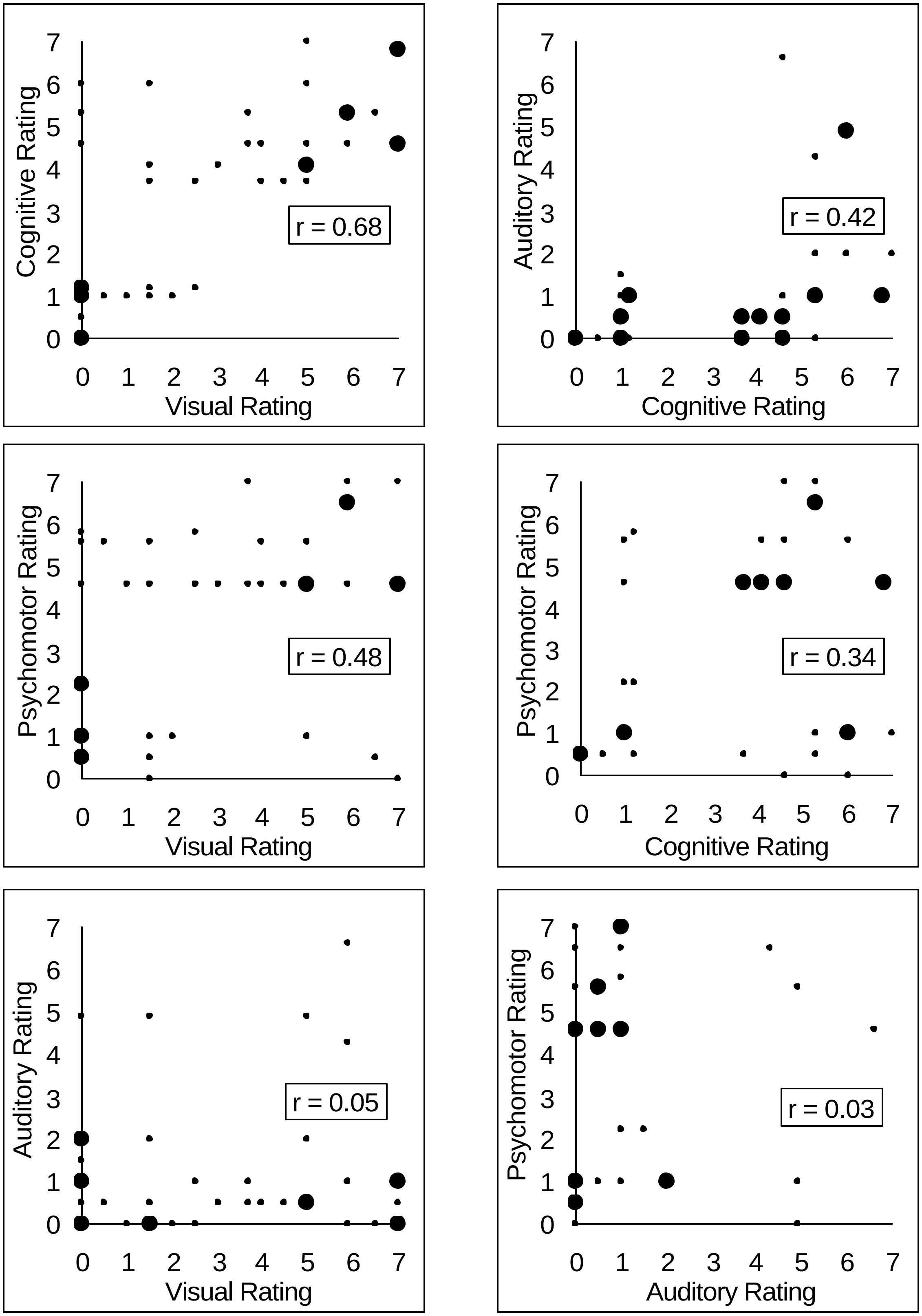


Figure 2. Demand Type Correlation Charts (by Subtask)

Using the Pass 2 sample of the ACAS data, how often were drivers exposed to each rating of demand?

Risk to a driver should consider not only the tasks to which a driver is exposed (as covered in a previous section), but how often that exposure occurs. Often exposure data is not available, so risk assessments can only consider task and subtask demands. That is not the case here.

The Pass 2 ACAS sample is roughly, but not perfectly, balanced for road superclass and driver age and sex. Table 22 shows the number of times in the 15,962 frames that each visual demand occurred. Almost 92% of the time, there was no visual demand due to secondary tasks, often because a secondary task was not being performed. There were, however, 7 instances in which multiple tasks were performed (rating sum=8.5). Including all of the data, the mean visual demand per frame was 0.31. However, when demand was present, it varied considerably as indicated by the large standard deviation relative to the mean (1.27). When the cases of no demand were removed, the mean demand was 3.86 with a standard deviation of 2.53.

Table 22. Observed Frequency of Occurrence of Visual Demands

Rating	# of Occur-rences	%		Code Name
		Overall	0 Excluded	
0.0	14680	91.97		No visual activity
0.5	12	0.08	0.94	Visually register/detect image-case d
1.0	13	0.08	1.01	Visually register/detect image-case c
1.5	515	3.23	40.17	Visually register/detect image-case b
2.0	89	0.56	6.94	Visually register/detect image-case a
2.5	67	0.42	5.23	Visually locate/align
3.0	6	0.04	0.47	Visually discriminate-case b
3.7	11	0.07	0.86	Visually discriminate-case a
4.0	14	0.09	1.09	Visually inspect/check
4.5	28	0.18	2.18	Visually locate/align-case b
5.0	51	0.32	3.98	Visually locate/align-case a
5.9	17	0.11	1.33	Visually read-case b
6.5	25	0.16	1.95	Visually read-case a
7.0	427	2.68	33.31	Visually scan/search/monitor
8.5	7	0.04	0.55	
Total	15962			

The visual demand noted was primarily associated with 2 classes of subtasks, visually scan/search/monitor (33%, rating 7.0) and visually register/detect image-case b (40%, rating 1.5). The 7.0 ratings are associated with an assortment of tasks described earlier. The 1.5 was for a variety of subtasks, most commonly involving conversation with a passenger. Interestingly, the 2 rating values also had a large number of subtasks associated with them, 10% and 18% respectively.

Table 23 shows that in the Pass 2 auditory demand, just over 70% of the frames sampled had no auditory demand. The mean demand was 0.63 when all of the data was considered, and 2.25 when zero was removed. Based on frequency of occurrence, the most common demand (2.0) was orienting to a sound, which occurred about 10% of the time, but for about 1/3 of the instances where there was auditory demand.

Table 23. Observed Frequency of Occurrence of Auditory Demands

Rating	# of Occur-rences	%		Code Name
		Overall	0 Excluded	
0.0	11490	71.98		No auditory activity
0.5	970	6.08	21.69	Detect/register sound-case c
1.0	151	0.95	3.38	Detect/register sound-case b
1.5	640	4.01	14.31	Detect/register sound-case a
2.0	1586	9.94	35.47	Orient to sound (general orientation)
2.5	19	0.12	0.42	Verify auditory feedback
3.0	19	0.12	0.42	Interpret semantic content
3.5	112	0.70	2.50	Detect/register sound-case c
4.3	17	0.11	0.38	Detect/register sound-case b
4.9	891	5.58	19.92	Detect/register sound-case a
5.4	62	0.39	1.39	
6.4	5	0.03	0.11	Discriminate sound characteristics
Total	15962			

In the subtask tallies, the 3 common subtask codes were “detect/register sound-cases b&c.” Here, when exposure is considered, “case b” was relatively less common and “orient to sound” more common.

In terms of frequency of occurrence (Table 24), the situation for cognitive demands is quite complex because cognitive tasks were much more likely to occur with other tasks, which is why many of the cognitive demands were so large. When all data was considered, the mean cognitive demand was 1.38. With cases of zero demand excluded, the mean demand was 3.86. Interestingly, the number of frames for which cognitive demand was 0.0 (64%) is the lowest of the 4 demand scales. Of the demand levels, the most common demand was 6.0, rather high, which represented 15% of all frames observed, but 41% of the nonzero cases. When compared with the subtask counts (where exposure is not considered), in this case, the codes associated with ratings 4.1 (compromise value) and 4.6 (evaluation/judgment) are much less common and 6.0 (encoding/recall) is much more common.

Table 24. Observed Frequency of Occurrence of Cognitive Demands

Rating	# of Occur-rences	%		Code Name
		Overall	0 Excluded	
0.0	10244	64.18		No cognitive activity
0.5	124	0.78	2.17	Less demanding than Automatic (1.0)
1.0	2206	13.82	38.58	Automatic (simple association)
1.2	114	0.71	1.99	Alternative selection
1.5	37	0.23	0.65	
1.7	1	0.01	0.02	
2.0	5	0.03	0.09	
2.2	8	0.05	0.14	
3.7	93	0.58	1.63	Comparable to Sign/signal recognition
4.1	11	0.07	0.19	Compromise between Sign/signal recognition (3.7) & Evaluation/judgment (consider simple aspect) (4.6)
4.2	2	0.01	0.03	
4.6	261	1.64	4.56	Evaluation/judgment (consider simple aspect)
4.7	4	0.03	0.07	
5.1	3	0.02	0.05	
5.3	41	0.26	0.72	Encoding/decoding, recall
5.6	34	0.21	0.59	
6.0	2320	14.53	40.57	Encoding/decoding, recall
6.3	10	0.06	0.17	
6.5	7	0.04	0.12	
6.8	68	0.43	1.19	Evaluation/judgment (consider several aspects)
7.0	224	1.40	3.92	Estimation, evaluation, conversion
7.2	14	0.09	0.24	
7.8	15	0.09	0.26	
9.7	12	0.08	0.21	
10.1	24	0.15	0.42	
10.5	1	0.01	0.02	
10.6	60	0.38	1.05	
12.8	19	0.12	0.33	
	15692			

Table 25 shows the frequency of occurrence of various psychomotor demands. In terms of frequency of occurrence, the mean psychomotor demand was 0.75 for all cases, 2.23 when cases of zero psychomotor demand were removed. When compared with the subtask counts, the major difference is that manipulative codes (4.6) were much more common(38% of all subtasks). The most common demand source, speech, occurred in 19% of all cases and in 57% of the nonzero cases.

Table 25. Observed Frequency of Occurrence of Psychomotor Demands

Rating	# of Occur-rences	Frequency		Code Name
		Overall	0 Excluded	
0.0	10618	66.52		No psychomotor activity
0.5	252	1.58	4.72	Less than speech
1.0	3061	19.18	57.28	Speech
1.5	76	0.48	1.42	
2.0	14	0.09	0.26	
2.2	624	3.91	11.68	Discrete actuation
2.7	18	0.11	0.34	
3.2	117	0.73	2.19	
4.6	140	0.88	2.62	Manipulative
5.1	2	0.01	0.04	
5.6	836	5.24	15.64	Manipulative + speech
5.8	67	0.42	1.25	Discrete adjustive
6.1	19	0.12	0.36	
6.5	17	0.11	0.32	Symbolic production
6.6	63	0.39	1.18	
10.2	18	0.11	0.34	
11.2	20	0.13	0.37	
	15962			

Subtask total demand

Subtask total demand was computed as the sum of the 4 demand ratings, the accepted method of computation. There is, however, no reason to believe that all 4 demand types have an equal impact on driving, and that question should be the topic of further investigation.

For all frames examined, approximately 64% had no demand of any type due to secondary tasks. Including those frames, the mean demand was 3.06 with a standard deviation of 5.34, relatively large. The maximum was 30.7. Excluding the total demand=0 trials, the mean was 8.54 with a standard deviation of 5.74. Figure 3 shows the distribution of the total demand, with a demand of 9 being the most common nonzero value.

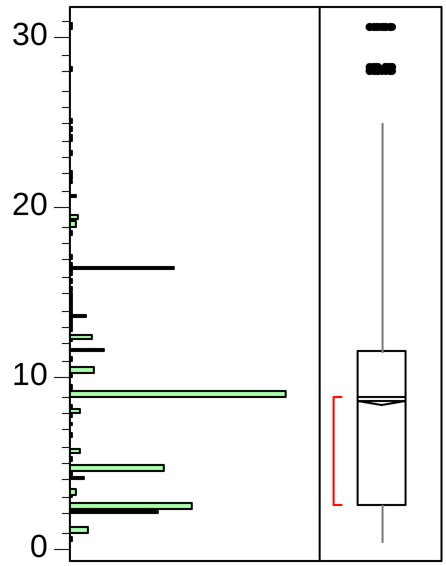


Figure 3. Distribution of non-Zero Total Demands

Creating a list of tasks and task combinations that is based on exposure is difficult because most of the high demand situations involve multiple tasks. Appendix H shows the list of total demand based on the Pass 2 data.

Does the demand drivers typically experience (per unit time, ignoring exposure duration) vary with the road type driven and the driver's age and sex?

To precisely estimate the demand per unit time, exposure needs to be equalized as a function of driver age, driver sex, and road superclass. Data from Pass 2 of the analysis in Yee, Green, Nguyen, Schweitzer, and Oberholtzer (2007), a related report from the SAVE-IT project, was examined as a starting point. As a reminder (see Yee, Green Nguyen, Schweitzer, and Oberholtzer, 2006), data was coded in 2 passes. In Pass 1, 2914 clips were selected, roughly, but not exactly equal in frequency by age*sex*road superclass combination (Table 26).

Table 26. Distribution of the Pass 1 Clips (N=2914)

		Road Type							
		Limited Access		**Major**		**Minor**			
Age	**Sex**	**Inter-state**	**Free-way**	**Major Arterial**	**Minor Arterial**	**Col-lector**	**Local**	**TOTAL**	
Young	Women	103	101	40	105	106	80	535	1048
	Men	104	103	48	100	107	51	513	
Middle	Women	105	80	56	106	103	80	530	956
	Men	100	48	22	103	106	47	426	
Old	Women	81	80	15	80	101	57	414	910
	Men	105	95	39	103	102	52	496	
TOTAL		598	507	217	597	625	367	2914	
		1105		814		992			

From those clips, some 819 clips (15,962 frames, Table 27) were examined, of which 403 involved distraction and 416 were defined as drivers engaged in a secondary task. Only a sample of the Pass 1 clips was examined as there was just too much data to analyze frame by frame within resource constraints. Again, as a reminder, this sampling scheme was used because very commonly drivers are not distracted, so analyzing clips in terms of their natural frequency of occurrence would have put the emphasis on nondistracted driving, when in fact the interest is in distraction.

Table 27. Distribution of Pass 2 Frames (N=15962)

		Road Type							
		Limited Access		**Major**		**Minor**			
Age	**Sex**	**Inter-state**	**Free-way**	**Major Arterial**	**Minor Arterial**	**Col-lector**	**Local**	**TOTAL**	
Young	Women	655	557	159	666	651	437	3125	
	Men	632	573	195	591	533	197	2721	5846
Middle	Women	671	336	235	532	809	607	3190	
	Men	713	276	40	395	514	218	2156	5346
Old	Women	359	436	118	393	646	254	2206	
	Men	635	570	198	576	333	252	2564	4770
TOTAL		3665	2748	945	3153	3486	1965		
		6413		4098		5451		15962	

Thus, the starting point for this analysis was a table from Pass 2 with 15,962 lines, 1 per frame, with columns for each of the tasks and a value in the cell of that frame-task combination when a subtask occurred. In each cell, there was only 1 value because there were never 2 instances of the different subtasks for the same task occurring at the same time (e.g., lighting a cigarette and ashing it (or another) at the same time). Using the tabular data in this report, the visual, auditory, cognitive, and psychomotor demands were determined for each cell in that table (frame number - subtask combination) and summed for each frame (as there were instances where 2 secondary task occurred at the same time). The VACP totals for each frame were summed using a lookup function that determined the road age*sex*road superclass combination for which that occurred. Those totals appear in Appendix I. Those totals were then divided by the number of frames for each age*sex*road superclass combination in Table 27, determined by adding the number of frames in each pair of columns.

The results of those calculations appear in Table 28. The highest demand cells were cognitive demands for young women on minor roads (2.12), followed by cognitive demands of middle-aged men on limited access roads (1.86). The lowest demand was visual demand for middle-aged women on major roads. However, keep in mind that the data in this table overestimates the demand experienced per unit time (or per frame) because the Pass 2 data was biased toward distracting tasks. One could use the data in Table 29 as a guide toward which tasks (and which demands) are overestimated. Stratified sampling was used to aid in the examination of differences between road types and drivers, and that subtask coding occurred only in Pass 2.

Table 28. Mean Demand/Frame by Age, Sex, and Road Superclass

Demand	Age	Sex	Limited Access	Major Roads	Minor Roads
Visual	Young	Female	0.14	0.34	0.34
		Male	0.40	0.44	0.26
	Middle	Female	0.19	0.10	0.43
		Male	0.53	0.55	0.15
	Old	Female	0.12	0.14	0.06
		Male	0.30	0.48	0.70
Auditory	Young	Female	0.62	0.94	0.93
		Male	0.65	1.22	0.88
	Middle	Female	0.37	0.60	0.48
		Male	0.97	0.48	0.35
	Old	Female	0.49	0.40	0.52
		Male	0.61	0.34	0.29
Cognitive	Young	Female	1.36	1.57	2.12
		Male	1.13	1.87	1.66
	Middle	Female	0.86	1.40	1.25
		Male	1.86	1.19	0.78
	Old	Female	1.28	1.18	1.49
		Male	1.30	1.20	1.15
Psychomotor	Young	Female	0.60	1.18	1.12
		Male	0.92	1.63	1.03
	Middle	Female	0.36	0.71	0.56
		Male	1.35	0.69	0.36
	Old	Female	0.31	0.34	0.35
		Male	0.69	0.49	0.48
Total	Young	Female	2.71	4.03	4.51
		Male	3.10	5.16	3.82
	Middle	Female	1.77	2.81	2.72
		Male	4.71	2.91	1.64
	Old	Female	2.19	2.06	2.42
		Male	2.90	2.52	2.62

Table 29. Task Frequencies in Pass 1 and Pass 2 Samples
Note: The total percentage exceeds 100 because in some of the clips 2 secondary tasks (and in very few cases 3) occurred at the same time..

Distracting Task	Pass 1 Original %	Pass 2 Original %
No Distracting Task	54.9	64.0
Conversation	19.6	11.9
Chewing Gum	9.9	9.0
Grooming	7.6	5.7
Cell Phone	4.8	5.2
In-Car System Use	3.7	1.6
Internal Distraction	2.7	1.7
Eating/Drinking	2.4	2.6
Smoking	1.2	1.4
Reading	0.2	0.2
Chewing Tobacco	0	0
Writing	0	0
Typing	0	0
Total	**107.1**	**103.3**

ANOVA was used to examine the demand/frame means, with demand type, age, sex, and road type as the main effects, as well as all pairwise interactions of those terms. In that ANOVA, the effects of demand type (p<.0001), age (p<.0001), sex (p=0.03), and age*road type (p=0.005) were the only significant factors.

Figure 4 shows the effects of demand type and road. Notice that the primary difference is that the cognitive demand is much greater overall, roughly double the other demands and the largest of all differences found in the ANOVA (0.8 scale demand units). As was noted, the main effect of road type was not significant, but the trend was for major roads to have the highest demand per frame (per unit time) (0.81), followed by minor roads (0.78), followed by limited access roads (0.71). In terms of the interactions with road type, it appears mostly to be due to differences in visual and auditory demands on minor roads. The specific reason for this difference is unknown at the current time.

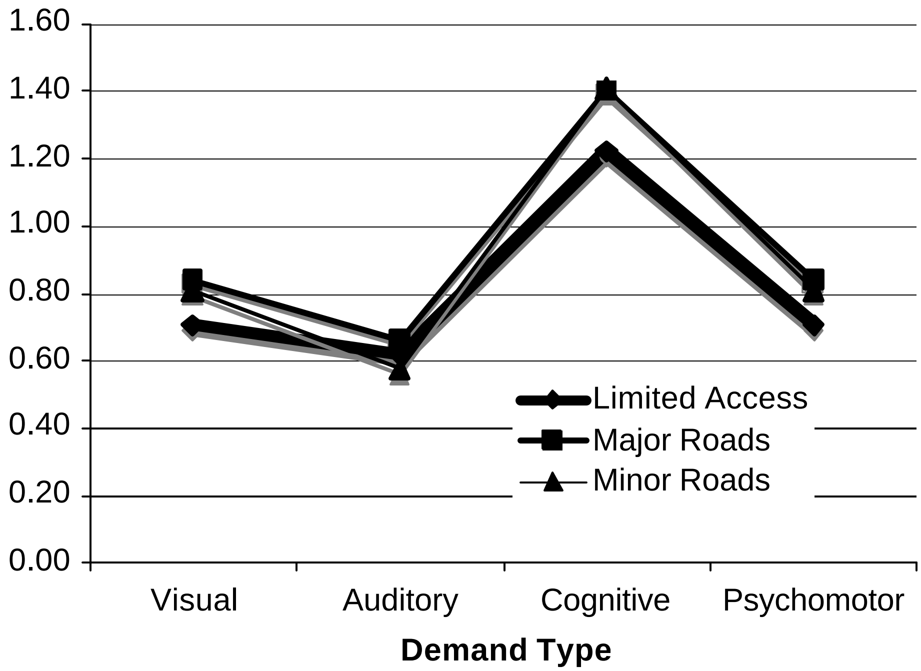


Figure 4. Mean Demand/Frame vs. Demand Type and Road

Although these means seem quite small relative to the range of each of the 4 scales, keep in mind that the mean can be misleading in this case because problems occur when drivers engage in secondary tasks, and the demand at that moment is much greater. The mean here served only to indicate which situations could place the driver at relatively greater risk.

Figure 5 shows that in general men experience slightly more demand than women overall, with the demand experienced declining with age. The sex gap grows with age, though the gap for middle-aged and older drivers is about the same. A next step in the analysis would be to explore if this is because some drivers undertake fewer tasks, less demanding tasks, or both.

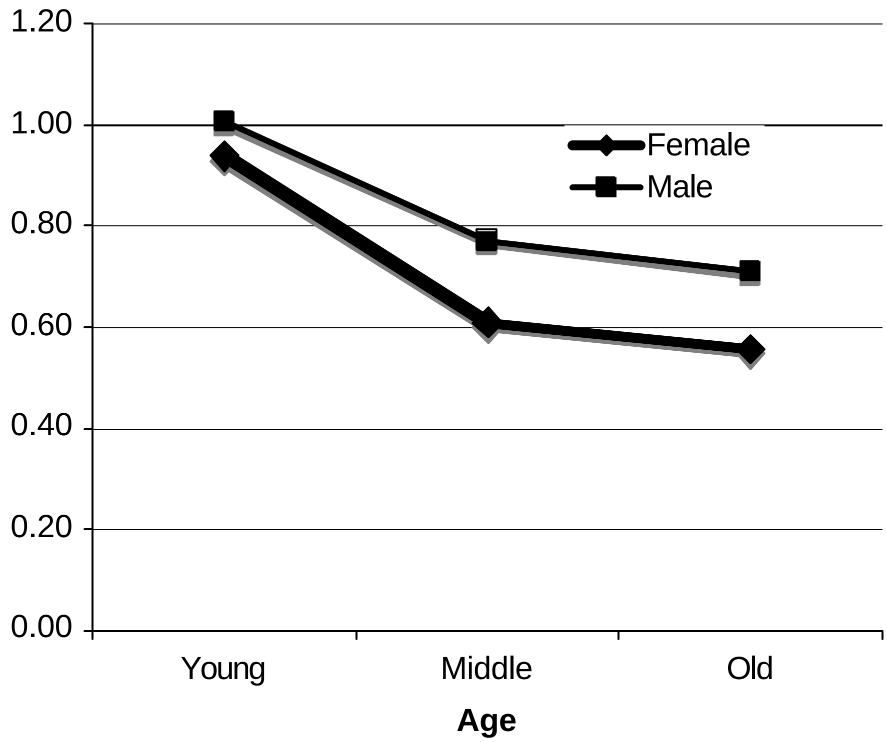


Figure 5. Mean Demand/Frame vs. Driver Age and Sex

Figure 6 shows the age*road type interaction. It appears that the source of this interaction lies in the tasks younger drivers undertook on minor and major roads vs. other drivers.

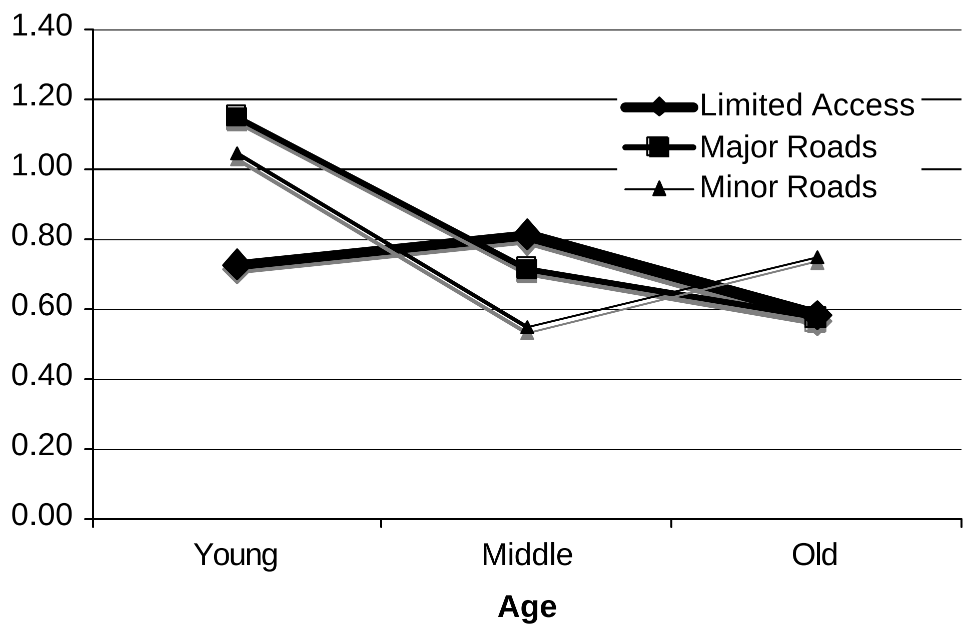


Figure 6. Mean Demand/Frame vs. Driver Age and Road Type

Figure 7 shows a very unusual interaction, sex with road type. It is unknown why women experienced different demand levels as a function of road type (less for lower class roads). The experience of men was fairly consistent.

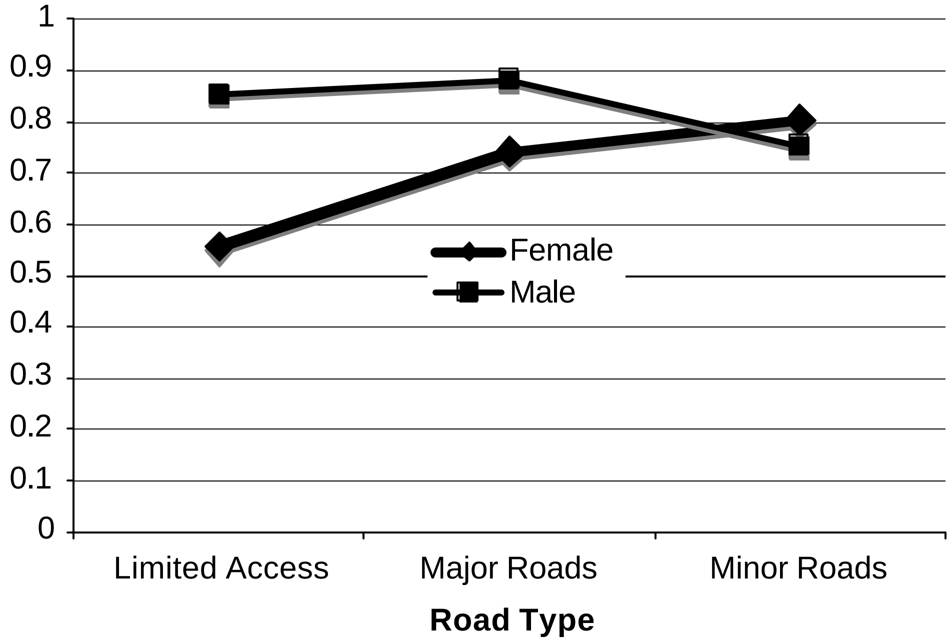


Figure 7. Mean Demand/Frame vs. Road Type and Driver Age, Sex

In the complete ACAS dataset, what is the aggregate exposure to each demand type and total demand?

The risks drivers experience due to secondary tasks is the product of the demands associated with each subtask times how often drivers perform that task and conditioned on where the task is performed. In contrast to previous analyses, this question considers all driving, not just the Pass 2 sample, and aggregate exposure. Accordingly, the demand/frame data (Table 28) was multiplied by the actual number of frames for each road type for each age and sex group (Table 30), ignoring ramps and unpaved and unknown roads (and pooled into superclasses). The results are shown in Table 31. What matters for Table 31 are the relative, not the absolute values. Keep in mind that this exposure data is imperfect as it is based on the Pass 2 sample, though it could conceivably be adjusted in some way using the data in Table 29.

Table 30. Exposure to Various Road Types in ACAS (# Frames in Entire Dataset)

RoadClass	**Sex**	**Age Group**			
		20-30	**40-50**	**60-70**	**Total**
Ramp	Female	113	79	66	258
	Male	102	99	71	272
		215	178	137	530
Interstate	Female	787	738	736	2261
	Male	821	811	788	2420
		1608	1549	1524	4681
Freeway	Female	1097	506	561	2164
	Male	654	471	648	1773
		1751	977	1209	3937
Arterial	Female	170	266	177	613
	Male	242	212	252	706
		412	478	429	1319
MinorArterial	Female	1110	763	582	2455
	Male	592	1021	730	2343
		1702	1784	1312	4798
Collector	Female	1214	1063	825	3102
	Male	1046	1041	915	3002
		2260	2104	1740	6104
Local	Female	606	495	339	1440
	Male	294	403	353	1050
		900	898	692	2490
Unpaved	Female	17	31	6	54
	Male	55	47	39	141
		72	78	45	195
Unknown	Female	1482	1631	2495	5608
	Male	1320	942	2805	5067
		2802	2573	5300	10675
Total		11722	10619	12388	34729

Table 31. Aggregate Demand Using the Entire ACAS Data As Exposure

Demand	**Age**	**Sex**	**Limited Access**	**Major Roads**	**Minor Roads**
Visual	Young	Female	263.8	435.2	618.8
		Male	590.0	367.0	348.4
	Middle	Female	236.4	102.9	669.9
		Male	679.5	678.2	216.6
	Old	Female	155.6	106.3	69.8
		Male	430.8	471.4	887.6
Auditory	Young	Female	1168.1	1203.2	1692.6
		Male	958.8	1017.5	1179.2
	Middle	Female	460.3	617.4	747.8
		Male	1243.5	591.8	505.4
	Old	Female	635.5	303.6	605.3
		Male	876.0	333.9	367.7
Cognitive	Young	Female	2562.2	2009.6	3858.4
		Male	1666.8	1559.6	2224.4
	Middle	Female	1069.8	1440.6	1947.5
		Male	2384.5	1467.3	1126.3
	Old	Female	1660.2	895.6	1734.4
		Male	1866.8	1178.4	1458.2
Psychomotor	Young	Female	1130.4	1510.4	2038.4
		Male	1357.0	1359.4	1380.2
	Middle	Female	447.8	730.6	872.5
		Male	1730.7	850.8	519.8
	Old	Female	402.1	258.1	407.4
		Male	990.8	481.2	608.6
Total	Young	Female	5105.6	5158.4	8208.2
		Male	4572.5	4303.4	5118.8
	Middle	Female	2201.9	2891.5	4237.8
		Male	6038.2	3588.0	2368.2
	Old	Female	2840.4	1563.5	2816.9
		Male	4164.4	2474.6	3322.2
Sum			24923.1	19979.5	26072.0

Several interesting findings emerge. First, in terms of overall demand from greatest to least, the order is minor roads, limited access roads, and major roads, suggesting a need for workload studies to focus on minor roads (which is not often the case). Also note that the aggregate demand varies over quite a wide range, from 69.8 for the visual demand for older men on minor roads, to 3858.4 for the cognitive demand for young men on minor roads.

Figure 8 shows the same results as Figure 4 (demand type and road), only the data has been adjusted for exposure. In fact, the data is not too different from the prior case because the largest differences due to exposure by road and by age group*sex are on the order of 25%. However, the relative decrease in visual demand and the slight relative increase in limited access roads is noteworthy as being a source of demand relative to other types of roads. Another noteworthy change is the relative decrease of the contribution of major roads to total demand, with estimated totals of approximately 25,000 for limited access roads, 20,000 for major roads, and 26,000 for minor roads. Keep in mind that the ACAS FOT did not capture the initial driving of every trip, so the minor road totals are underestimated.

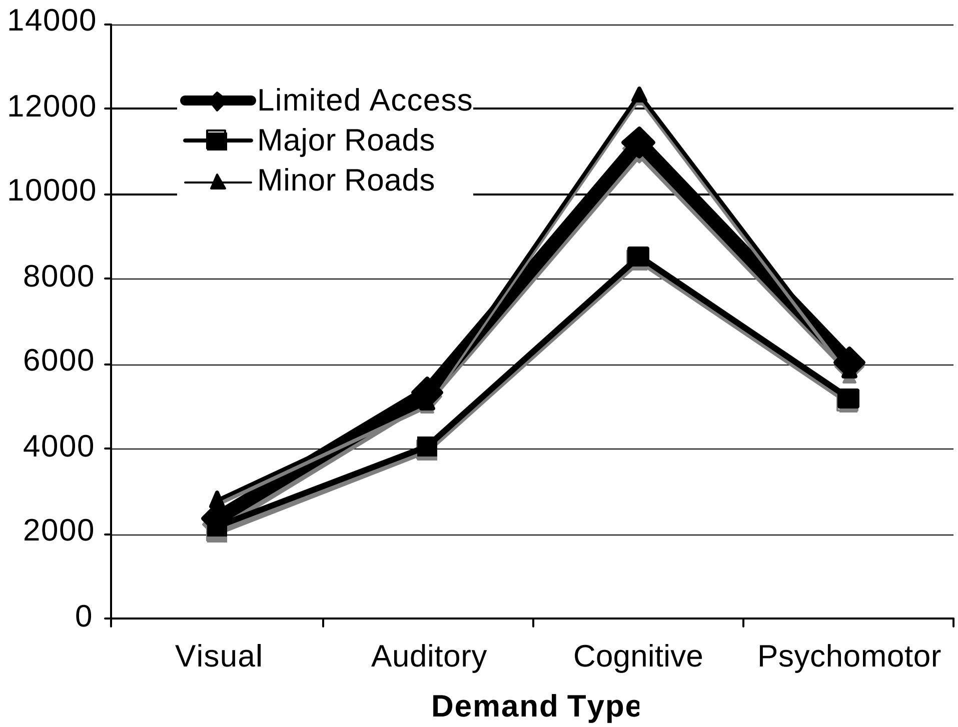


Figure 8. Total Demand vs. Demand Type and Road

The results in Figure 9, showing aggregate demand, are somewhat similar from those in Figure 5, showing demand/frame. There is a general decline in demand with age. However, for younger drivers, there is a reversal of who experiences the greatest demand (here, women).

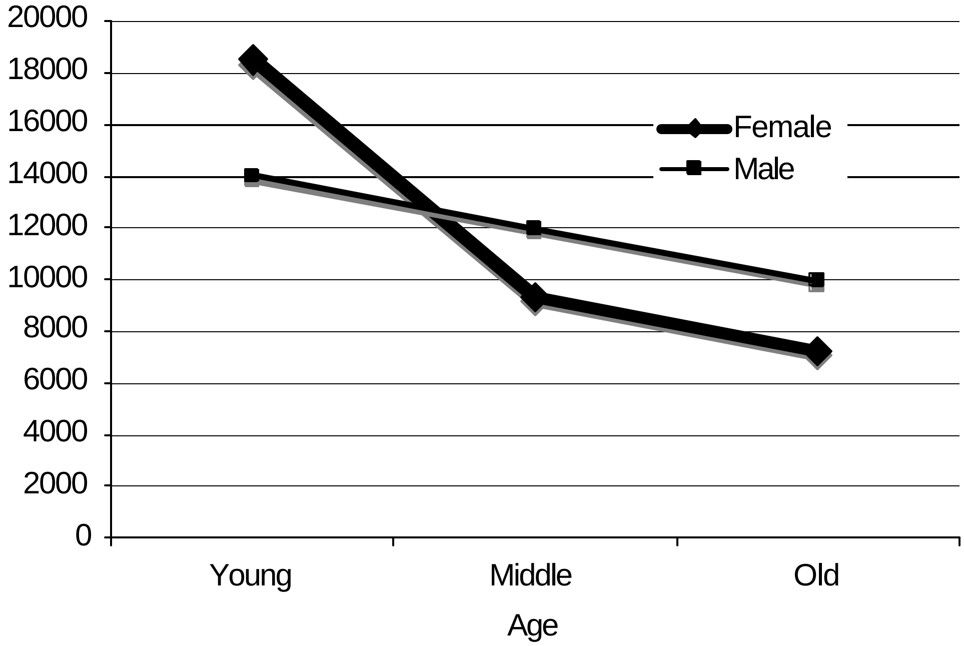


Figure 9. Total Demand vs. Driver Age and Sex

Figure 10 shows how exposure affects combinations of driver age and road type. The primary difference from Figure 6 is an increase in demand for younger drivers on limited access roads and a relative increase as well for older drivers.

For each road type and all demand types, young drivers had the highest demand ratings, followed by middle-aged drivers. Older drivers had the lowest demand ratings. The difference between young and middle-aged groups was greater than the difference between middle-aged and older groups (1.45 times the overall aggregate and 1.27 times the overall aggregate, respectively). These age differences are driven by cell phone-related subtasks, especially subtask 1.4, conduct cell phone conversation, which young drivers performed 3.3 times as often as middle-aged drivers and 26.8 times as often as older drivers.

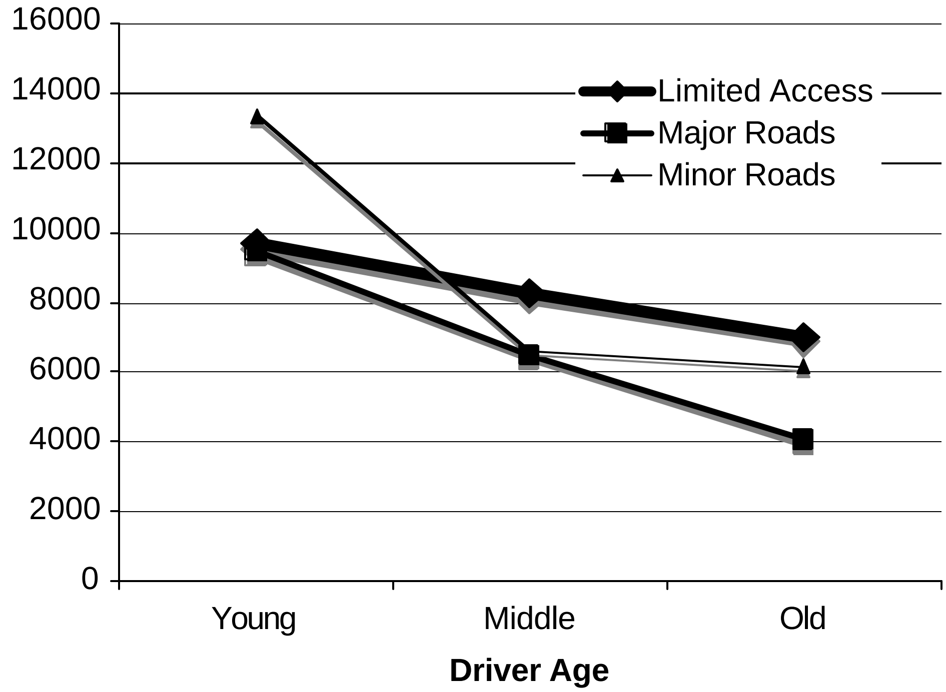


Figure 10. Total Demand vs. Driver Age and Road Type

Figure 11 looks quite different from Figure 7, which does not consider exposure although the ordering of points (which sex has the greatest demand for each road type) remains the same.

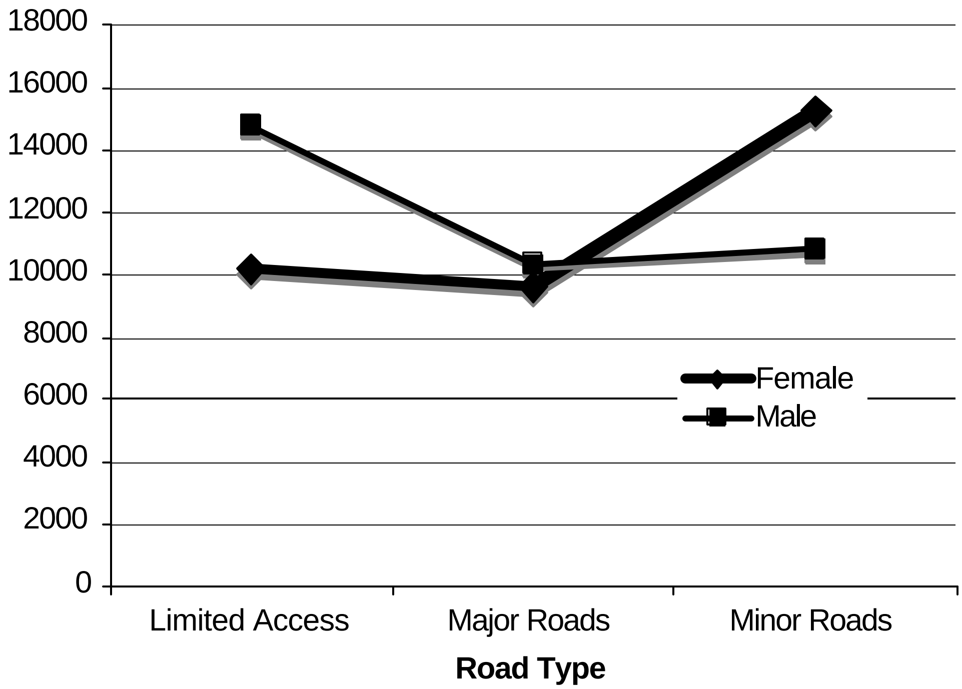


Figure 11. Total Demand vs. Road Type and Driver Sex

In general, men had higher visual and psychomotor demands (1.59 and 1.32 times the female aggregate, respectively) while driving due to increased frequency of glance and cell phone tasks, while women had higher cognitive demand (1.24 times) due to more frequent in-vehicle conversation. Summing all the demand types, men had higher overall demand (1.66 times) on limited access roads, women had higher overall demand (1.80 times) on minor roads, and they were not significantly different on major roads.

As a whole, the data suggests there are differences in terms of which road types, driver ages, etc. experience the greatest demand due to whether exposure is considered. Including exposure seems to have the greatest effect on the rank order of differences for younger drivers. However, what is most interesting is that including exposure does not change the finding that cognitive demand is consistently highest, though including exposure does unexpectedly decrease the relative importance of visual demand2.

CONCLUSIONS

What are the demand characteristics of real subtasks?

The purpose of this question is to determine the visual, auditory, cognitive, psychomotor, and total demands of real subtasks and which are most and least demanding.

A total of 10 tasks (use phone, eat/drink, smoke, chew tobacco, chew gum, groom, read, write, type, use in-car system, internal distraction, converse) were examined in detail, with each task being partitioned into 3 to 12 subtasks. Those subtasks involve preparing to do the task (lighting a cigarette), doing it (smoking), and completing it (e.g., ashing). For each of those tasks, visual, auditory, cognitive, and psychomotor demand ratings were developed by multiple analysts using the anchors (0-to-7 scale) from the U.S. Army IMPRINT modeling tool.

According to those ratings, the auditory demands ranged from 0.0 to 7.0 with 20 of the 68 subtasks having a visual demand of 0.0. Averaging across subtasks, the visual demand was 3.1 with a standard deviation of 2.7. The most numerous subtask codes were visually scan/search/monitor (10 unique instances, 7.0) and visually locate/align (12 instances, 5.0). In brief, highly visual subtasks tended to require visual assessment of an unpredictable situation, such as monitoring a lighter to wait for cigarette ignition, and then bringing the flame to the exact location that it is needed. Low visual demand subtasks included conversation, ashing cigarettes, and ending typing.

For auditory demands, the range was 0.0 to 6.6 with a mean of 0.9 and standard deviation of 1.3. Twenty of the 68 subtasks had no auditory demand. Except for a few values at the top of the range, most were at the bottom. Of the 48 unique instances, 15 were 1.0 and 22 were 0.5, both of which were related to detecting/registering sound. For the most part, the subtasks observed did not have high auditory demands, and those that did were mostly conversation-based.

For cognitive demands, the subtask range was from 0.0 to 7.0 with a mean of 3.7 and a standard deviation of 2.1. Only 3 of the 68 subtasks had no cognitive demand. The tasks with the highest cognitive demands concerned spills, dealing with insects and pets, other unpredictable activities, and conversation. Subtasks had demands of either 1 or lower, or 3.5 or higher. Of the 65 unique tasks, 12 involved sign/signal recognition and evaluation/judgment (4.1), 11 involved simple automatic associations (1.0), and 10 involved evaluation judgment (4.6).

Psychomotor subtask demands ranged from 0.0 to 7.0 with a mean of 3.5 and a standard deviation of 2.6. Most values were either 4.5 or higher, or 2.5 or lower. Only 3 of the 68 subtasks had no psychomotor demand. Common subtasks (of the 65 unique tasks) were manipulation (26 instances, 4.6) and speech (13 instances, 1.0). High demand tasks involved a coordinated psychomotor action such as drinking from a cup, typing, lighting a cigarette, or dialing a phone. Low demand tasks sometimes involved holding something (cigarette, comb, gum in the mouth).

Thus, comparing subtask demands, the mean for 3 of the 4 scales averaged 3.0 to 3.5 expect for auditory demand, which was below 1.0. However, in assessing demands, it is apparent that exposure, at least using the Pass 2 data, is critical, with significant differences in subtask occurrence and associated demand.

The most highly demanding subtasks overall (based on the sum of instantaneous subtask demands) tended to involve reaction to unanticipated events and the use of technology. High demand subtasks included dialing a hand-held phone (22.0), answering a cell phone (21.7), lighting a cigar/cigarette (19.6), spilling/dropping food (19.4), spilling/dropping food or drink (19.4), catching a falling object (19.4), being distracted by insects and pets (19.4), and typing with 2 thumbs (19.2) or 1 thumb (18.7). For these tasks, both visual and cognitive demands were high.

Standard practice in these analyses is to assume that when tasks are performed in close temporal proximity, they are performed in parallel. In that situation, the total demand is the sum of the demands of the individual tasks, which can lead to large demand values. In fact, it could be that subjects did not truly perform the tasks in parallel, but quickly switched between them. Though the observation periods here were much shorter than is typical for these analyses (5 s snapshots), the analysts believed the tasks were conducted in parallel, though some degree to demand reduction due to rapid task switching cannot be ruled out. Even if switching occurred in every situation, keep in mind that there is an overhead for timesharing—the goals and state of the current tasks must be saved and the new goals and task states reloaded in much the same way that a computer interrupt service routine has overhead.

Furthermore, these subtask estimates do not consider task duration or task frequency, which was considered in a subsequent section. As an example, disastrous spills, for example spilling a cup of coffee onto the floor, occur far less frequently than the average driver dials a hand-held phone. However, when attention to a spill occurs, it is likely to last longer than dialing a phone. What matters most is that the aggregate exposure to dialing (frequency*duration/event) is likely to be much greater than exposure to spills.

What is the relationship between demands for various resources within subtasks?

Four pairs of demand types were found to be moderately positively correlated (Table 33). Particularly noteworthy is the correlation between visual and cognitive demands, though correlations between visual-psychomotor (hand-eye coordination) and cognitive-auditory (listen to sounds) demands are noteworthy. Thus, ignoring that different demands have differential effects on driving, one cannot determine the extent to which a task interferes with driving by examining only 1 of the 4 demands, as the correlations are far from perfect.

Table 33. Demand Type Correlations

Demand Type	r
Visual-Cognitive	0.68
Visual-Psychomotor	0.48
Cognitive-Auditory	0.42
Cognitive-Psychomotor	0.34
Visual-Auditory	0.05
Auditory-Psychomotor	0.03

As a footnote, simply looking at the correlations does not tell the full story. For several combinations of demands, it was not that there was a general trend for them to increase together, but rather that they both had either fairly high or fairly low demand values. This was the case, for example, for visual and cognitive demand.

Using the Pass 2 sample of the ACAS data, how often were drivers exposed to each rating of demand?

More specifically, how often did each rating occur? The Pass 2 ACAS sample is roughly, but not perfectly, balanced for road superclass, driver age, and driver sex. Almost 92% of the time, there was no visual demand due to secondary tasks, often because a secondary task was not being performed. Accordingly, the mean demand was low (0.3, though it increased to 3.9 when the cases of no demand were removed).

There were a few (7) instances of extremely high demand (8.5) when multiple tasks were performed. However, more notably, for just under 3% overall (but 33% of the nonzero cases), the visual demand was the demand scale maximum, 7.0. However, there were 7 instances in which multiple tasks were performed (rating sum=8.5).

For auditory demand, there were far more frames where the demand was not zero (28%). However, both the mean demands with and without these zero cases removed (0.6, 2.3) tended to be low. Noteworthy was the absence of cases where the auditory demand was the scale maximum (7.0). Further, the only demand level for which there was a significant number of frames (5.6% overall) had a rating of 4.9. This suggests auditory demand could be less of a concern.

That was not true for cognitive demand. Some 35% of the frames had nonzero values and the mean demand was 1.4 when all frames were included and 3.9 when frames with no demand were excluded. However, this is of considerable concern because almost 1% of the time there were multiple tasks occurring where the aggregate cognitive demand was in excess of 7.0 (and 1.4% of the time it was 7.0).

Nonzero psychomotor demands occurred in 34% of the frames, with a mean of 0.8 for all frames and 2.2 when frames with no demand were removed. There were some cases (0.2%) where the demand exceeded 7.0, the single task maximum, because multiple tasks were being conducted.

Finally, in terms of the total demand, the value was not zero in 36 of all frames. It was 3.1 when all trials were considered, and 8.5 when the zero demand trials were excluded. The maximum was 30.7. The most common nonzero value was 9.

Does the demand drivers typically experience vary with the road type driven and the driver's age and sex?

Here, demand is the mean per unit time. Demands varied in a fairly consistent manner. Overall ,cognitive demand was consistently highest for all road types by a factor of about 2 per frame, but when exposure is considered, visual and psychomotor demands become relatively low. Interestingly, there were no consistent road type differences, though there may be some complex and difficult-to-explain road by age interactions.

In general, overall demand decreased with age. However, there were some interesting differences due to sex. From the perspective of per frame (per exposure), the mean demand experienced by women was less than that of men.

In the complete ACAS dataset, what is the aggregate exposure to each demand type and total demand?

In addition to per unit time, exposure to demand can be determined when adjusted for driving exposure (aggregated across time). Each of these approaches has strengths and weaknesses. One might think of the first approach as being analogous to fatalities per mile, and the second to total fatalities. The difficulty with using the second approach to examine differences is that less common situations are sampled infrequently, making differences more difficult to identify. However, in sampling, the first approach (the estimate of the total consequences) is probably less accurate.

The aggregated exposure was determined by multiplying the mean rate for each demand type-road superclass-age-sex combination by the number of clips in the entire ACAS dataset for each road superclass-age-sex combination.

Drivers experienced the greatest overall demand on minor roads, followed by limited access roads and then major roads, in that order, suggesting a need for workload studies to pay greater attention to minor roads, often not the case. Overall, aggregate demand varies over quite a wide range, from about 70 (visual demand, older men, minor roads), to 3,860 (cognitive demand, young men, minor roads).

A second noteworthy trend is the increase in the relative importance of cognitive demand when exposure is included. As with the per frame data, cognitive demand is about double auditory and psychomotor demand, but in this case those 2 demands are about double visual demand, rather than equal to it.

Another key difference is that instead of women experiencing consistently lower demand than males, young women have the highest exposure to aggregated demand. This is the opposite of what one would expect.

Putting the findings into context

It is difficult to find a study that is perfect, as the time, funds, staff, etc., are rarely available. Within the context of what the research plan called for, this study goes well beyond those aims and the authors do not believe that any of the weaknesses noted here critically impact the findings in this report.

This data may be the first attempt to systematically and comprehensively categorize and quantify the demand of a wide range of common secondary tasks and subtasks that occur while driving in terms of the visual, auditory, cognitive, and psychomotor demands using an accepted rating scale for each demand. These ratings were determined in a structured manner.

Some may quibble that inter-rater reliability was not quantified using some sort of sampling process. However, in this project, the goal was to develop a rating scheme and a method for applying it to a dataset. As a consequence, the process was constantly evolving and, in the end, agreement was perfect.

Admittedly, there were challenges in classifying some of the driver activities because there was no sound provided with the video and the clips were short (5 s). The lack of sound primarily affects the conversation and phone tasks, though based on the visual evidence, the analysts were confident of their ratings. Having sound would have improved the dataset, but it is not a fatal weakness.

What is also noteworthy about the sample is the size and quality of the dataset. The data was obtained from real drivers driving on real roads in vehicles that were for personal use without an experimenter in the vehicle. The data was quite naturalistic, though the ACAS sample under-represents minor roads. However, many of the findings are based on the analysis of over 15,000 samples distributed over a range of road types, driver ages, and driver sexes. This sample is of sufficient size to detect differences of interest.

However, given the sampling strategy was to detect differences of interest, the data is not as useful in estimating actual exposure of drivers to demand levels and may be more appropriate for estimating relative differences rather than absolute levels.

Probably the most significant question is how to treat the IMPRINT ratings. Each of the 4 scales has a range of 0.0 to 7.0. How to compare those demands is unknown. Does a visual demand of 7.0 have the same impact on driving as a 7.0 on the cognitive scale? Is this true for all driving situations, and, if not, what are the exceptions?

Furthermore, total workload is assumed to be a simple additive combination of the 4 scales, but it remains unknown if simple addition is the appropriate mathematical combination. Horrey and Wickens (2003) suggest simple addition may not be the best solution.

With all of these concerns, these data still provide a significant contribution to the literature on driving. They provide a foundation for understanding a wide range of problems associated with driver overload and driver distraction, especially those associated with new technology. Understanding and resolving these problems could lead to significant reductions in the number of crashes.

One of the major problems with many studies in the driving literature is that the studies are not comparable. Researchers have subjects perform all sorts of real and artificial tasks while driving to understand the process of driving. However, since there are no common quantitative metrics for describing those tasks, other than performance measures that vary quite widely in their usage, there is no way to compare the test conditions. The authors would like to urge their colleagues to consider using VACP ratings or some other standard measures to provide a basis for comparison.

What should be done next?

This report presents VACP ratings for a large number of real-world secondary tasks, and provides information that can be used to assess their effect on driving. However, additional information, which is beyond the scope of this project, is needed to fully utilize these ratings. Questions that need to be answered include:

1. What is the effect of “pure” tasks (almost exclusively one demand) on various aspects of driving performance as a function of the level of that demand? As a first step, one might be able to use the published literature to address this question, with analysts giving VACP ratings to tasks described in experimental reports. Since ratings rely on observing tasks, not just reading about them, it may be necessary for tasks described in the literature to be simulated by the analysts.

2. What are the additive effects of tasks with specific combinations of V, A, C, and P values on driving?

3. At what levels of V, A, C, and P is driving degraded and how does that vary with the performance measure?

4. What is the real-world exposure of drivers to various levels and combinations of visual, auditory, cognitive, and psychomotor demands (values initially estimated here)?

5. What are the subtask demands if this analysis were extended by partitioning visual and auditory demands into focal and ambient, and psychomotor demands into speech and manual? Do the advantages of that additional refinement outweigh the effort to obtain them? Are there advantages to further refinement of cognitive demands?

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APPENDIX A – ROAD TYPES AND DESCRIPTIONS

Table 34. Description of Road Types as Defined by the ACAS Dataset

Super-class	Road type	Description
Limited Access	Interstate	A road that is not a grade and has limited access, limited crossings, and a U.S. DOT interstate designation
	Freeway	A road that is not a grade and has limited access and limited crossing, but does not have a U,S, DOT interstate designation
Major	Arterial	A primary road that allows for high volume, high speed traffic movement with access at grade and few speed changes
	Minor Arterial	A secondary road with high volume but lower speed traffic than arterials that connect arterials
Minor	Collector	A road that distributes traffic among neighborhoods with moderate traffic volume that generally connects with arterials and limited access roadways
	Local	A road that distributes traffic in and around neighborhoods with low volume and low speed traffic
	Unpaved	A road generally used to distribute traffic to rural destinations that has very low volume traffic and low to moderate speed traffic
	Ramp	Roads that are not at grade and serve as connections between limited access roads
	Unknown	A driving area not designated as a public roadway, such as a parking lot or public/private facility
	TOTAL	

APPENDIX B – SUBTASK GROUPS AND DESCRIPTIONS

Table 35. Cell Phone Subtasks

ID	Description	Begins When:	Ends When:	Ratings			
				V	A	C	P
1.0	**Cell Phone**						
1.1	Prepare to use cell phone	Subject moves hand to reach for phone	Subject initiates another subtask with the cell phone	5.0	0.5	4.1	4.6
1.2	Dial phone – Hand-held	Subject presses first button	Subject initiates another subtask with the cell phone	5.9	4.3	5.3	6.5
1.3	Dial phone – Hands-free	Subject speaks first word	Subject initiates another subtask with the cell phone	0	2.0	5.3	1.0
1.4	Converse on cell phone (talk, listen)	Subject waits for a response (number is already dialed, phone is at ear)	Subject presses "End" button or closes phone	0	4.9	6.0	5.6
1.5	Hold cell phone	Subject holds phone in hand (no activity is taking place with the cell phone)	Subject initiates another subtask with the cell phone	0	0	0	0.5
1.6	Hang up cell phone/end call	Subject takes phone from ear (to put phone down or press "End" button)	Subject returns hand to a resting position or initiates another subtask	5.0	0.5	3.7	4.6
1.7	Answer cell phone	Subject reaches for phone upon hearing it ring	Subject holds phone in hand and answers call or initiates another subtask	5.9	6.6	4.6	4.6

Table 36. Eat/Drink Subtasks

ID	Description	Begins When:	Ends When:	Ratings V	A	C	P
2.0	**Eat/Drink**						
2.1	Prepare to eat	Subject moves hand to reach for food	Subject initiates another subtask with the food	5.0	0.5	4.1	4.6
2.2	Prepare to drink	Subject moves hand to reach for drink	Subject initiates another subtask with the drink	5.0	0.5	4.1	4.6
2.3	Eat/bite food - not wrapped	Subject raises food or opens mouth	Subject closes mouth	0.5	0.5	1.0	5.6
2.4	Eat/bite food - wrapped	Subject raises food or opens mouth	Subject closes mouth	4.0	0.5	4.6	5.6
2.5	Chew food	Subject moves jaw (to grind food)	Subject swallows food	0	0.5	1.0	1.0
2.6	Drink from straw or sip from opening (includes cans, bottles)	Subject raises drink or opens mouth	Subject swallows	1.5	0	1.0	5.6
2.7	Drink from open-top container (cup)	Subject raises drink or opens mouth	Subject swallows	7.0	0	4.6	7.5
2.8	Finish eating	Subject moves to put away wrappers or uneaten food	Subject returns hand to a resting position or initiates another subtask	4.0	0.5	3.7	4.6
2.9	Finish drinking	Subject takes cup or container from mouth for the last time (to set it down or dispose of it)	Subject returns hand to a resting position or initiates another subtask	4.5	0.5	3.7	4.6
2.10	Spill/drop food	Foods slips from subject's grasp	Subject returns hand to a resting position or initiates another subtask	7.0	1.0	6.8	4.6

Table 37. Eat/Drink and Smoke Cigar/Cigarette Subtasks

ID	Description	Begins When:	Ends When:	Ratings

				V	A	C	P
2.0	**Eat/Drink**						
2.11	Spill/drop drink	Drink slips from subject's grasp	Subject returns hand to a resting position or initiates another subtask	7.0	1.0	6.8	4.6
2.12	Hold food/drink	Subject holds food/drink in hand (no other activity is taking place with the food or drink)	Subject returns hand to a resting position or initiates another subtask	0	0	0.5	0.5
3.0	**Smoke Cigar/Cigarette**						
3.1	Prepare to light cigar or cigarette	Subject moves hand to reach for lighter or cigar/cigarette	Subject initiates another subtask with the cigar/cigarette	5.0	0.5	4.6	4.6
3.2	Light cigar or cigarette	Subject attempts to light the lighter	Subject pulls lighter away from cigar/cigarette	7.0	1.0	4.6	7.0
3.3	Smoke cigar or cigarette	Subject draws on cigar/cigarette	Subject removes cigar/cigarette from mouth for the final time	2.0	0	1.0	1.0
3.4	Finish smoking	Subject removes cigar/cigarette from mouth for the final time	Subject puts cigar/cigarette out and returns hand to a resting state	2.5	0	3.7	4.6
3.5	Hold cigar or cigarette	Subject holds cigar/cigarette in hand, or holds in mouth and does not draw on it	Subject initiates another subtask with the cigar/cigarette	0	0	0.5	0.5
3.6	Ash cigar or cigarette	Subject moves hand holding cigar/cigarette to ashtray or window	Subject moves hand to a resting position or initiates another subtask	1.0	0	1.0	4.6

Table 38. Chewing Tobacco and Chewing Gum Subtasks

ID	Description	Begins When:	Ends When:	Ratings			
				V	A	C	P
4.0	**Chewing Tobacco**						
4.1	Prepare to chew tobacco	Subject moves hand to reach for tobacco	Subject places tobacco in mouth	5.0	0.5	4.1	4.6
4.2	Chew tobacco	Subject mouth is closed	Subject moves hand to dispose of tobacco (spittoon, window, etc.)	0	0	1.0	1.0
4.3	Spit (chewing tobacco in mouth)	Subject moves hand to reach for spittoon, or subject spits (through open window)	Subject returns hand to a resting position	5.0	0.5	4.1	5.6
4.4	Remove chewing tobacco from mouth	Subject moves hand to remove the tobacco from mouth	Subject moves hand to a resting position or initiates another subtask	5.0	0.5	4.1	5.6
5.0	**Chewing Gum**						
5.1	Hold gum in mouth	Subject's mouth is static	Subject initiates another subtask with the gum	0	0	0	0.5
5.2	Prepare to chew gum	Subject moves hand to reach for gum	Subject places piece of unwrapped gum in mouth	5.0	0.5	4.1	4.6
5.3	Blow gum bubble	Subject stretches gum	Bubble pops	0	1.0	1.0	1.0
5.4	Remove popped gum bubble	Subject moves to collect gum	Subject has all gum in mouth	0	1.0	4.6	4.6
5.5	Chew gum	Subject lowers jaw	Subject's jaw is static	0	0.5	1.0	1.0
5.6	Bite/lick lips	Subject moves lips/tongue	Subject's lips/ tongue are at rest	0	0	1.0	1.0

Table 39. Chewing Gum and Grooming Subtasks

ID	Description	Begins When:	Ends When:	Ratings			
				V	A	C	P
5.0	**Chewing Gum**						
5.7	Tongue motion	Subject moves tongue (excludes tongue motion to keep gum in place)	Subject's tongue returns to a resting state or subject closes mouth (tongue inside mouth)	0	0	1.0	1.0
5.8	Finish chewing gum	Subject moves to take gum from mouth or spit gum out	Subject returns head/hand to a resting position	2.5	0	3.7	4.6
6.0	**Grooming**						
6.1	Prepare to groom	Subject moves hand to reach for grooming tool or to perform grooming task with hand	Subject initiates another grooming subtask	1.5	0	1.2	0.5
6.2	Groom - hand only	Subject touches grooming area with hand	Subject removes hand from grooming area	0	1.5	1.0	2.2
6.3	Groom - using tool	Subject touches grooming area with grooming tool	Subject removes hand holding grooming tool from grooming area	3.7	0.5	4.6	4.6
6.4	Hold grooming tool	Subject holds grooming tool in hand while not touching the grooming area	Subject initiates another grooming subtask	0	0	0	0.5
6.5	Finish grooming	Subject removes hand or grooming tool from grooming area	Subject moves hand to a resting position or initiates another subtask	1.5	0	3.7	0.5

Table 40. Read, Write, and Type Subtasks

ID	Description	Begins When:	Ends When:	Ratings			
				V	A	C	P
7.0	**Read**						
7.1	Prepare to read	Subject moves hand to reach for reading material	Subject initiates another reading subtask	5.0	0.5	4.1	4.6
7.2	Read	Subject opens reading material	Subject initiates another reading subtask	6.5	0	5.3	0.5
7.3	Put away/fold reading materials	Subject moves to close reading material	Subject moves hand to a resting position or initiates another subtask	3.0	0.5	4.1	4.6
8.0	**Write**						
8.1	Prepare to write	Subject moves hand to reach for writing utensil	Subject initiates another writing subtask	7.0	0.5	4.6	4.6
8.2	Write	Subject touches writing utensil to writing surface	Subject initiates another writing subtask	5.9	0	5.3	6.5
8.3	Put away writing materials	Subject moves to put away writing utensils	Subject moves hand to a resting position or initiates another subtask	3.0	0.5	4.1	4.6
9.0	**Type**						
9.1	Prepare to type	Subject moves hand to reach for device	Subject initiates another typing subtask	1.5	0.5	4.1	4.6
9.2	Type with 1 thumb	Subject types first character	Subject initiates another typing subtask	5.9	1.0	5.3	6.5
9.3	Type with 2 thumbs	Subject types first character	Subject initiates another typing subtask	5.9	1.0	5.3	7.0
9.4	Type on full keyboard	Subject types first character	Subject initiates another typing subtask	3.7	1.0	5.3	7.0

Table 41. Type, In Car System Use, and Internal Distraction Subtasks

ID	Description	Begins When:	Ends When:	Ratings			
				V	A	C	P
9.0	**Type**						
9.5	End typing	Subject types last character	Subject returns hand to a resting position or initiates another subtask	1.5	0.5	4.1	4.6
10.0	**In-Car System Use**						
10.2	Use steering wheel control	Subject moves hand to use steering wheel control	Subject's hand returns to a resting position	0	1.0	1.2	2.2
10.3	Use stalk control	Subject moves hand to use stalk control	Subject returns hand to a resting position or initiates another subtask	0	1.0	1.2	5.8
10.4	Use IP, column, or center console control	Subject moves hand to use IP, column, or center console control	Subject returns hand to a resting position or initiates another subtask	2.5	1.0	1.2	5.8
10.5	Use door control	Subject moves hand to use door control	Subject returns hand to a resting position or initiates another subtask	0	1.0	1.2	2.2
10.6	Glance only - monitor in-car system	Subject glances away from road	Subject returns attention to the road	7.0	0	4.6	0
11.0	**Internal Distraction**						
11.1	Catch falling object/ prevent object from moving, reach/lean/ pick up	Subject moves hand to reach for object	Subject returns hand to a resting position or initiates another subtask	7.0	1.0	6.8	4.6
11.2	Insect-related distraction	Subject moves hand from resting position to attend to insect	Subject returns hand to a resting position or initiates another subtask	7.0	1.0	6.8	4.6

Table 42. Internal Distraction and Conversation Subtasks

ID	Description	Begins When:	Ends When:	Ratings			
				V	A	C	P
11.0	**Internal Distraction**						
11.3	Pet-related distraction	Subject moves hand to attend to pet	Subject returns hand to a resting position or initiates another subtask	7.0	1.0	6.8	4.6
11.4	Glance only - monitor internal distraction	Subject glances away from road	Subject returns attention to the road	7.0	0	4.6	0
13.0	**Conversation**						
13.1	Converse with unknown	Subject converses, but subject's eyes or head is not focused toward a discernable passenger		0	2.0	6.0	1.0
13.2	Converse with passenger - speak	Subject speaks to a passenger		1.5	2.0	6.0	1.0
13.3	Converse with passenger - listen	Subject listens to a passenger speak (passenger is talking to the driver		1.5	4.9	6.0	0
13.4	Sing/talk to self	Subject sings/talks to himself/herself. There is no passenger in the car and subject is not using a cell phone.		0	2.0	5.3	1.0
13.5	Talk to someone outside vehicle (not by phone)	Subject yells/converses with person outside vehicle through the driver's side window		5.0	4.9	6.0	1.0
13.6	Road rage	Subject is visibly agitated (may be talking to self or passenger, may be yelling)		5.0	2.0	7.0	1.0

APPENDIX C – VISUAL DEMAND RATINGS AND EXPLANATIONS

Table 43. Visual Demand Ratings and Explanations

Subtask ID	Subtask Description	Visual Code	Coding Explanation
2.7	Drink from open-top container (cup)	7.0	**Visually scan/search/monitor**; subject must monitor fluid level on open-top container while driving to avoid spilling
2.10	Spill/drop food	7.0	**Visually monitor/scan/search**; subject must discern the extent, location, and severity of spill
2.11	Spill/drop drink	7.0	**Visually monitor/scan/search**; subject must discern the extent, location, and severity of spill
3.2	Light cigar/cigarette	7.0	**Visually scan/search/monitor**; driver must monitor the cigarette to determine how well it lights
8.1	Prepare to write	7.0	**Visually scan/search/monitor**; subject must find appropriate writing materials, which are unlikely to be readily found
10.6	Glance only - monitor in-car system	7.0	**Visually scan/search/monitor**; subject needs to assess the object
11.1	Catch falling object/ prevent object from moving, reach/lean/ pick up	7.0	**Visually scan/search/monitor**; task and result can be unpredictable
11.2	Insect-related distraction	7.0	**Visually scan/search/monitor**; task and result can be unpredictable
11.3	Pet-related distraction	7.0	**Visually scan/search/monitor**; task and result can be unpredictable
11.4	Glance only - monitor internal distraction	7.0	**Visually scan/search/monitor**; subject needs to assess the object
7.2	Read	6.5	**Visually read (5.9)** for books, **Visually scan/search/monitor (7.0)** for maps
1.2	Dial phone - Hand-held	5.9	**Visually Read**; subject will read the number being pressed
1.7	Answer cell phone	5.9	**Visually Read**; subject will read the number and name of caller

Subtask ID	Subtask Description	Visual Code	Coding Explanation
8.2	Write	5.9	**Visually Read**; subject will read while writing
9.2	Type with 1 thumb	5.9	**Visually Read**; subject will read the letter, number or character pressed
9.3	Type with 2 thumbs	5.9	**Visually Read**; subject will read the letter, number or character pressed
1.1	Prepare to use cell phone	5.0	**Visually locate/align**; subject must look at object to know its position
1.6	Hang up cell phone/end call	5.0	**Visually locate/align**; subject must locate a spot to store cell phone
2.1	Prepare to eat	5.0	**Visually locate/align**; subject must look at object to know its position
2.2	Prepare to drink	5.0	**Visually locate/align**; subject must look at object to know its position
3.1	Prepare to light cigar/cigarette	5.0	**Visually locate/align**; subject must look at object to know its position
4.1	Prepare to chew tobacco	5.0	**Visually locate/align**; subject must look at object to know its position
4.3	Spit (chewing tobacco in mouth)	5.0	**Visually locate/align**; subject must aim when spitting
4.4	Remove chewing tobacco from mouth	5.0	**Visually locate/align**; subject must look to know where to place chewed tobacco
5.2	Prepare to chew gum	5.0	**Visually locate/align**; subject must look at object to know its position
7.1	Prepare to read	5.0	**Visually locate/align**; subject must look at object to know its position

Subtask ID	Subtask Description	Visual Code	Coding Explanation
13.5	Talk to someone outside vehicle (not by phone)	5.0	**Visually locate/align;** subject looks at person with whom the subject is speaking
13.6	Road rage	5.0	**Visually locate/align**; subject looks at person with whom the subject is angry
2.9	Finish drinking	4.5	Less demanding than **Visually locate/align (5.0)**; subject will locate spot to put (full) container while drinking, but may simply throw empty container in another part of the car
2.4	Eat/bite food - wrapped	4.0	**Visually inspect/check**; subject examines where/how to bite
2.8	Finish eating	4.0	Average demand is comparable to **Visually inspect/check**; subject need only inspect a spot to put wrappers, and is not expected to put partially-eaten food down after every bite
6.3	Groom - using tool	3.7	Average demand is comparable to **Visually discriminate**, as the tool will usually be a brush, and the subject will occasionally look in mirror while brushing
9.4	Type on full keyboard	3.7	Average demand is comparable to **Visually discriminate**, as subject will not have to look at keys, but will occasionally read screen
7.3	Put away/fold reading materials	3.0	Less demanding than **Visually discriminate, 3.7**, as subject may simply place materials in passenger seat or hand materials to a passenger
8.3	Put away writing materials	3.0	Less demanding than **Visually discriminate. 3.7**, as subject may simply place materials in passenger seat or hand materials to a passenger
3.4	Finish smoking	2.5	Subject may locate place to put cigarette butt (**Visually locate/align, 5.0**), but may also merely flick cigarette butt out of window
5.8	Finish chewing gum	2.5	Subject may locate place to put gum (**Visually locate/align, 5.0**), but may also merely spit gum out of window
10.4	Use IP, column, or center console control	2.5	Subject may locate button or switch (**Visually locate/align, 5.0**), but may also know where to reach without looking

Subtask ID	Subtask Description	Visual Code	Coding Explanation
3.3	Smoke cigar/ cigarette	2.0	More demanding than **Visually register/detect image (1.0)**, as the subject will rarely inspect the cigarette, and smoke will obscure the driver's view
2.6	Drink from straw or sip from opening (includes cans, bottles)	1.5	More demanding than **Visually register/detect image (1.0)**; drinking from a straw imposes little visual demand, but a bottle could obscure some of the subject's field of view
6.1	Prepare to groom	1.5	More demanding than **Visually register/detect image (1.0)**, as subject may occasionally search for a tool
6.5	Finish grooming	1.5	More demanding than **Visually register/detect image (1.0)**, as subject may occasionally need to search for a place to store tool
9.1	Prepare to type	1.5	More demanding than **Visually register/detect image (1.0)**; it is assumed the subject is most likely to use a Blackberry (or similar device), and the subject will have that clipped to his or her belt
9.5	End typing	1.5	More demanding than **Visually register/detect image (1.0)**; it is assumed the subject is most likely to use a Blackberry (or similar device), and the subject will have that clipped to his or her belt
13.2	Converse w/ passenger - speak	1.5	More demanding than **Visually register/detect image (1.0)**, as subject may occasionally focus on the passenger
13.3	Converse w/ passenger - listen	1.5	More demanding than **Visually register/detect image (1.0)**, as subject may occasionally focus on the passenger
3.6	Ash cigar/ cigarette	1.0	**Visually register/detect image**; subject will merely detect that ash has been removed, with very little detail required
2.3	Eat/bite food - not wrapped	0.5	Less demanding than **Visually register/detect image (1.0)**; food without wrappers often involved discrete pieces (such as candy, fries), with very little visual fixation needed

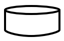
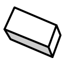
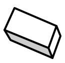
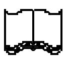
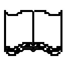
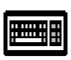
APPENDIX D – AUDITORY DEMAND RATINGS AND EXPLANATIONS

Table 44. Auditory Demand Ratings and Explanations

Subtask ID	Subtask Description	Aud. Code	Coding Explanation
1.7	Answer cell phone	6.6	**Discriminate sound characteristics**; subject must determine if the ring tone belongs to the subject's phone
1.4	Converse on cell phone (talk, listen)	4.9	**Interpret semantic content**; subject has to understand speech
13.3	Converse with passenger - listen	4.9	**Interpret semantic content**; subject has to understand speech
13.5	Talk to someone outside vehicle (not by phone)	4.9	**Interpret semantic content**; subject has to understand speech
1.2	Dial phone – Hand-held	4.3	**Verify auditory feedback**; subject listens for the dial tone while entering numbers
1.3	Dial phone – Hands-free	2.0	**Orient to sound (general orientation)**; subject pays some attention to own voice
13.1	Converse with unknown	2.0	**Orient to sound (general orientation)**; subject pays some attention to own voice
13.2	Converse with passenger - speak	2.0	**Orient to sound (general orientation)**; subject pays some attention to own voice
13.4	Sing/talk to self	2.0	**Orient to sound (general orientation)**; subject pays some attention to own voice
13.6	Road rage	2.0	**Orient to sound (general orientation)**; subject pays some attention to own voice
6.2	Groom - hand only	1.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
2.10	Spill/drop food	1.0	**Detect/register sound**; the sound of dropped food can serve as a cue that a spill occurred
2.11	Spill/drop drink	1.0	**Detect/register sound**; the sound of a dropped container or fluid can serve as a cue that a spill occurred

Subtask ID	Subtask Description	Aud. Code	Coding Explanation
3.2	Light cigar/cigarette	1.0	**Detect/register sound**; the sound of the flint being struck can serve as a cue that the lighter is being lit
5.3	Blow gum bubble	1.0	**Detect/register sound**; subject detects "pop" sound
5.4	Remove popped gum bubble	1.0	**Detect/register sound**; the pop can serve as a cue that the bubble has burst
9.2	Type with 1 thumb	1.0	**Detect/register sound**; the sound of a key clicking can serve as a cue that the key was pressed
9.3	Type with 2 thumbs	1.0	**Detect/register sound**; the sound of a key clicking can serve as a cue that the key was pressed
9.4	Type on full keyboard	1.0	**Detect/register sound**; the sound of a key clicking can serve as a cue that the key was pressed
10.2	Use steering wheel control	1.0	**Detect/register sound**; the clicking sound can serve as a cue that the button or switch was pressed
10.3	Use stalk control	1.0	**Detect/register sound**; the clicking sound can serve as a cue that the button or switch was pressed
10.4	Use IP, column, or center console control	1.0	**Detect/register sound**; the clicking sound can serve as a cue that the button or switch was pressed
10.5	Use door control	1.0	**Detect/register sound**; the clicking sound can serve as a cue that the button or switch was pressed
11.1	Catch falling object/ prevent object from moving, reach/lean/ pick up	1.0	**Detect/register sound**; a sound can serve as a cue that something has happened
11.2	Insect-related distraction	1.0	**Detect/register sound**; a sound can serve as a cue that something has happened

Subtask ID	Subtask Description	Aud. Code	Coding Explanation
11.3	Pet-related distraction	1.0	**Detect/register sound**; a sound can serve as a cue that something has happened
6.3	Groom - using tool	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
1.1	Prepare to use cell phone	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
1.6	Hang up cell phone/end call	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
2.1	Prepare to eat	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
2.2	Prepare to drink	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
2.3	Eat/bite food - not wrapped	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
2.4	Eat/bite food - wrapped	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
2.5	Chew food	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
2.8	Finish eating	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
2.9	Finish drinking	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
3.1	Prepare to light cigar/cigarette	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
4.1	Prepare to chew tobacco	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)

Subtask ID	Subtask Description	Aud Code	Coding Explanation
 4.3	Spit (chewing tobacco in mouth)	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
 4.4	Remove chewing tobacco from mouth	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
 5.2	Prepare to chew gum	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
 5.5	Chew gum	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
 7.1	Prepare to read	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
 7.3	Put away/fold reading materials	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
 8.1	Prepare to write	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
 8.3	Put away writing materials	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
 9.1	Prepare to type	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)
 9.5	End typing	0.5	Less demanding than **Detect/register sound**; this subtask generates noise (background static)

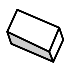
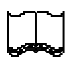
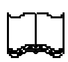
APPENDIX E – COGNITIVE DEMAND RATINGS AND EXPLANATIONS

Table 45. Cognitive Demand Ratings and Explanations

Subtask ID	Subtask Description	Cog. Code	Coding Explanation
13.6	Road rage	7.0	**Estimation, evaluation, conversion**; high cognitive demand due to loss of emotional control, strong focus on object of anger
2.10	Spill/drop food	6.8	**Evaluation/judgment (consider several aspects)**; subject must consider the spill's location, extent, importance, etc.
2.11	Spill/drop drink	6.8	**Evaluation/judgment (consider several aspects)**; subject must consider the spill's location, extent, importance, etc.
11.1	Catch falling object/ prevent object from moving, reach/lean/ pick up	6.8	**Evaluation/judgment (consider several aspects)**; subject must consider the object's location, speed, importance, etc.
11.2	Insect-related distraction	6.8	**Evaluation/judgment (consider several aspects)**; subject must consider the object's location, speed, importance, etc.
11.2	Pet-related distraction	6.8	**Evaluation/judgment (consider several aspects)**; subject must consider the object's location, speed, importance, etc.
1.4	Converse on cell phone (talk, listen)	6.0	More demanding than **Encoding/ decoding, recall**; context is often important to consider during conversation
13.1	Converse with unknown	6.0	More demanding than **Encoding/ decoding, recall**; context is often important to consider during conversation
13.2	Converse with passenger - speak	6.0	More demanding than **Encoding/ decoding, recall**; context is often important to consider during conversation
13.3	Converse with passenger - listen	6.0	More demanding than **Encoding/ decoding, recall**; context is often important to consider during conversation
13.5	Talk to someone outside vehicle (not by phone)	6.0	More demanding than **Encoding/ decoding, recall**; context is often important to consider during conversation
1.2	Dial phone - Hand-held	5.3	**Encoding/decoding, recall**; subject must remember the phone number or person to call

Subtask	Subtask Description	Cognitive Code	Coding Explanation
1.3	Dial phone – Hands-free	5.3	**Encoding/decoding, recall**; subject must remember the phone number or person to call
7.2	Read	5.3	**Encoding/decoding, recall**; subject must decode and interpret information
8.2	Write	5.3	**Encoding/decoding, recall**; subject must encode information
9.2	Type with 1 thumb	5.3	**Encoding/decoding, recall**; subject must encode information
9.3	Type with 2 thumbs	5.3	**Encoding/decoding, recall**; subject must encode information
9.4	Type on full keyboard	5.3	**Encoding/decoding, recall**; subject must encode information
13.4	Sing/talk to self	5.3	**Encoding/decoding, recall**; subject must encode information
1.7	Answer cell phone	4.6	**Evaluation/judgment (consider simple aspect)**; subject must decide whether to take the call
2.4	Eat/bite food - wrapped	4.6	**Evaluation/judgment (consider simple aspect)**; subject must judge how far to bite to avoid wrapper
2.7	Drink from open-top container (cup)	4.6	**Evaluation/judgment (consider simple aspect)**; subject must consider how much to tilt container
3.1	Prepare to light cigar/cigarette	4.6	Comparable to **Evaluation/judgment (consider simple aspect)**, as multiple items require additional planning
3.2	Light cigar/cigarette	4.6	**Evaluation (consider simple aspect)**; as subject must consider how well the cigarette is lit
5.4	Remove popped gum bubble	4.6	**Evaluation (consider simple aspect**; how much gum is stuck to mouth?
6.3	Groom - using tool	4.6	**Evaluation/judgment (consider simple aspect)**; subject likely to groom with tool until desired effect (the simple aspect) is achieved

Subtask	Subtask Description	Cognitive Code	Coding Explanation
8.1	Prepare to write	4.6	Comparable to **Evaluation/judgment (consider simple aspect)**, as multiple items require additional planning
10.6	Glance only - monitor in-car system	4.6	**Evaluation/judgment**; subject must assess the state of the in-car system
11.4	Glance only - monitor internal distraction	4.6	**Evaluation/judgment**; subject must assess the state of the internal distraction
1.1	Prepare to use cell phone	4.1	Compromise between **Sign/signal recognition (3.7)** and **Evaluation/judgment (consider simple aspect) (4.6)**; judgment to perform subtask has already been made, but planning is still a factor
2.1	Prepare to eat	4.1	Compromise between **Sign/signal recognition (3.7)** and **Evaluation/judgment (consider simple aspect) (4.6)**; judgment to perform subtask has already been made, but planning (another subtask depends on how well this is executed) is still a factor
2.2	Prepare to drink	4.1	Compromise between **Sign/signal recognition (3.7)** and **Evaluation/judgment (consider simple aspect) (4.6)**; judgment to perform subtask has already been made, but planning (another subtask depends on how well this is executed) is still a factor
4.1	Prepare to chew tobacco	4.1	Compromise between **Sign/signal recognition (3.7)** and **Evaluation/judgment (consider simple aspect) (4.6)**; judgment to perform subtask has already been made, but planning (another subtask depends on how well this is executed) is still a factor
4.3	Spit (chewing tobacco in mouth)	4.1	Compromise between **Sign/signal recognition (3.7)** and **Evaluation/judgment (consider simple aspect) (4.6)**; judgment to perform subtask has already been made, but planning (care is needed when spitting) is still a factor

Subtask	Subtask Description	Cognitive Code	Coding Explanation
 4.4	Remove chewing tobacco from mouth	4.1	Compromise between **Sign/signal recognition (3.7)** and **Evaluation/judgment (consider simple aspect) (4.6)**; judgment to perform subtask has already been made, but planning (care is needed when putting away the tobacco) is still a factor
 5.2	Prepare to chew gum	4.1	Compromise between **Sign/signal recognition (3.7)** and **Evaluation/judgment (consider simple aspect) (4.6)**; judgment to perform subtask has already been made, but planning (another subtask depends on how well this is executed) is still a factor
 7.1	Prepare to read	4.1	Compromise between **Sign/signal recognition (3.7)** and **Evaluation/judgment (consider simple aspect) (4.6)**; judgment to perform subtask has already been made, but planning (another subtask depends on how well this is executed) is still a factor
 7.3	Put away/fold reading materials	4.1	Compromise between **Sign/signal recognition (3.7)** and **Evaluation/judgment (consider simple aspect) (4.6)**; judgment to perform subtask has already been made, but planning (care is needed when putting away the reading material) is still a factor
 8.3	Put away writing materials	4.1	Compromise between **Sign/signal recognition (3.7)** and **Evaluation/judgment (consider simple aspect) (4.6)**; judgment to perform subtask has already been made, but planning (care is needed when putting away the writing materials) is still a factor
 9.1	Prepare to type	4.1	Compromise between **Sign/signal recognition (3.7)** and **Evaluation/judgment (consider simple aspect) (4.6)**; judgment to perform subtask has already been made, but planning (another subtask depends on how well this is executed) is still a factor

Subtask	Subtask Description	Cognitive Code	Coding Explanation
9.5	End typing	4.1	Compromise between **Sign/signal recognition (3.7)** and **Evaluation/judgment (consider simple aspect) (4.6)**; judgment to perform subtask has already been made, but planning (care is needed when putting away the device) is still a factor
1.6	Hang up cell phone/end call	3.7	Comparable to **Sign/signal recognition**; task is ready to be finished
2.8	Finish eating	3.7	Comparable to **Sign/signal recognition**; task is ready to be finished
2.9	Finish drinking	3.7	Comparable to **Sign/signal recognition**; task is ready to be finished
3.4	Finish smoking	3.7	Comparable to **Sign/signal recognition**; task is ready to be finished
5.8	Finish chewing gum	3.7	Comparable to **Sign/signal recognition**; task is ready to be finished
6.5	Finish grooming	3.7	Comparable to **Sign/signal recognition**; task is ready to be finished
6.1	Prepare to groom	1.2	Comparable to deciding which way to turn at an empty T-intersection (**Alternative selection, 1.2**), as subject will occasionally retrieve a tool
10.2	Use steering wheel control	1.2	**Alternative selection**; subject has to select one of several buttons/switches
10.3	Use stalk control	1.2	**Alternative selection**; subject has to select one of several buttons/switches
10.4	Use IP, column, or center console control	1.2	**Alternative selection;** subject has to select one of several buttons/switches
10.5	Use door control	1.2	**Alternative selection;** subject has to select one of several buttons/switches
2.3	Eat/bite food - not wrapped	1.0	**Automatic (simple association);** biting is an automatic action
2.5	Chew food	1.0	**Automatic (simple association);** chewing is an automatic action

Subtask	Subtask Description	Cognitive Code	Coding Explanation
2.6	Drink from straw or sip from opening (includes cans, bottles)	1.0	**Automatic (simple association);** swallowing is an automatic action
3.3	Smoke cigar/ cigarette	1.0	**Automatic (simple association)**; inhaling is an automatic action
3.6	Ash cigar/ cigarette	1.0	**Automatic (simple association)**; tapping cigarette (to remove ash) is an automatic action
4.2	Chew tobacco	1.0	**Automatic (simple association)**; holding tobacco (and related spit) in mouth is an automatic action
5.3	Blow gum bubble	1.0	**Automatic (simple association)**; blowing a bubble is an automatic action
5.5	Chew gum	1.0	**Automatic (simple association)**; chewing is an automatic action
5.6	Bite/lick lips	1.0	**Automatic (simple association)**; biting or licking lips is an automatic action
5.7	Tongue motion	1.0	**Automatic (simple association)**; tongue motion is an automatic action
6.2	Groom - hand only	1.0	**Automatic (simple association)**; grooming with the hands (mainly itching, rubbing) is an automatic action
2.12	Hold food/drink	0.5	Less demanding than **Automatic (1.0)**; holding food or drink is mostly static and requires only maintaining a specific orientation (to avoid spilling)
3.5	Hold cigar/ cigarette	0.5	Less demanding than **Automatic (1.0)**; holding a cigarette is mostly static and requires only maintaining a specific orientation (to avoid burning)

APPENDIX F – PSYCHOMOTOR DEMAND RATINGS AND EXPLANATIONS

Table 46. Psychomotor Demand Ratings and Explanations

Subtask	Subtask Description	Psychomotor Code	Coding Explanation
2.7	Drink from open-top container (cup)	7.0	Cumulative demand from **Symbolic production (6.5)**, as the subject tilts cup to a specific angle (a precise, one-handed subtask), and **Speech (1.0)**, as the subject's drinking motions are comparable to speaking
3.2	Light cigar/cigarette	7.0	Comparable to **Serial discrete manipulation**; subject performs a subtask that requires precision (bringing flame to end of cigarette) with two hands
9.3	Type with 2 thumbs	7.0	**Serial discrete manipulation**; subject presses multiple keys in succession with both hands
9.4	Type on full keyboard	7.0	**Serial discrete manipulation**; subject presses multiple keys in succession with both hands
1.2	Dial phone - Hand-held	6.5	Comparable to **Symbolic production**; subject performs a subtask that requires precision (entering numbers) with one hand
8.2	Write	6.5	**Symbolic production**; subject is writing
9.2	Type with 1 thumb	6.5	**Symbolic production**; subject performs a subtask that requires precision (pressing keys) with one hand
10.3	Use stalk control	5.8	**Discrete adjustive**; it is assumed that the stalk control will have multiple, discrete settings
10.4	Use IP, column, or center console control	5.8	**Discrete adjustive**; it is assumed that the IP, column, or center console control will have multiple, discrete settings
1.4	Converse on cell phone (talk, listen)	5.6	Cumulative demand from **Manipulative (4.6)**, as the subject brings the phone to the mouth and ear, and **Speech (1.0)**, as the subject is speaking

Subtask	Subtask Description	Psychomotor Code	Coding Explanation
2.3	Eat/bite food - not wrapped	5.6	Cumulative demand from **Manipulative (4.6)**, as the subject brings the food to the mouth, and **Speech (1.0)**, as the subject's biting motions are comparable to speaking
2.4	Eat/bite food - wrapped	5.6	Cumulative demand from **Manipulative (4.6)**, as the subject brings the food to the mouth, and **Speech (1.0)**, as the subject's biting motions are comparable to speaking
2.6	Drink from straw or sip from opening (includes cans, bottles)	5.6	Cumulative demand from **Manipulative (4.6)**, as the subject brings the container to the mouth, and **Speech (1.0)**, as the subject's drinking motions are comparable to speaking
4.3	Spit (chewing tobacco in mouth)	5.6	Cumulative demand from **Manipulative (4.6)**, as the subject brings the spittoon or other container to the mouth, and Speech **(1.0)**, as the subject's spitting motions are comparable to speaking
4.4	Remove chewing tobacco from mouth	5.6	Cumulative demand from **Manipulative (4.6)**, as the subject takes the tobacco from the mouth, and **Speech (1.0)**, as the subject must maintain spit to prevent drooling
1.1	Prepare to use cell phone	4.6	**Manipulative**; subject has to handle object to retrieve it
1.6	Hang up cell phone/end call	4.6	**Manipulative**; subject handles object when storing it
1.7	Answer cell phone	4.6	**Manipulative**; subject has to handle object to retrieve it
2.1	Prepare to eat	4.6	**Manipulative**; subject has to handle object to retrieve it
2.2	Prepare to drink	4.6	**Manipulative**; subject has to handle object to retrieve it

Subtask	Subtask Description	Psychomotor Code	Coding Explanation
2.8	Finish eating	4.6	**Manipulative**; subject has to handle object to store or dispose of it
2.9	Finish drinking	4.6	**Manipulative**; subject handles object when storing or otherwise disposing of it
2.10	Spill/drop food	4.6	**Manipulative**; subject will handle the food or a rag to clean up mess
2.11	Spill/drop drink	4.6	**Manipulative**; subject will handle the container or a rag to clean up mess
3.1	Prepare to light cigar/cigarette	4.6	**Manipulative**; subject has to handle objects to retrieve them
3.4	Finish smoking	4.6	**Manipulative**; subject has to handle object to store or dispose of it
3.6	Ash cigar/cigarette	4.6	**Manipulative**; subject manipulates cigarette to remove ash
4.1	Prepare to chew tobacco	4.6	**Manipulative**; subject has to handle object to retrieve it
5.2	Prepare to chew gum	4.6	**Manipulative**; subject has to handle object to retrieve it
5.4	Remove popped gum bubble	4.6	**Manipulative**; it is assumed the subject will remove the gum with the hand
5.8	Finish chewing gum	4.6	**Manipulative**; subject has to handle object to store or dispose of it
6.3	Groom - using tool	4.6	**Manipulative**; subject handles tool to groom
7.1	Prepare to read	4.6	**Manipulative**; subject has to handle object to retrieve it
7.3	Put away/fold reading materials	4.6	**Manipulative**; subject has to handle object to retrieve it
8.1	Prepare to write	4.6	**Manipulative**; subject has to handle objects to retrieve them
8.3	Put away writing materials	4.6	**Manipulative**; subject handles objects when storing or otherwise disposing of them

Subtask	Subtask Description	Psychomotor Code	Coding Explanation
9.1	Prepare to type	4.6	**Manipulative**; subject has to handle object to retrieve it
9.5	End typing	4.6	**Manipulative**; subject has to handle object to store it
11.1	Catch falling object/prevent object from moving, reach/ lean/pick up	4.6	**Manipulative**; subject handles object to prevent it from falling
11.2	Insect-related distraction	4.6	**Manipulative**; subject uses hand to attend to insect, not deemed to be especially precise
11.3	Pet-related distraction	4.6	**Manipulative**; subject uses hand to attend to pet, not deemed to be especially precise
6.2	Groom - hand only	2.2	Comparable to **Discrete actuation**; scratching or rubbing is similar in many respects to pressing a button repeatedly
10.2	Use steering wheel control	2.2	**Discrete actuation**; it is assumed the steering wheel control is typically a simple button
10.5	Use door control	2.2	**Discrete actuation**; it is assumed the door control is typically a simple button
1.3	Dial phone – Hands-free	1.0	**Speech**; subject is talking
2.5	Chew food	1.0	**Comparable to Speech**; chewing is similar in many respects to speaking
3.3	Smoke cigar/cigarette	1.0	**Comparable to Speech**; inhaling while maintaining the cigarette in the mouth is similar in many respects to speaking
4.2	Chew tobacco	1.0	**Comparable to Speech;** chewing is similar in many respects to speaking
5.3	Blow gum bubble	1.0	**Comparable to Speech**; blowing a bubble is similar in many respects to speaking
5.5	Chew gum	1.0	**Comparable to Speech**; chewing is similar in many respects to speaking

Subtask	Subtask Description	Psychomotor Code	Coding Explanation
5.6	Bite/lick lips	1.0	Comparable to **Speech**; biting/licking lips is similar in many respects to speaking
5.7	Tongue motion	1.0	Comparable to **Speech**; tongue motion is similar in many respects to speaking
13.1	Converse with unknown	1.0	**Speech**; subject is talking
13.2	Converse with passenger - speak	1.0	**Speech**; subject is talking
13.4	Sing/talk to self	1.0	**Speech**; subject is talking
13.5	Talk to someone outside vehicle (not by phone)	1.0	**Speech**; subject is talking
13.6	Road rage	1.0	**Speech**; subject is talking
1.5	Hold cell phone	0.5	Less demanding than **Speech (1.0)**; though the subject's hand is occupied, the subtask is static
2.12	Hold food/drink	0.5	Less demanding than **Speech (1.0)**; though the subject's hand is occupied, the subtask is static
3.5	Hold cigar/cigarette	0.5	Less demanding than **Speech (1.0)**; though the subject's hand is occupied, the subtask is static
5.1	Hold gum in mouth	0.5	Less demanding than **Speech (1.0)**; though the subject's mouth is occupied, the subtask is static
6.1	Prepare to groom	0.5	Less demanding than **Speech (1.0)**; the subject will rarely need to handle a tool before grooming
6.4	Hold grooming tool	0.5	Less demanding than **Speech (1.0)**; though the subject's hand is occupied, the subtask is static
6.5	Finish grooming	0.5	Less demanding than **Speech (1.0)**; the subject will rarely need to handle a tool after grooming
7.2	Read	0.5	Less demanding than **Speech (1.0)**; though the subject's hand is occupied, the subtask is static

APPENDIX G – RANK ORDER OF TOTAL DEMAND BY SUBTASK

Table 47. Rank Order of Total Demand by Subtask

Subtask	Name	V	A	C	P	Total
1.5	Hold cell phone	0	0	0	0.5	0.5
5.1	Remove chewing tobacco from mouth	0	0	0	0.5	0.5
6.4	Groom - using tool	0	0	0	0.5	0.5
2.12	Hold food/drink	0	0	0.5	0.5	1
3.5	Finish smoking	0	0	0.5	0.5	1
4.2	Prepare to chew tobacco	0	0	1	1	2
5.6	Chew gum	0	0	1	1	2
5.7	Bite/lick lips	0	0	1	1	2
2.5	Chew food	0	0.5	1	1	2.5
5.5	Remove popped gum bubble	0	0.5	1	1	2.5
5.3	Prepare to chew gum	0	1	1	1	3
6.1	Finish chewing gum	1.5	0	1.2	0.5	3.2
3.3	Light cigar or cigarette	2	0	1	1	4
10.2	End typing	0	1	1.2	2.2	4.4
10.5	Use IP, column, or center console control	0	1	1.2	2.2	4.4
6.2	Prepare to groom	0	1.5	1	2.2	4.7
6.5	Hold grooming tool	1.5	0	3.7	0.5	5.7
3.6	Hold cigar or cigarette	1	0	1	4.6	6.6
2.3	Eat/bite food - not wrapped	0.5	0.5	1	5.6	7.6
10.3	Use steering wheel control	0	1	1.2	5.8	8
2.6	Drink from straw or sip from opening (includes cans, bottles)	1.5	0	1	5.6	8.1
1.3	Dial phone – Hands-free	0	2	5.3	1	8.3
13.4	Converse with passenger - speak	0	2	5.3	1	8.3
13.1	Pet-related distraction	0	2	6	1	9
5.4	Blow gum bubble	0	1	4.6	4.6	10.2
10.4	Use stalk control	2.5	1	1.2	5.8	10.5
13.2	Glance only - monitor internal distraction	1.5	2	6	1	10.5
9.1	Put away writing materials	1.5	0.5	4.1	4.6	10.7
9.5	Type on full keyboard	1.5	0.5	4.1	4.6	10.7
3.4	Smoke cigar or cigarette	2.5	0	3.7	4.6	10.8
5.8	Tongue motion	2.5	0	3.7	4.6	10.8
10.6	Use door control	7	0	4.6	0	11.6
11.4	Insect-related distraction	7	0	4.6	0	11.6
7.3	Read	3	0.5	4.1	4.6	12.2
8.3	Write	3	0.5	4.1	4.6	12.2

Subtask	Name	V	A	C	P	Total
7.2	Prepare to read	6.5	0	5.3	0.5	12.3
13.3	Converse with unknown	1.5	4.9	6	0	12.4
2.8	Finish eating	4	0.5	3.7	4.6	12.8
2.9	Finish drinking	4.5	0.5	3.7	4.6	13.3
6.4	Groom - hand only	3.7	0.5	4.6	4.6	13.4
1.6	Hang up cell phone/end call	5	0.5	3.7	4.6	13.8
1.1	Prepare to use cell phone	5	0.5	4.1	4.6	14.2
2.1	Prepare to eat	5	0.5	4.1	4.6	14.2
2.2	Prepare to drink	5	0.5	4.1	4.6	14.2
4.1	Ash cigar or cigarette	5	0.5	4.1	4.6	14.2
5.2	Hold gum in mouth	5	0.5	4.1	4.6	14.2
7.1	Finish grooming	5	0.5	4.1	4.6	14.2
2.4	Eat/bite food - wrapped	4	0.5	4.6	5.6	14.7
3.1	Prepare to light cigar or	5	0.5	4.6	4.6	14.7
13.6	Sing/talk to self	5	2	7	1	15
4.3	Chew tobacco	5	0.5	4.1	5.6	15.2
4.4	Spit (chewing tobacco in mouth)	5	0.5	4.1	5.6	15.2
1.4	Converse on cell phone (talk, listen)	0	4.9	6	5.6	16.5
8.1	Put away/fold reading materials	7	0.5	4.6	4.6	16.7
13.5	Converse with passenger - listen	5	4.9	6	1	16.9
9.4	Type with 2 thumbs	3.7	1	5.3	7	17
8.2	Prepare to write	5.9	0	5.3	6.5	17.7
9.2	Prepare to type	5.9	1	5.3	6.5	18.7
2.7	Drink from open-top container (cup)	7	0	4.6	7.5	19.1
9.3	Type with 1 thumb	5.9	1	5.3	7	19.2
2.10	Spill/drop food	7	1	6.8	4.6	19.4
2.11	Spill/drop drink	7	1	6.8	4.6	19.4
11.1	Glance only - monitor in-car system	7	1	6.8	4.6	19.4
11.2	Catch falling object/	7	1	6.8	4.6	19.4
11.3	prevent object from moving, reach/lean/pick up	7	1	6.8	4.6	19.4
3.2	cigarette	7	1	4.6	7	19.6
1.7	Answer cell phone	5.9	6.6	4.6	4.6	21.7
1.2	Dial phone – Hand-held	5.9	4.3	5.3	6.5	22

APPENDIX H – RANK ORDER TOTAL DEMAND FROM THE PASS 2 DATA

Table 48. Total Demand from the Pass 2 Data

# Frames	V	A	C	P	Total Demand
10228	0	0	0	0	0
16	0	0	0	0.5	0.5
124	0	0	0.5	0.5	1
579	0	0	1	1	2
815	0	0.5	1	1	2.5
13	0	0.5	1	1.5	3
44	1.5	0	1.2	0.5	3.2
89	2	0	1	1	4
1	1.5	0	1.7	1	4.2
3	0	1	1.2	2.2	4.4
616	0	1.5	1	2.2	4.7
2	1.5	0	2.2	1.5	5.2
18	0	1.5	1.5	2.7	5.7
51	1.5	0	3.7	0.5	5.7
6	1.5	0.5	2.2	1.5	5.7
9	1	0	1	4.6	6.6
2	1.5	0	4.2	1	6.7
5	0	2	2	3.2	7.2
12	0.5	0.5	1	5.6	7.6
73	1.5	0	1	5.6	8.1
4	1.5	0.5	4.7	1.5	8.2
9	0	2	5.3	1	8.3
1393	0	2	6	1	9
19	1.5	0	1.5	6.1	9.1
7	0	2	6	1.5	9.5
7	0	2	6.5	1.5	10
90	1.5	2	6	1	10.5
67	2.5	1	1.2	5.8	10.5
3	1.5	2	6	1.5	11
237	7	0	4.6	0	11.6
12	1.5	2	7.2	1.5	12.2
15	6.5	0	5.3	0.5	12.3
147	1.5	4.9	6	0	12.4
1	1.5	2	7	2	12.5
1	4	0.5	3.7	4.6	12.8
13	1.5	2.5	7	2	13
28	4.5	0.5	3.7	4.6	13.3

# Frames	V	A	C	P	Total Demand
11	3.7	0.5	4.6	4.6	13.4
1	7	0	5.6	1	13.6
104	0	3.5	7	3.2	13.7
13	5	0.5	3.7	4.6	13.8
33	7	0.5	5.6	1	14.1
10	5	0.5	4.1	4.6	14.2
6	1.5	4.9	7	1	14.4
8	1.5	2	9.7	1.5	14.7
13	4	0.5	4.6	5.6	14.7
1	5	0.5	4.1	5.1	14.7
10	6.5	0.5	6.3	1.5	14.8
8	1.5	3.5	7	3.2	15.2
4	1	2	7	5.6	15.6
2	3	4.9	7.2	0.5	15.6
4	3	2	9.7	1.5	16.2
680	0	4.9	6	5.6	16.5
3	5	1	5.1	5.6	16.7
5	1.5	6.4	7	2.2	17.1
19	0	4.9	7	6.6	18.5
44	0	5.4	7	6.6	19
68	7	1	6.8	4.6	19.4
43	7	2	10.6	1	20.6
9	7	1	7.8	5.6	21.4
6	7	1.5	7.8	5.6	21.9
17	5.9	4.3	5.3	6.5	22
6	5	2.5	10.1	5.6	23.2
6	8.5	4.9	10.6	0	24
20	1.5	4.9	7	11.2	24.6
1	8.5	1	10.5	5.1	25.1
11	7	4.9	10.6	5.6	28.1
19	7	3	12.8	5.6	28.4
18	5	5.4	10.1	10.2	30.7
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APPENDIX I – VACP AGGREGATE DEMANDS BY ROAD SUPERCLASS, AGE GROUP, AND SEX

Table 49. Aggregate Demands by Road Superclass, Age Group, and Sex

			Limited Access	Major Roads	Minor Roads	Row Sum	Age Sum	Demand Sum
Visual	Young	Female	169	279	370	818	1835	4944
		Male	480.5	345.5	191	1017		
	Middle	Female	189.5	74.5	612	876	1753.5	
		Male	526	239	112.5	877.5		
	Old	Female	96.5	70	51	217.5	1355.5	
		Male	358.5	372.5	407	1138		
Auditory	Young	Female	748.3	773	1015.6	2536.9	4920	10070.3
		Male	784.8	958.6	639.7	2383.1		
	Middle	Female	372.2	458.5	673.4	1504.1	2929.1	
		Male	961	210	254	1425		
	Old	Female	386.5	203.5	464.9	1054.9	2221.2	
		Male	735.3	261.5	169.5	1166.3		
Cognitive	Young	Female	1648.7	1295.2	2306.6	5250.5	9290	21497.7
		Male	1361.2	1467.5	1210.8	4039.5		
	Middle	Female	861.8	1076.5	1767.1	3705.4	6627.5	
		Male	1837.5	515.6	569	2922.1		
	Old	Female	1013.8	602.2	1342.8	2958.8	5580.2	
		Male	1013.8	932.4	675.2	2621.4		
Psycho-motor	Young	Female	722.4	975	1219.6	2917	6056.1	12453.7
		Male	1106.6	1283.2	749.3	3139.1		
	Middle	Female	360.4	546.5	798.9	1705.8	3608	
		Male	1334.4	301.1	266.7	1902.2		
	Old	Female	247.3	175.7	316	739	2789.6	
		Male	834.8	381	834.8	2050.6		
Sum		18150.8	13797.5	17017.4	48965.7	48965.7		

APPENDIX J – MEAN DEMAND/FRAME BY DEMAND TYPE

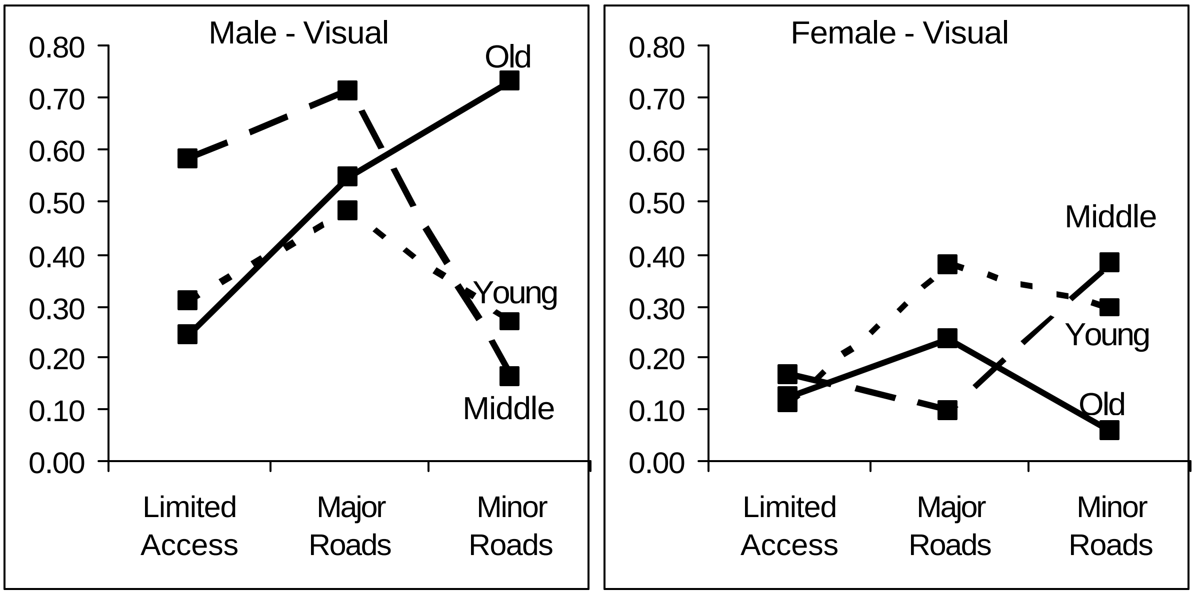

Figure 12. Visual Demand Means Based on Sex, Age, and Road Superclass

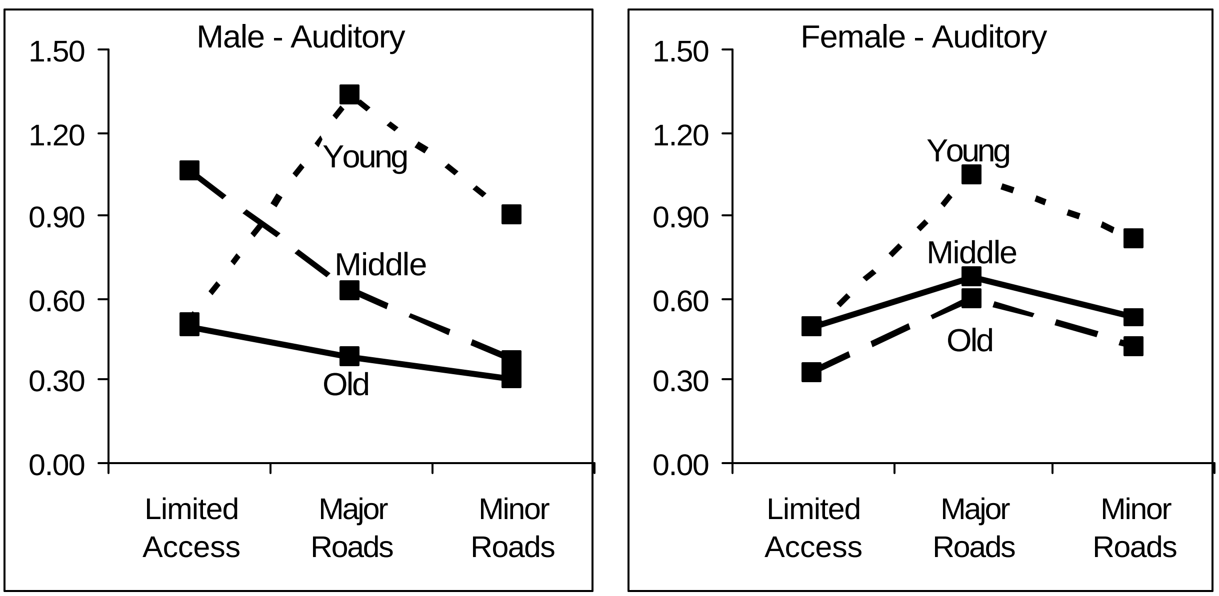

Figure 13. Auditory Demand Means Based on Sex, Age, and Road Superclass

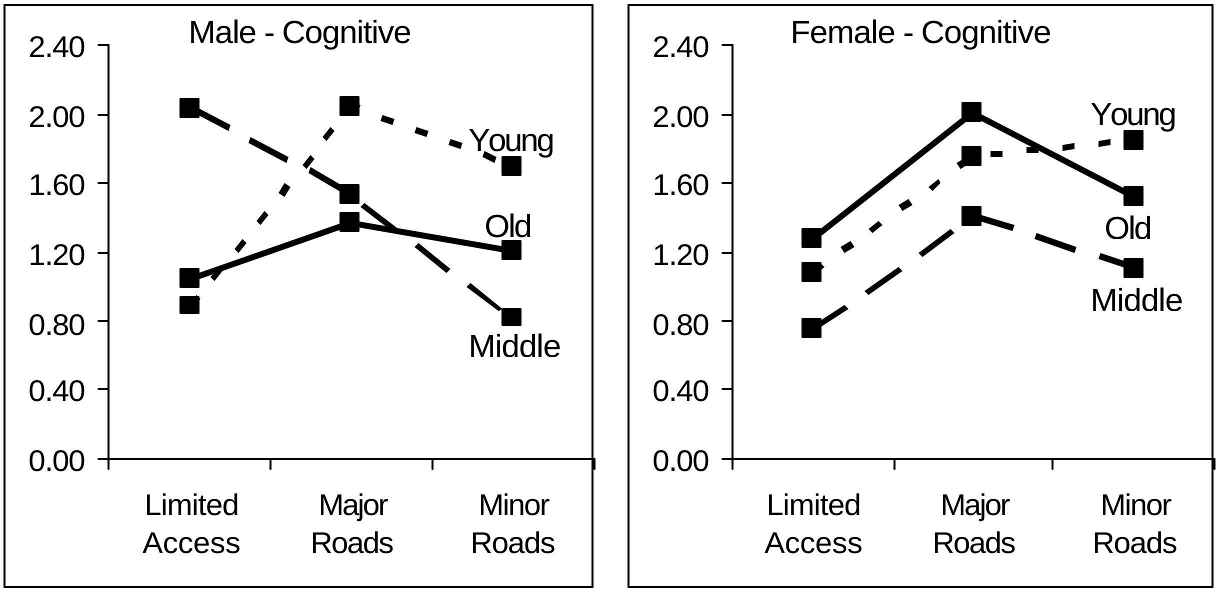

Figure 14. Cognitive Demand Means Based on Sex, Age, and Road Superclass

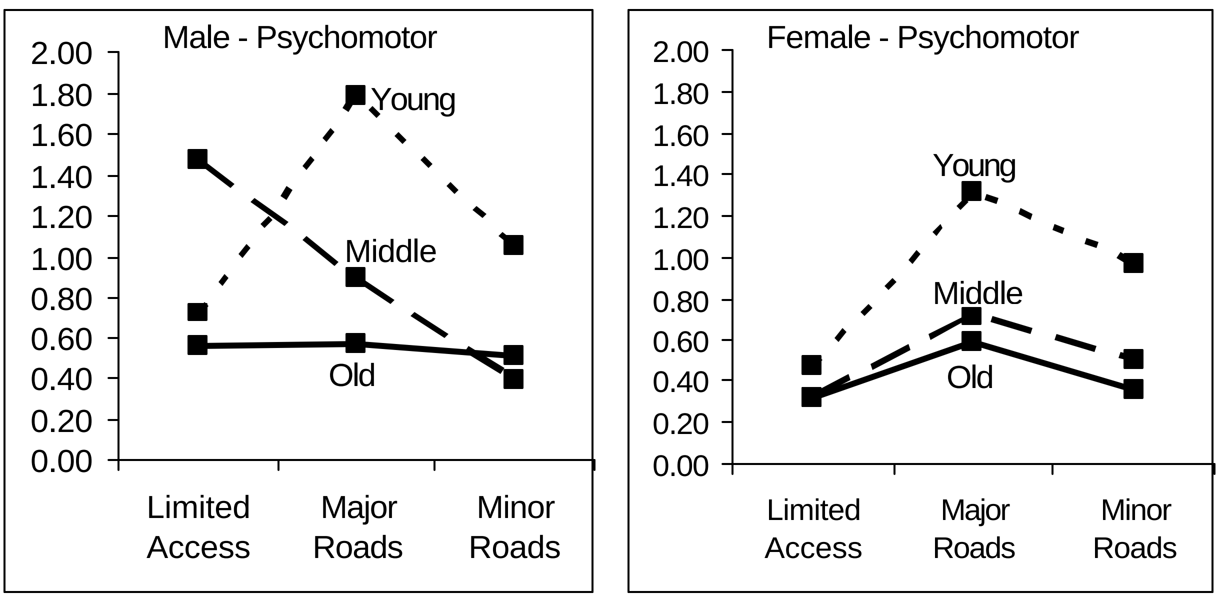

Figure 15. Psychomotor Demand Means Based on Sex, Age, and Road Superclass

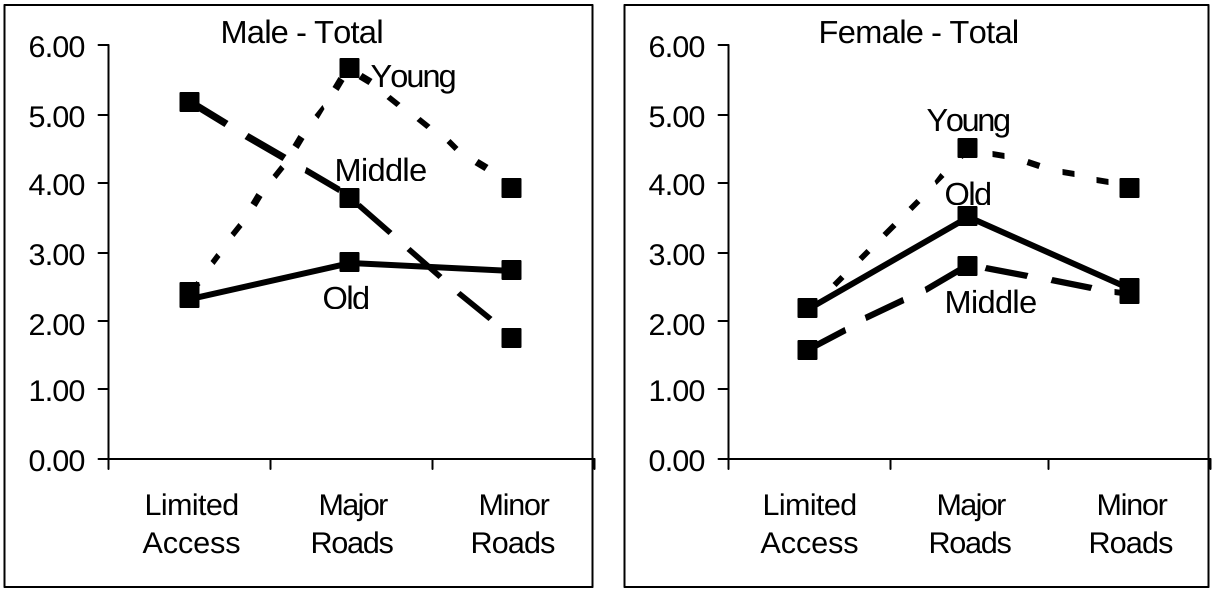

Figure 16. Total (sum of VACP) Demand Means Based on Sex, Age, and Road Superclass