INTRODUCTION

- Drivers manage multiple tasks:
  - Primary driving tasks
    - Steer, accelerate, brake, choose and maintain speed and lane, navigate, monitor hazards
  - Secondary tasks
    - Today - converse with other passengers, eat, drink, groom, listen to audio entertainment, use portable devices, place phone call, adjust mirrors, set cruise control, access OnStar, etc.
    - New – communicate, entertain, navigate, Internet tasks, address book tasks, etc.
ISSUES

- How determine which secondary tasks may interfere with primary driving tasks?
  - Without an answer, how is it possible to:
    - Minimize driver distraction?
    - Develop design and driver performance standards for secondary tasks?
- What key dimensions of driver performance provide a complete and valid assessment of secondary task effects on primary driving performance?
  - Numerous measures of driver performance have been explored, and intercorrelations between measures have been described.
  - By examining the structure within those correlations, it is possible to identify the underlying driver performance dimensions.

OBJECTIVE AND SCOPE

- The main objective was to determine the underlying dimensions of driver performance during the conduct of secondary manual tasks inside a moving vehicle.
- The scope of the study was restricted to:
  - Tasks that could be performed using the eyes and hands (visual-manual)
    - Visual-manual is most common in vehicles today, and so was deemed of importance to study first, compared to voice, haptic or other methods.
  - Only one secondary task at a time
    - It was felt necessary to understand the effect of single secondary tasks first, before studying them in combination.
METHODS

- Subjects
  - Equal numbers of licensed drivers assigned to two age groups: 18-34 and 45-65 years.
  - Equal numbers of males and females assigned to each experimental condition (vehicle system), within each age group.
  - A total of 81 paid subjects participated in the on-road study.

- Vehicles and Vehicle Systems
  - Five vehicles: four sedans, one sport-utility vehicle.
  - One manufacturer made four of the vehicles, and another the fifth.
  - Different in-vehicle information systems had been installed in four of the vehicles.
  - One vehicle did not have an information system but had a prototype radio interface.
  - Three of the systems were experimental prototypes for demonstration purposes, not scheduled for production then or now.
  - The system without the information function is now in production, and the fifth was a commercial system.

METHODS: SECONDARY TASKS

- The tasks were selected to represent typical tasks that drivers would do in a vehicle with the functions available to them for a given system.

- 79 tasks chosen were selected from the categories of:
  - Communication (e.g., phone dialing)
  - Entertainment (radio, CD, information)
  - Navigation (e.g., route destination entry)
  - Internet tasks (e.g., get weather, sports stories)
  - Address book (e.g. data entry)
  - Conventional tasks that are commonly done in the vehicle today
METHODS: EXPERIMENTAL DESIGN

- The main independent variable manipulated between subjects was Vehicle System (5 total).
- Twelve to 18 drivers were stratified by age (younger, older) and gender (male, female) within each of the five vehicle systems.
- The main independent variable manipulated within subjects was Tasks (13 to 18 per vehicle system).

METHODS: DEPENDENT VARIABLES

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METHOD: FACILITIES

Center portion of Virginia Tech Transportation Institute (VTTI) Smart Road:

- 1.0-mile, two-lane roadway
  - Turn-arounds at each end used for practice sessions
- Curves, hills and bridges, but no intersections
  - Roadside ravines and/or hillsides on both sides of the roadway, as well as bridges and bridge abutments, meant that the driving experience was more challenging than on a closed-course test track or straightaway on which lane wander might have little practical consequence.
- The road was closed to traffic other than the vehicles involved in the testing.

METHOD: APPARATUS

Visual Events Detection Task

- The instrumentation for this task consisted of two red lights mounted on the vehicle (intended conceptually to emulate visual roadway events such as a vehicle braking), together with software to control their presentation.
- One or the other light randomly turned on three to six seconds after the brake pedal was pressed in response to a prior light event. Which light came on in that period (hood or side) was also randomly determined.
- A light remained on until the driver responded to it.
- Responses longer than 3.5 seconds were recorded as a miss.
METHOD: APPARATUS

PROCEDURE

- All subjects were given a demo trial, then a training trial, for every task while in the training area. The training for each task was done immediately before the road test trial.
  - This procedure, as per previous investigations with this method (not shown), typically produces a level of training that is likely at or near the maximum of the short-term learning curve for that particular task for that subject.

- Further details of the experimental procedure are given in:
PROCEDURE: ROAD TEST TRIAL

DATA PROCEDURES

- Each variable for each task was averaged across all subjects tested for that task, yielding a 79 x 15 input data matrix.
- A 15 x 15 correlation matrix between the variables was then calculated across the 79 tasks.
- Principal Component Analysis (PCA) was then used to reduce the dimensionality of the standardized data set (i.e. each variable is normalized to a mean of zero and a standard deviation of one) to the major orthogonal dimensions.
### RESULTS: CORRELATIONS

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Table 1. Correlation matrix between all 15 variables across all 79 tasks. Bolded r-values are statistically significant at p < 0.000001 (r > 0.522).

### MAIN RESULT

- Using Principal Component Analysis, all the redundancy between variables in the correlation matrix was removed – the PCs are orthogonal.
- The information was simplified and represented in the first three principal component dimensions, without loss of significant information.
- The three dimensions taken together can explain 83% of the total variation (in all the tasks and all the variables), which is deemed substantial.
RESULTS: DIMENSION 1 (61%)

RESULTS: DIMENSION 2 (17%)
RESULTS: DIMENSION 3 (5%)

RESULTS: DIM 2 x DIM 1
**RESULTS: TASK SCORES**

- The 79 tasks can now be scored in terms of the three orthogonal dimensions, instead of the 15 original variables.
- Control limits can now be established on the scores in each of the three primary dimensions, to determine if tasks are inside or outside control limits for acceptable driving performance.

**DISCUSSION**

- Dimension 1 is interpreted as *overall driver demand*.
- Dimension 2 is interpreted as *low-workload-but-high-inattentiveness*.
  - It specifies tasks that make drivers less attentive or more insensitive to outside events than expected, given their visual-manual workload, and contrasts them with tasks for which attentiveness is greater than expected for their given visual-manual workload.
  - Likely associated with a larger class of driver attentional phenomena termed *mind-off-road*.
- Dimension 3 is interpreted as *peripheral insensitivity*.
  - Opposing responsiveness for peripheral vs. central events.
  - Possible narrowing of visual attention to the central visual field.
**BENEFITS**

1. Replaces a large set of variables by only three dimensions.
   - The tasks can be represented as points in a 3-dimensional space formed by those dimensions.

2. May reduce errors in classifying tasks as inside or outside control limits for acceptable driving performance.
   - May reduce false positives that claim a task is outside control limits when it really is inside control limits.
     - By looking at fewer dimensions than variables there is less scope for false positive errors.
     - Reduces customer frustration from false lockouts.
   - May reduce false negatives that claim a task is inside control limits when it really is outside control limits.
     - Multivariate methods may find different types of outliers (tasks outside of control limits) not seen by the original variables.
     - Enables early detection of issues and improved design of products.

**CONCLUSIONS**

1. *Overall driver demand* as defined by Principal Component Analysis is a separate driver performance dimension from low-workload-but-high-inattentiveness, and vice versa; peripheral insensitivity is an added dimension, separate from the first two.

2. These three dimensions by themselves can explain a substantial portion of the total variation in all the tasks and all the variables studied.

3. Scoring tasks on these dimensions instead of the original variables may reduce errors in classifying tasks as inside or outside control limits for acceptable driving performance.

4. No single variable by itself (e.g. task time, peripheral light % misses) can capture all the important variations in driver performance during secondary in-vehicle manual tasks.

5. A multivariate design and analysis is required.