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An instrumented vehicle assessment of problem behavior and driving style: Do younger males really take more risks?

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Abstract

An instrumented vehicle was used to obtain behavioral data from 61 drivers ranging in age from 18 to 82. Each driver completed a personality questionnaire and participated in a study described as an evaluation of cognitive mapping and way-finding abilities. An evaluation of relationships between age, personality and driving style revealed that driver age and type A personality characteristics were significant predictors of vehicle speed and following distance, $P < 0.05$. However, contrary to the earlier research, which relies heavily on a self-reported driving criterion, no significant gender differences were obtained. A factor analysis of several at-risk driving behaviors identified a cluster of correlated driving behaviors that appeared to share a common characteristic identified as aggressive/impatient driving. It is suggested that the correlated cluster of driving behavior provide objective support for the assumptions of response generalization and problem behavior theory. Results are discussed with regard to implications for safe driving interventions and a problem behavior syndrome.

Keywords: Instrumented vehicle assessment; Problem behavior; Driving style

1. Introduction

At-risk driving is a tragic problem in contemporary society. In 1998, for example, driver behavior in the US led to 37 081 fatalities and more than 2 million serious injuries. As such, approximately 100 people die each day in a motor vehicle crash. This amounts to one death every 14 min (NHTSA, 2000). Drivers between the ages of 16 and 24 are over represented in these statistics. Ironically, these tragedies occur despite environmental safeguards designed to protect vehicle occupants and mandatory laws to control driving behavior. As a result, Geller (1991) called the US highways, a battleground claiming more lives than any war the US has seen.

Minor changes in driver behavior can prevent injury and save lives. For example, it is estimated that safety-belt use saved 10 414 lives in 1996 and 90 425 lives since 1975 (NHTSA, 1998). In fact, it is predicted that a one percent increase in the use of safety belts nationwide saves 200 lives per year (Nichols, 1998). Vehicle crashes have also been shown to correlate positively with vehicle speed as evidenced by an increase in crashes occurring concomitantly with increases in the national speed limit (Evans, 1991).

It seems that the majority of vehicle crashes can be attributed to driver behavior. Some people go their entire lives without experiencing a vehicle crash, while others are involved in multiple crashes throughout the course of their driving lives. Proponents of personality psychology argue that some people are more prone than others to take risks. Specifically, more than a decade ago, theoretical formulations and research findings suggested that at-risk driving (e.g. non-use of safety belts, speeding, and driving while intoxicated (DWI)) are components of a larger risky driving syndrome (Jessor, 1987; Beirness and Simpson, 1988;

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Donovan et al., 1988; Wilson and Jonah, 1988). Furthermore, it was suggested that certain social, psychological and behavioral factors (e.g. health-compromising behaviors such as smoking, drug use and heavy drinking) distinguished young drivers (ages 12–19), who became involved in vehicle crashes from those who did not (Beirness and Simpson, 1988), and were significant predictors of DWI, driving while using marijuana, and willingness to ride with alcohol-impaired drivers.

Certain personality differences have been shown to reliably predict people's at-risk driving behaviors. For example, Wilson (1990) demonstrated that non-users of safety belts were higher sensation seekers, more impulsive, and accumulated more traffic violations than moderate and consistent users of safety belts. Non-users of safety belts were also more likely to be males, younger and less educated than safety-belt users.

Sensation seeking (Zuckerman, 1994) has also been shown to correlate positively with self-reports of (a) DWI; (b) driving greater than 20 mph above the speed limit; (c) racing with another vehicle; and (d) illegal passes (Arnett, 1996). Like safety-belt non-use, these behaviors were reported more prevalently by males, who also scored higher on sensation seeking than females.

In his review of the sensation seeking literature, Jonah (1997) found a positive relationship between sensation seeking and risky driving with correlations ranging between 0.30 and 0.40. Of the SSS subscales, Jonah (1997) found thrill and adventure seeking to show the strongest relationship. Finally, in a study that distinguished sensation avoiders from sensation seekers, sensation avoiders were shown to prefer larger following distances between their vehicles and the vehicle in front than sensation seekers (Heino et al., 1996).

Additional relationships between personality and driving have been documented by Furnham and Saipe (1993), who reported that drivers convicted of traffic violations such as speeding and reckless driving scored relatively high on thrill-seeking and boredom susceptibility. Driving convictions were also negatively correlated with age and years of driving, and were more prominent among males. Indeed, younger drivers have been shown to speed more often (Wasielewsky, 1984), and follow more closely (Evans and Wasielewsky, 1983; Evans, 1991). Plus, younger drivers have been reported to score higher than older drivers on the aggressiveness subscale of the California Personality Inventory (Arnett, 1996).

The criterion measure of driving performance is typically derived from self-report or archival data (i.e. driving records). It has been claimed that 'use of self-reports to measure both personality and accidents limits the study because any (observed) correlation may be a response artifact' (Arthur and Graziano, 1996 p. 599). Indeed, Lajunen et al., 1997 demonstrated the tendency for participants to engage in impression management and self-deception when completing traffic behavior inventories. Specifically, these investigators showed that driver impression management correlated negatively with self-reported numbers of crashes, fines, speeding and incidences of driving aggression. Impression management correlated positively with self-reported compliance with rules of the road.

Moreover, archival data can be deficient because state records may under-report the actual number of vehicle crashes simply because the drivers involved chose not to report them (Arthur and Graziano, 1996). Failure to collect objective behavioral measures of driving performance and over-reliance on self-report data are serious short-comings of the traffic safety literature.

A distinct advantage of the present research over prior studies of at-risk driving is the use of a 'smart car.' The smart car is an instrumented vehicle capable of simultaneously video-recording and measuring several on-going driving behaviors without the driver's knowledge. These computer-generated dependent measures, in concert with real-time covert video recording of the participants' driving, allowed for unprecedented opportunities to perform a behavior analysis of driving performance in the context of normal driving. Thus, problems associated with truthfulness of self-report, infrequency of occurrence, and error variation due to in-vehicle observers were minimized or avoided altogether. Furthermore, although there have been a few attempts to determine the extent to which driving behaviors covary (Ludwig and Geller, 1991; Janssen, 1994; Ludwig and Geller, 1997), until this point no research paradigm has allowed for a comprehensive objective assessment of related driving behaviors.

2. Method

2.1. Participants and setting

Participants were 61 licensed drivers (29 males and 32 females) from southwest Virginia, ranging in age from 18 to 82 years ($M = 42$). They were recruited through a state university with posted flyers and advertisements in local newspapers. The flyers and newspaper ads specified that licensed drivers between the ages of 18 and 25, 35 and 45, and 65+ were needed for a study that involved driving, and would be paid $10.00 per h for their participation. Drivers meeting these age requirements were grouped as younger (10 males, 13 females), middle-aged (10 males, 12 females), and older (9 males, 7 females) drivers, respectively.

A protocol in which the study was presented as an investigation of direction-following abilities was approved by the institutional review board of the university, where the study was conducted. Videotape authority was not explicitly detailed in the informed consent documents, but was mentioned briefly as a potential tool to assist researchers in coding a driver's progress along the driving route. Approval was contingent on maintaining videotape files in a locked cabinet to which only the PI of the project (the first author) had access.

Prior to being scheduled for a research appointment, all participants were screened for potential health problems, use of prescription medicines and alcohol-use patterns that could potentially influence driving behavior. Each individual session took approximately 2 h to complete, 1 h for survey completion and 1 h for the driving trial.

2.2. Materials

2.2.1. Demographic survey

A demographic questionnaire probed subjects for standard personal information, including (a) date of birth; (b) gender; (c) education level; and (d) socio-economic status. Additionally, participants answered questions about their driving history including: (a) frequency of driving done per week and year; and (b) make and model of the vehicle they drive most often.

2.2.2. Way-finding survey

The way-finding questionnaire was a deception tool designed to create the illusion that subjects were being studied for their map-reading and direction-following skills. This instrument asked for 'yes' versus 'no' responses regarding the participants' verbal descriptions of their own ability to read maps, follow route directions and ask for help when lost. The questionnaire included a formal map-reading exercise during which participants were required to use a standard road map obtained from an auto club and navigate a route from their present location in Virginia to Athens, GA. To enhance the illusion and increase the perceived difficulty of this exercise, an unrelated route was highlighted from the location of origin. These data were not analyzed, but were only used to maintain the illusion of a way-finding study, established originally in the health-screening interviews and informed consent documents.

2.2.3. Risk-taking inventory

The subscales measuring the personality variables theoretically related to risk-taking were presented to subjects as a Cultural Perception Survey. These items were taken directly from the published literature and assessed (a) venturesomeness (a measure of thrill-seeking adapted from Eysenck et al., 1985; Clift et al., 1993); (b) impulsivity (adapted from Eysenck et al., 1985; Clift et al., 1993); (c) hostility — Buss-Durkee Hostility Scale (Velicer et al., 1985); (d) trait anger (Spielberger et al., 1983); (e) perceptions of invulnerability (adapted from Weinstein, 1980); (f) locus of control (Nowicki and Duke, 1974); and (g) type A personality (Jenkins et al., 1971; Glass, 1977).

Items were scored as the scales were originally designed and included Likert-type, yes/no, and multiple choice formats. Instructions indicating any changes in response format were clearly marked in bold lettering throughout the document. Participants were instructed to respond to all items truthfully as they applied to themselves. The risk-taking inventory was completed after the driving trial.

2.2.4. Manipulation check

A manipulation check was presented as a 'personal perception' survey. With three open-ended questions, it asked participants to describe (a) the primary objectives of the research; and (b) what, if anything, they had learned from their participation. This survey was completed by each subject twice, immediately after the driving session and at the conclusion of the post-drive questionnaire session.

2.2.5. Smart car

All driving performance measures were collected in an instrumented vehicle whose exterior and interior are no different than any standard private vehicle. Actually, the smart car is a 1995 Oldsmobile Aurora capable of video monitoring and recording several driving behaviors simultaneously and unobtrusively. In addition to the four concealed cameras, the size of a pin head, the following computer-collected measures were available through an on-line computer (a) driver safety-belt use; (b) number of times a turn-signal was used — left, right, and emergency flashers; (c) vehicle velocity including average speed, velocity changes, and velocity variance (in mph); and (d) following distance measured in meters.

The video data included a continuous view of: (a) the driver's face and head, thereby, enabling an analysis of where the driver was looking second by second; (b) the subject's hands for analyzing position on the steering wheel and various in-vehicle activities such as manipulating radio knobs; (c) the roadway environment in front of the vehicle; and (d) the area directly behind the vehicle. Thus, the video configuration shown continuously on the video monitor allowed for unprecedented study of on-going driver behaviors, as well as the context in which the behaviors occurred. More details on the data-collection features of the smart car are presented elsewhere (Boyce and Geller, 2001).

2.3. Procedure

2.3.1. Pre-drive

As soon as participants arrived for their scheduled appointments, they were greeted by the experimenter (the senior author or a trained research assistant) and escorted to a pre-test location furnished with a table, chair, and all research materials. The experimenter checked each driver's license for expiration date, driving restrictions, and a match between the photograph on the license and the participant.

The participants read and signed informed consent documents, which explicitly described the study as an investigation of way-finding and map-reading strategies. Subsequently they received hearing and vision tests. The hearing test consisted of reading six driving-related words to the subject in a normal volume and tone. Hearing was judged normal, if the subject repeated each of the words correctly.

Vision was tested with a standard Snellen eye chart. Each participant read the chart from a marked distance of 20 ft. with both eyes. Vision was judged normal, if corrected vision was 20/40 or better.

After completing the routine health screenings, each participant completed the demographic and way-finding questionnaire, including the map exercise. Once completed, all pre-test items were collected and the driving course was described. The route description included verbal instructions, written instructions with obvious route landmarks and a simple map. The course was designed to include all possible situations that could be encountered during the course of normal driving. As such, the route included downtown, rural and highway driving. Once subjects indicated familiarity with the driving course and all their questions were answered, they were escorted to the smart car.

Once in the vehicle, the driver-side seat, steering-wheel position, and rear-view and outside mirrors were adjusted for driver comfort and safety. With the experimenter seated in the front passenger seat of the vehicle, participants were then familiarized with certain features of the car, including operation of the (a) safety belt; (b) turn signals; (c) windshield wipers; (d) automatic transmission; (e) automatic windows; (f) defoggers/defrosters; (g) parking brake; and (h) vehicle cellular phone for use in emergencies.

Participants were asked to buckle-up before leaving the research site and all complied. In addition, they were told that with a driver-side airbag, the safest way to hold the vehicle steering wheel was with both hands, the left at the 9:00 position and the right at the 3:00 position. All participants demonstrated the suggested hand position during its description. Any questions were answered and the driving trial was started once it was determined the driver was buckled, and re-confirmed being comfortable with the operation of the vehicle and the route they were to drive.

2.3.2. Driving trial

The driving course selected included downtown, rural, and highway driving. Participants left the research site and proceeded to the city's main street (a four-lane highway) by way of campus roads. Once on the main street, they proceeded through the business district through downtown and continued through the business district on the other side of town. Once out of town, they experienced approximately 2 miles of two-lane rural driving until they merged onto a four-lane divided highway, on which they proceeded 5.2 miles. This stretch of road was hilly with four tight roadway curves. Although in general the speed limit on this highway is 55 mph, cautionary speed limit changes to 35 mph occur on three curvy portions. When reaching their destination, a convenience store off the four-lane highway, subjects were instructed to turn around and retrace the route they had just driven. To initiate this return, the drivers had to negotiate a precarious left-hand turn across the four-lane divided highway.

The route covered 22.3 miles roundtrip, took approximately 45 min to complete and included five intersection turns, 30 controlled intersections, 2 miles of suburb driving, 6 miles of business/downtown driving, 4 miles of rural driving, and 10 miles of highway driving. Speed limits were 25, 35, 45, or 55 mph, and were clearly marked with obvious speed limit signs. All driving occurred in dry weather during daylight hours.

2.3.3. Post-drive

After approximately 40 min, the experimenter watched for a participant to return from a driving trial. Upon arrival, the driver was greeted by the experimenter, who asked if he or she experienced any difficulty during the course of the drive. The participant was escorted to a post-test location furnished with a conference table, chairs and all questionnaire materials. The map and driving course directions were collected and the post-test session was initiated. During this session, participants completed the manipulation check.

Participants were provided with verbal instructions to initiate the testing session, and were told not to spend too much time on any one item. Response scoring systems (i.e. Likert-type and multiple choice) were explained. Once all questions were answered, subjects were left alone to complete the questionnaire. To maintain confidentiality, no names appeared on any questionnaire document.

2.4. Data coding

All data coding sessions were conducted by trained research assistants in a quiet conference room furnished with a large table and chairs, a 27-inch television set and super VHS videotape recorder with a remote control. Data coding started as the smart car crossed an obvious stop line at the first intersection of the driving route. Two methods of analysis were employed.

2.4.1. Partial interval recording

The video record of each 45-min driving trial was analyzed for the occurrence of safe versus at-risk vehicle speed, speed variation, and in-vehicle behaviors not relevant to the driving task (off-task behaviors) during each consecutive 15-s interval of the driving trial. The percentage of intervals in which off-task behavior occurred was used as a measure of risk due to inattention.

Speed variation was measured as the occurrence versus non-occurrence of passing events during each interval. A passing event occurred when: (a) a vehicle travelling in the same direction overtook the smart car and appeared in its entirety on the video monitor; or (b) a vehicle travelling in the same direction was overtaken by the smart car and went completely out of view on the video monitor.

Vehicle speed was sampled at the start of each consecutive 15-s interval by observing the speed reading in mph that appeared on the video monitor and comparing that observation to the posted speed limit along that portion of the driving route. Speeds in excess of 5 mph over the posted speed limit were coded as at-risk.

The passage of each interval was indicated with a microcassette tape recorder and tape that announced the number of each new interval as calibrated to a digital stopwatch. Trained research assistants recorded their observations on a data sheet divided into numbered blocks representing each consecutive interval. Each block contained a space for descriptors of each target behavior category. A copy of this data sheet with detailed instructions on its use is available upon request from the first author. Specific data coding procedures are also detailed elsewhere (Boyce and Geller, 2001).

Research assistants were instructed that the interval procedure was an 'all or none' method, which facilitated the collection of multiple target behaviors. As such, multiple occurrences of a single target behavior during any one interval were not counted, unless a subsequent occurrence of a behavior represented a different sub-category of the larger category (e.g. a left-hand pass followed by a right-hand pass). Therefore, the time-sampling procedure is best characterized as a 'partial interval' approach (Kazdin, 1994).

All data coded from this interval recording procedure were converted to percent safe scores. Prior to making independent observations, all research assistants were trained to an 85% reliability criterion for each behavioral category, and a 100% criterion for identifying route speed limits.

2.4.2. Discrete event recording

Following distance was recorded as a discrete event in a safe behavior opportunity (SBO) approach (Geller et al., 1989). That is, a SBO occurred each time the smart car started to follow a different car. Each event was coded from the videotape of each participant's driving trial and matched by video frame number to the computer-recorded speed and distance measures. Following events were determined to begin when: (a) a car was in front of the smart car in the same lane; (b) the car was no more than 5 s in front of the smart car; and (c) the smart car was traveling at least 20 mph.

The criterion of 5 s was determined by having observers select the first available roadway landmark and counting the number of video frames that passed from the time the back bumper of the preceding vehicle passed the landmark until the time, the front bumper of the smart car passed the same landmark (Evans, 1991; Heino et al., 1996). Each video frame was clearly visible on the video monitor and corresponded to one-tenth of 1 s in time.

Following events were defined as ending when (a) the smart car changed lanes; (b) the car being followed turned or changed lanes; (c) another vehicle entered in between the vehicle that initiated the following event and the smart car; (d) the smart car was held up at a stop light while the preceding vehicle made it through; or (e) the preceding vehicle was too far in front of the smart car to be clearly seen on the video monitor. To enable reliability checks, the video frame number indicating the start and end of each following event was recorded on a data collection sheet by two trained research assistants.

Average following distances (converted to a time measure) of less than 2 s were coded as at-risk. For each event, the time conversion was made by assessing the ratio of following distance measured in meters and speed measured in mph and comparing it to a minimum criterion of 0.9. Nine-tenths of a meter reflected 2 s of headway per mph. The mean following distance for the entire driving trial and mean speed was also recorded.

All following event data corresponding with speeds of less than 20 mph, or when no following distance was recorded by the smart car were eliminated from further analysis. This prevented a potential bias in the data created by the context of downtown driving, especially observations recorded when the smart car was routinely stopped behind other vehicles at an intersection or due to traffic. The percentage of following events during which the driving subject maintained a minimum 2-s following distance was used as the dependent measure (i.e. percent safe).

Turn-signal use was also summarized with a SBO approach. Specifically, trained observers recorded, on a coding sheet, the video frame numbers corresponding to the start of an intersection turn or lane change, the type of event and its direction. The criterion used to determine the start of the SBO was the point at which the driver had committed the experimental vehicle to turn or change lane position (e.g. movement of the car to the centerline when changing lanes). Videos could be reviewed such that only legitimate turns and lane changes were recorded. All observers were trained to a criterion of 85% reliability for determining the start of a SBO for turn-signal use.

Turn-signal SBOs were matched frame-by-frame to the computer record of driving performance in which left and right turn-signal use, emergency-flasher use, or no-signal use were coded automatically by the smart car. If the correct signal was used within 25 frames of the number recorded during video observations (within 2.5 s of the point determined to initiate the event), the event was coded as safe. Thus, the percentage of turns and lane changes preceded by a turn signal was used as the dependent measure. A copy of the check sheet used for coding turn-signal use and following distance is available upon request from the first author. Procedures are also detailed elsewhere (Boyce and Geller, 2001).

2.4.3. Assessing interobserver agreement

To assess the reliability of data obtained with the partial-interval approach, data coding was performed independently by two observers during the same session, and interobserver agreement evaluated on an interval-by-interval basis (Kazdin, 1994). We divided the number of intervals in which both observers scored the occurrence or non-occurrence of a certain behavior (agreements) and divided this total by the number of agreements plus disagreements (the number of intervals in which one observer scored the behavioral occurrence and the other did not) and multiplying by 100%. This procedure was performed separately for each of the time-sampled behaviors: speed, speed variation and off-task behaviors.

Following distance and turn-signal data were also coded in pairs. Reliability for following distance and turn signal use was assessed by having videos viewed a second time by a different pair of trained observers. The data coded during the second viewing were compared frame by frame with data coded during the first viewing. An agreement was scored for a SBO for turn-signal use if: (a) the two events matched within 25 frames; (b) the direction of the event (left vs. right) was in agreement; and (c) the type of event corresponded (lane change vs. intersection turn).

Following events were scored for agreement that the same event was observed based on beginning and ending frame numbers recorded independently by each pair of observers. Duration reliability was assessed by dividing the shorter duration recorded by the longer duration recorded and adding the fractions obtained for each following event recorded. The sum was divided by the total number of events recorded by both sets of observers and multiplying by 100%.

3. Results

3.1. Interobserver reliability

Independent observations were made on 43% of the 61 interval-recording sessions. Interobserver agreement was 93% for vehicle speed, 95% for speed variation and 91% for off-task behaviors. Independent observations were made on 30% of the 60 discrete event recording sessions (all of the sessions for which these data were available). Agreement was 87% for turn-signal use and 85% for the occurrence of following events. Interobserver agreement for duration of following events was 87%. The majority of the discrepancies for duration of a following event occurred as a result of observers recording the start of an event at different points.

3.1.1. Manipulation check

Results from the manipulation check revealed that 95% (58) of the 61 participants described the study as a test of direction-following and map-reading abilities. The three remaining subjects indicated they were unsure of the true purpose of the research.

3.1.2. Overall analysis

The effects of age and gender on the five primary dependent measures (speeding, speed variation, off-task behaviors, turn-signal use and following distance) were analyzed with multivariate analysis of variance (MANOVA) procedures with gender (male vs. female) and age (younger, middle-aged, older) as the between-subject factors. All dependent measures were calculated as a percent safe score based on observations from the interval or event recording procedures on 60 subjects. Data from one female in the younger group were eliminated from this analysis because a failure of the in-vehicle computer during her driving trial prevented the measurement of her turn-signal use and following distances.

Multivariate Hotelling–Lawley's trace statistic yielded an overall significant main effect for age, $F(10, 98) = 1.42$, $P < 0.001$. Overall, younger drivers drove more at-risk than middle-aged and older drivers and middle-aged drivers drove more at-risk than older drivers. Each dependent measure is discussed below. No other effects were significant at the 0.05 level.

3.1.3. Speeding

Univariate results indicated a significant age effect for speeding, $F(2, 54) = 17.71$, $P < 0.001$. Fisher's LSD revealed that older drivers (90% safe) maintained a safe vehicle speed significantly more often than younger drivers (62% safe) and middle-aged drivers (81% safe), who were also significantly more safe than younger drivers, $P < 0.05$. In general, men and women were observed speeding equally often. The percent safe

Table 1
Means and standard deviations (S.D.) of percent safe scores for the five target behaviors and measures of mean speed and following distance

Target behavior	Younger		Middle-aged		Older	
	Males ($n = 10$)	Females ($n = 12$)	Males ($n = 10$)	Females ($n = 12$)	Males ($n = 9$)	Females ($n = 7$)
Speeding[a]	$M = 58.5$ S.D. = 14.3	$M = 66.1$ S.D. = 16.9	$M = 83.1$ S.D. = 15.3	$M = 78.8$ S.D. = 20.2	$M = 91.4$ S.D. = 3.5	$M = 90.0$ S.D. = 6.4
Speed variation[a]	$M = 81.8$ S.D. = 4.9	$M = 86.1$ S.D. = 4.4	$M = 84.6$ S.D. = 4.4	$M = 85.3$ S.D. = 6.3	$M = 86.7$ S.D. = 5.3	$M = 82.6$ S.D. = 7.5
On-task behavior[a]	$M = 70.6$ S.D. = 20.3	$M = 60.8$ S.D. = 22.6	$M = 79.4$ S.D. = 11.1	$M = 75.9$ S.D. = 18.1	$M = 84.2$ S.D. = 8.8	$M = 91.1$ S.D. = 6.9
Turn-signal use[a]	$M = 89.7$ S.D. = 9.7	$M = 92.2$ S.D. = 9.5	$M = 79.3$ S.D. = 23.4	$M = 82.8$ S.D. = 22.4	$M = 72.3$ S.D. = 23.1	$M = 87.6$ S.D. = 10.9
Following distance[a]	$M = 53.2$ S.D. = 25.2	$M = 43.9$ S.D. = 23.5	$M = 71.5$ S.D. = 26.5	$M = 61.7$ S.D. = 19.8	$M = 85.7$ S.D. = 8.7	$M = 78.4$ S.D. = 22.5
Mean speed in mph	$M = 38.4$ S.D. = 1.8	$M = 38.0$ S.D. = 1.9	$M = 36.1$ S.D. = 2.6	$M = 37.4$ S.D. = 2.2	$M = 34.0$ S.D. = 2.0	$M = 34.7$ S.D. = 2.1
Mean following Distance in meters	$M = 36.0$ S.D. = 5.7	$M = 33.0$ S.D. = 4.5	$M = 39.9$ S.D. = 7.4	$M = 37.9$ S.D. = 5.2	$M = 43.0$ S.D. = 4.3	$M = 43.5$ S.D. = 10.6

[a] Score reported as percent safe, M = mean, S.D. = standard deviation.

scores for speeding, organized by age and gender, are presented in Table 1.

The percent safe scores for speeding were also analyzed by dividing the roundtrip driving session into two halves: the drive from versus the drive back to the research site. Repeated measures ANOVA revealed a significant main effect for section of the driving session, $F(1, 55) = 20.28$, $P < 0.01$ and a Section by age interaction, $F(2, 55) = 10.78$, $P < 0.01$. Fisher's LSD indicated that subjects maintained a safe vehicle speed more often during the first half of their drives (81% safe) than the second half (74% safe), $P < 0.05$. Additionally, simple effects tests revealed that younger subjects exhibited the greater decrease in maintaining a safe vehicle speed during the second half of the drive (69 vs. 53% safe) than middle-aged drivers (83 vs. 79% safe) and older drivers (91% safe during both halves). Measures of mean speed for each half of the driving trial are depicted per each age group in Fig. 1.

3.1.4. Following distance

Univariate results indicated a significant age effect for the percentage of following events that drivers maintained at least 2 s of time between the smart car and a preceding vehicle, $F(2, 54) = 10.86$, $P < 0.001$. Specifically, LSD procedures revealed that older drivers (82% safe) maintained a safe following distance more often than younger drivers (49% safe) and middle-aged drivers (67% safe), who were also more safe than younger drivers, $P < 0.05$. Additionally, although not statistically significant ($P < 0.10$), when collapsed across age, males (70% safe) followed a minimum of 2 s behind the car in front of them more frequently than females (59% safe).

Finally, repeated measures ANOVA performed on following distance in meters revealed that all drivers (for which data could be divided, $n = 57$) followed more closely during the second half of their driving sessions than during the first half, $F(1, 51) = 6.06$, $P < 0.05$. Although not statistically significant, this difference was most pronounced for younger drivers (15 vs. 11 m) than middle-aged (13.6 vs. 12.6 m) or older drivers (15.2 vs. 14.7 m), and thus resembled the findings for vehicle speed. The percent safe scores for following distance, organized by age and gender, are presented in Table 1. Fig. 2 depicts a plot of mean following distance for each half of the driving trial per each age group.

3.1.5. Off-task behavior

Univariate results indicated a significant age effect for the occurrence of off-task behaviors, $F(2, 54) = 8.20$, $P < 0.01$. Specifically, LSD procedures showed that older drivers (88% safe) and middle-aged drivers

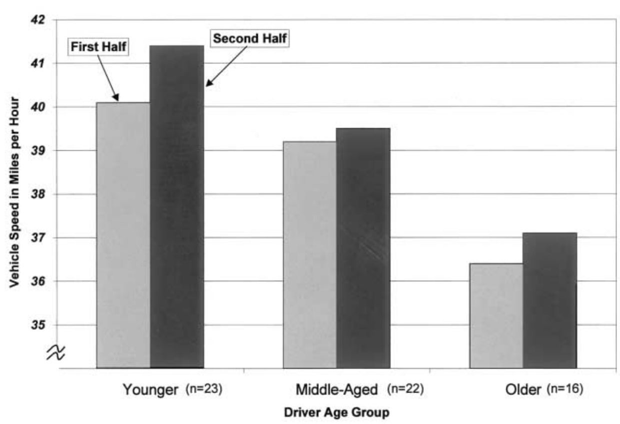

Fig. 1. Mean speeds per age group for first and second half of route.

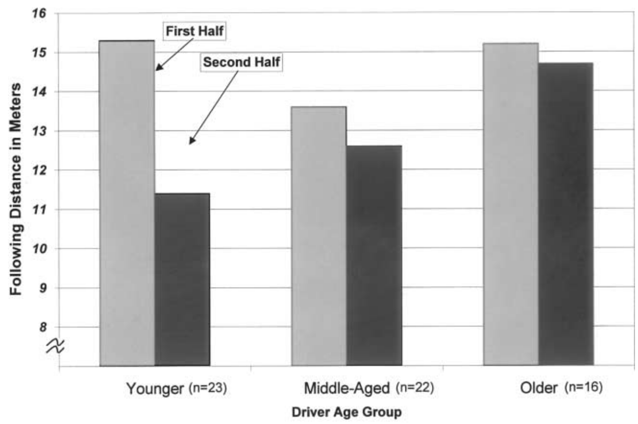

Fig. 2. Mean following distances per age group for first and second half of route.

(78% safe) were significantly safer than younger drivers (66% safe), $P < 0.05$, but did not differ significantly from each other with regard to the amount of off-task behavior they exhibited during the driving trial, $P > 0.05$. The only gender difference was that young females (61% safe) exhibited substantially more off-task behaviors than their male counterparts (71% safe), $P < 0.10$. There were no differences in off-task behavior as a function of first versus second half of the drive, $P > 0.50$. The percent safe scores for off-task behavior, organized by age and gender, are presented in Table 1. Fig. 3 depicts the relationship of off-task behavior with turn-signal use for each age group.

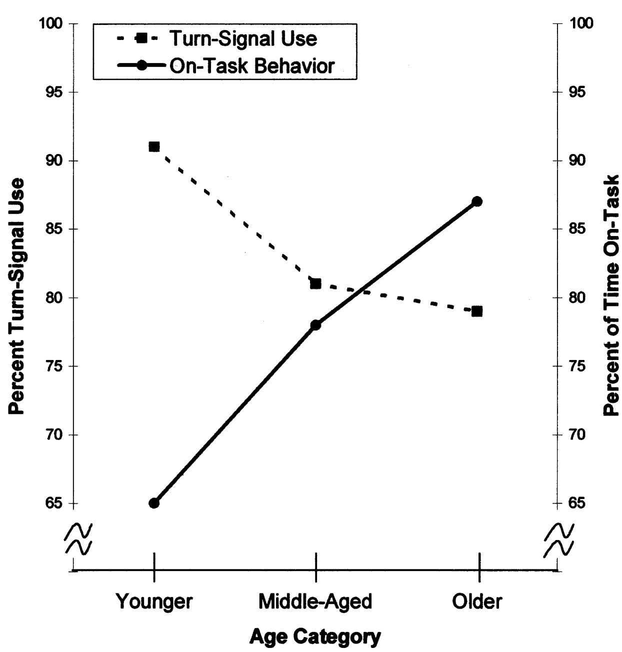

Fig. 3. Relationship between off-task behavior and turn-signal use per age group.

3.1.6. Turn-signal use

Univariate results indicated that the effect of age on the proportion of times a turn-signal was used per opportunity approached significance, $F(2, 54) = 2.42$, $P < 0.10$. Although not statistically significant, LSD procedures revealed that younger drivers (91% safe) used their turn-signal more than middle-aged (81% safe) or older drivers (80% safe), $P < 0.10$, who did not differ from each other, $P > 0.80$. Due to the differential opportunity to use turn signals during each half of the drive, no comparisons between first and second halves of the drive were made with respect to turn-signal use. The percent safe scores for turn-signal use, organized by age and gender, are given in Table 1. Fig. 3 depicts the relationship between turn-signal use and off-task behavior for each age group.

3.1.7. Speed variation

No significant gender or age differences were obtained in speed variation operationalized as the occurrence of passing events observed during the partial interval recording procedure. This result held true for the passing behavior overall (experimental participants and other drivers passing the experimental participant), and for the passing behavior of just experimental participants evaluated alone.

3.2. Defining clusters of at-risk driving behaviors

Since driver risk-taking can vary on different dimensions, the behaviors coded from video recordings were subjected to an exploratory factor analysis to define categories of at-risk driving performance. Specifically, a maximum likelihood factor extraction was performed on the five primary dependent measures converted to percent safe scores. The maximum likelihood extraction with a varimax rotation extracted two factors. Inspection of the rotated correlation matrix revealed that speeding, off-task behavior, and following distance loaded significantly onto Factor 1 accounting for 36.6% of the variance in driving, while turn-signal use loaded significantly onto Factor 2, accounting for an additional 5.3% of the variance. Only variables with loadings of 0.40 or higher with these two factors were retained. Table 2 shows the zero-order correlations observed among the five measures of safe driving.

3.3. Predicting driving style

Statistical regression procedures were used to study relationships between individual differences and the various objective measures of at-risk driving. A summary of significant results from planned stepwise multiple regression procedures performed on the entire sample of drivers is presented in Table 3 and described below.

Table 2
Simple correlations among observed driving measures

%Safe	Speed	Following	On-task	Passing	Signal use
Speed	1.0				
Following	0.73[a]	1.0			
On-task	0.41[a]	0.43[a]	1.0		
Passing	0.28[b]	0.25[b]	0.15	1.0	
Signal use	0.12	−0.004	−0.02	0.06	1.0

[a] $P<0.01$.
[b] $P<0.05$.

3.3.1. Speeding

When all predictors were entered into the regression equation in a stepwise fashion, age entered significantly, $P<0.001$, accounting for 38% of the variance. Specifically, age correlated positively with percent safe speed, $r=0.61$, $P<0.01$. With regard to overall mean driving speed per trial, age and type A were significant predictors in the stepwise regression, $P<0.05$. Age correlated negatively with mean speed ($r=-0.59$, $P<0.01$), whereas type A was correlated positively with mean speed ($r=0.33$, $P<0.01$). The model age plus type A accounted for 42% of the total variance in mean vehicle speed.

3.3.2. Following distance

Only age correlated significantly with percent safe following distance ($r=0.54$, $P<0.01$) indicating that older drivers followed at safe distances more often than younger drivers. Regarding mean following distance when the experimental vehicle was traveling at least 20 mph, age and type A were significant predictors, $P<0.05$. Age correlated positively with mean following distance ($r=0.50$) and accounted for 25% of the variance. In contrast, type A correlated negatively with mean following distance ($r=-0.30$) and accounted for an additional 6% of the variance.

3.3.3. Off-task behaviors

When all predictors were entered into the regression equation in a stepwise fashion, age entered significantly ($P<0.05$) accounting for 24% of the total sample variance. More off-task behavior was exhibited as the driving group got younger, $r=-0.48$, $P<0.05$.

3.3.4. Turn-signal use

Only age was significantly correlated with percent safe turn-signal use ($r=-0.28$, $P<0.05$) accounting for 8% of the variance in turn-signal use. This indicated that younger drivers used their turn-signals more often than older drivers.

3.3.5. Speed variation

Vehicle passing events were broken down into occurrences of the experimental subject passing other vehicles versus being passed, and a stepwise regression analysis was run on each measure.

Age entered the regression equation significantly, $P<0.01$, and accounted for 15% of the variance in the drivers' passing behavior. Perceptions of invulnerability also entered significantly, $P<0.05$, and accounted for an additional 6% of the variance. Thus, age plus invulnerability accounted for 21% of the total variance in the number of times experimental subjects passed another vehicle. Frequency of passing correlated negatively with both age, $r=-0.39$, $P<0.01$ and perceptions of invulnerability, $r=-0.25$, $P<0.05$.

Similar analyses were performed on the occurrence of other cars passing the experimental vehicle. Both locus of control and perception of invulnerability interacted significantly with age, $P<0.05$, accounting for 6 and 5% of the variance, respectively. Thus, the sample was split by the age categories, and procedures were performed on each subsample of data to determine the influence of locus of control and perceptions of invulnerability on each. This analysis revealed locus of control (31% of the variance) and perceptions of

Table 3
Planned stepwise regression of demographics and personality variables on the primary measures of at-risk driving

Predictors	R	R^2	AR^2	r
Speeding				
Age	0.61	0.38	0.38	0.61
Mean speed				
Age	0.59	0.35	0.35	−0.59
Type A	0.65	0.42	0.07	0.33
Speed variation	–	–	–	–
Speed variation-use				
Age	0.39	0.15	0.15	0.39
Invulnerability	0.46	0.21	0.06	0.25
Extraneous behavior				
Age	0.48	0.24	0.24	0.48
Turn-signal use				
Age	0.28	0.08	0.08	−0.28
Following distance				
Age	0.54	0.29	0.29	0.54
Mean following distance				
Age	0.50	0.25	0.25	0.50
Type A	0.56	0.31	0.06	−0.30

invulnerability (22% of the variance) entered the regression equation significantly for only older drivers, $P < 0.05$. For this analysis, locus of control plus perceptions of invulnerability accounted for 54% of the total variance in the number of times older drivers were passed by another vehicle during their driving trials. Both locus of control and perceptions of invulnerability were negatively correlated with percent safe passing (being passed less often) for older drivers ($r = -0.56$ and -0.34, respectively, $P < 0.05$). In other words, older drivers exhibiting an external locus of control and higher perceptions of invulnerability were passed more often than the older drivers exhibiting tendencies for an internal locus of control and lower perceptions of invulnerability.

4. Discussion

The primary aim of this research was to unobtrusively examine relationships among several driving behaviors, as had not earlier been done. As expected, age was significantly related to several at-risk driving behaviors, and type A personality was a significant predictor of speeding and close following. However, contrary to the earlier research, robust gender differences were not found. Finally, results suggested that speeding, close following and time spent emitting behaviors unrelated to driving correlate significantly with one another. This latter result provides evidence for a response class of driving behaviors, a necessary condition for response generalization (Bandura, 1969). In the context of at-risk driving, response generalization can be viewed as a more general and standard term for problem behavior syndrome (Jessor, 1987; Jonah, 1997).

4.1. Implications for safe driving intervention

In the current study, driving behavior was assessed with a computer and continuous video recordings of an entire driving trial in the context of normal traffic. Participants drove alone, with instructions that they obey all traffic laws during the course of their driving session. As such, confounds of reactivity typically associated with the presence of an in-vehicle observer and response artifacts plaguing self-reports of driving were avoided. Since it was possible to code continuous video records reliably, this research presented an unprecedented opportunity to unobtrusively observe multiple driving behaviors, as they occurred in real time.

It is presumed that phenomena such as danger compensation (Peltzman, 1975; Wilde, 1994) versus response generalization (Bandura, 1969; Falk, 1971) operate as a function of the extent to which behaviors covary in a negative or positive direction, respectively. Furthermore, it is claimed that such knowledge may have great implications for selecting the target behaviors on which to intervene, and that this knowledge may help to increase the ecological validity of behavior change intervention (Ludwig and Geller, 1991, 1997). Thus, it becomes instructive to assess how driving behaviors covary with one another.

The factor analysis revealed that speeding, following distance and off-task behaviors loaded significantly onto one factor, while turn-signal use appeared as a separate factor. Additionally, inspection of zero-order correlations indicated that the most robust positive relationships existed between maintaining a safe vehicle speed, percent safe scores for off-task behaviors and maintaining a safe distance behind the vehicle in front.

These results have both practical and theoretical implications. Theoretically, these findings offer support for the concept of a problem behavior syndrome within the context of driving (Jessor, 1987; Jonah and Dawson, 1987). That is, it can be concluded that if drivers exhibit one of these at-risk driving behaviors, they are more likely to exhibit others. From a practical perspective, it can be speculated that intervening to increase the occurrence of one behavior in this class, for example maintaining safe vehicle speed, will have concomitant desirable effects on the other behaviors. This is predicted by response generalization theory, and has been demonstrated in intervention research targeting safety-related behavior (e.g. Ludwig and Geller, 1991; Streff et al., 1993; Ludwig and Geller, 1997).

The cluster of behaviors appears to 'impose' the presence of the smart car on other traffic, either by dictating travel speed through velocity, or minimizing physical boundaries between vehicles as when following too closely. Thus, these behaviors all appear to be linked by changing the driving environment in a manner that could be described as 'aggressive' or 'impatient'. As a result, the related behaviors can be described as socially acceptable ways of acting out with anonymity and only a minimum probability of receiving aversive consequences (a traffic crash or driving fine). Consequently, it could be claimed that the correlated behaviors are united in that they all reflect calculated risk-taking motivated by reaching a destination more quickly or efficiently.

As suggested by response generalization theory, the present results indicate that the focus of driving interventions should be a single target behavior such as speeding, which anchors a response class of 'aggressive' driving. Such a focus could increase the practicality, cost effectiveness and social validity of driver training programs and court-ordered remedial driving classes for drivers convicted of traffic violations. More specifically, results suggest that if one can increase the proportion of times a driver follows the speed limit, they may also maintain safer following distances, increase the amount of time spent on-task, and as a result reduce the probability of a vehicle crash. This is precisely what was reported by Ludwig and Geller (1997) who found that a goal-setting and feedback intervention targeting intersection stops also had a beneficial impact on safety-belt use and turn-signal use when participants were involved in designing and implementing the intervention. This is intuitive because intervening to change the context of driving to reduce problem behaviors that are directly related to one another, as one problem behavior changes so should the others, and in the same direction. This phenomenon follows from the presumption that the observed behaviors are being controlled by the same environmental contingencies.

4.2. Age differences

As predicted, younger drivers drove more at-risk than middle-aged or older drivers. Furthermore, within-group analyses of the driving trial divided into two halves revealed that younger participants drove significantly faster during the second half of their drive, and followed the car in front of them substantially closer. Thus, it seems the younger drivers habituated to the driving environment more quickly than older drivers.

Younger drivers were more at-risk on each behavior measured except turn-signal use. When broken down to lane changes, and right versus left turns, the age difference in turn-signal use manifested itself equally often for all turning events. That is, younger drivers used their turn-signals during each of these events approximately 90% of the time, whereas middle-aged and older drivers signaled on these occasions less than 80% of the time. Finally, older drivers were least likely to use their turn signals when changing lanes (75%).

Turn-signal use, currently defined as a means of signaling one's driving intentions, was important only in the presence of other traffic. Less turn-signal use by older drivers could be an indication that for them, turn signals were used only in traffic and for younger drivers was a habit. Perhaps these differences reflect different driving histories. Since our measure of turn-signal use did not include traffic presence as a variable, we could not evaluate the behavior as occurring habitually (regardless of traffic) versus intentionally (only when another driver could benefit from the communication).

While the result indicating younger drivers use their turn signal more often than older drivers is encouraging, younger drivers spent more time off-task than middle-aged or older drivers. The low percentage of time younger drivers attended specifically to the driving task exacerbates the risk created by their faster driving and closer following. This suggests that time spent on task when driving may be a behavior worthy of special intervention. Geller (1996) has discussed how safety is a fight against human nature because of the naturally reinforcing consequences following at-risk alternatives. The amount of off-task behavior exhibited by drivers does not seem to provide the traditional reinforcers such as fun or arriving at your destination more quickly (as when speeding) and, therefore, may be particularly amenable to behavioral intervention.

That drivers take fewer risks on the road as they get older is the most robust and common individual-difference finding in the research literature on driving safety (Evans, 1991; Elander et al., 1993). In fact, Elander et al. report that crash involvement is a negatively decelerating curve when plotted against age. They concluded that 17-year-old drivers have a 50% greater probability of a crash than do 25 year olds, who in turn have a 35% greater probability than 50 year olds. The present results support these data, as high speeds and close following distances are good predictors of vehicle crashes (Evans, 1991).

To explain age differences in driving behavior, Jonah and Dawson (1987) reported that younger drivers perceive less risk in most driving situations than older drivers. Additionally, it has been suggested that older drivers take a longer time to get accustomed to novel driving situations (Evans, 1991), and thus as argued earlier, younger drivers habituate more quickly. This concept was manifested in the current behavioral data by greater decreases in safe driving during the second half of the driving session by younger drivers than older or middle-aged drivers.

4.3. Gender differences in driving behavior

It has been shown consistently that males report more risky driving than females. This was demonstrated by Wilson (1990) for safety-belt use, and by Arnett (1996) for speeding, illegal passes and DWI. Moreover, Evans (1991) documented the overrepresentation of males in national vehicle crash statistics and Jonah (1990) reported more pronounced age differences in driving risk for males than females. These findings were supported in the review by Elander et al. (1993), who concluded that after controlling for driving exposure, females were less likely to be involved in a vehicle crash than males, and this gender difference was greatest among young and inexperienced drivers. While such findings are common, the results of the present research do not support these conclusions nor the hypothesis that males, in general, take more risks on the road than females (Jessor, 1987; Elander et al., 1993). Although it is possible that characteristics of our sample, or the operational definitions of our dependent measures precluded gender differences from being observed in the current context, it could also be argued that gender differences obtained in earlier studies are artifacts of measurement error.

The gender data reported in earlier studies of driving performance were usually obtained from self-report surveys. That is, subjects in these studies typically expressed, in writing, the frequency they engaged in specific at-risk driving behaviors such as speeding and following too close. For example, the Driving Behavior Questionnaire (Burns and Wilde, 1995) is a measurement tool commonly used to assess driving behavior. As such, certain response artifacts could have contributed to significant measurement error (Arthur and Graziano, 1996; Lajunen et al., 1997).

More specifically, it is possible that prior findings associating females with less risk when driving resulted from a greater social desirability bias among females than males. In other words, males are more willing to admit to their at-risk driving behavior. For example in their review of individual differences related to vehicle crash risk, Elander et al. (1993) reported that males consistently expressed a greater willingness to commit driving violations than females. Regardless, the present behavioral data showed that males and females in three different age groups drive with relatively the same degree of risk.

4.4. The interaction of personality variables and demographics

The literature has shown reliable positive relationships between driving risk and (a) sensation seeking (Furnham and Saipe, 1993; Burns and Wilde, 1995; Arnett, 1996; Jonah, 1997); (b) aggressiveness (Arnett, 1996; Arthur and Graziano, 1996); (c) impulsivity (Wilson, 1990; Stanford et al., 1996); (d) external locus of control (Nowicki and Strickland, 1973); and (e) patterns of other psychosocial influences associated with problem behavior (Jessor, 1987). Unfortunately, the relationships between these individual differences and the at-risk driving assessed in the current research were not so clear. Since the majority of earlier research relied on self-report or archival data to measure driving (i.e. the criterion), inconsistencies between prior and current findings could be an artifact of measurement methodology.

It was certainly surprising that relationships between the venturesomeness construct and risky driving were not obtained, given the robust relationships between SSS and at-risk driving reported in the literature (e.g. Jonah, 1997). The venturesomeness scale is an abbreviated version of the thrill-seeking subscale of Zuckerman's SSS, which has shown strong relationships with risky driving (e.g. Jonah, 1997). The use of venturesomeness, instead of the entire SSS may be construed as a limitation of the current investigation and may account for our failure to replicate this generally robust finding. On the other hand, it is also possible that the absence of such relationships are due to the composition of our sample or with different measurement methodology. Future research using the objective measures described here will reveal the answer to this question.

With the objective driving criteria used in the present research, only the type A dimension was a significant predictor of risky driving (i.e. mean speed and mean following distance). However, the positive correlation with mean speed was modest, accounting for only 7% of the sample variance above the age variable which entered the regression equation first. That people exhibiting type A characteristics drove relatively fast is no surprise. This is consistent with the profile of the type A personality, who is impatient and competitive (Spence et al., 1987). In fact, the items on the survey used to assess type A probed specifically for a preference for a fast-paced lifestyle (Spence et al., 1987). Although we are not aware of another direct demonstration of a relationship between type A and driving, the present results appear to support prior correlations between the impatience and achievement strivings components of type A and 'at-risk' lifestyle choices and behaviors (Spence et al., 1987). Type A as a predictor of aggressive driving styles is clearly worthy of further research.

5. Conclusion

The present research provides the first objective evidence for a relationship among several driving behaviors including vehicle speed, vehicle following distance, and various off-task behavior that clustered into a response class of behaviors that increase risk for a vehicle crash. This supports a major presumption of response generalization theory.

The dependent measures were obtained without the confounds associated with assessing driving behavior via self-report, archival data, or an in-vehicle observer. The typical age effect shown with survey data was replicated with the innovative technology used here, but the standard gender effect was not. It is noteworthy that type A personality was a significant predictor of speeding and close following. Evidence that younger drivers habituate to the driving environment more quickly than older drivers was also presented. Finally, it was claimed that this information may be used to design more effective interventions to increase safe driving, especially among younger males and females before a problem behavior syndrome develops.

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