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# Estimates of Driving Abilities and Skills in Different Conditions

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Key Words: aged • brain damage, chronic • evaluation process, occupational therapy

*Objectives.* This research was a preliminary effort to determine whether various driving situations seemed to require different driving skills and abilities and to identify the relative demands of specific physical, perceptual, cognitive, behavioral, and operational skills and abilities in different driving situations.

*Method.* Experienced driver evaluators and trainers estimated the magnitude of driving abilities and skills for different photographed driving situations. Pictures of driving scenarios were counterbalanced for road type, traffic condition, and weather condition.

*Results.* A multifactorial analysis of variance of the total score for each scenario revealed significant main effects for road type and traffic condition but not for weather condition. Highway and city driving were rated as significantly more demanding overall than residential driving, but no difference was found between city and highway driving. Estimates of the overall demands for driving in heavy traffic were significantly greater than in light traffic. However, driving in inclement weather was not regarded as significantly more demanding than driving in sunny weather. Additionally, significant interaction effects were found for road type by weather condition and traffic by weather condition but not for road type by traffic condition.

Through multivariate methods to evaluate the significance of individual abilities and skills across conditions, significant main and interactive effects were found for road type, traffic condition, and weather condition. Post hoc analyses showed the impact of these effects on such abilities and skills as scanning, attention and concentration, information-processing speed, and others.

*Conclusion.* Evaluators' quantified estimates of driving demands showed driving as a complex task that (a) requires high levels of abilities and skills in all situations; (b) demands greater abilities in some situations than in others; and (c) involves different kinds and various degrees of abilities and skills, depending on the demand characteristics of the situation.

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Rehabilitationists, particularly occupational therapists, are increasingly called on to evaluate the driving ability of persons whose skills are suspect because of cerebral injury (i.e., traumatic brain injury, stroke), cardiovascular and other medical conditions, progressive brain disorders (i.e., Alzheimer's disease), and medical frailty due to advancing age. Most of these persons want to drive for as long as possible to preserve their independence; access to employment and social activities; and self-esteem, which is provided, in part, by mobility in the community. However, many have residual or sequelae of their condition that can adversely affect safe motor

vehicle operation and increase risk of injuries to themselves or others. The desire to simultaneously ensure the safety of all drivers on the road and support the driving privileges of persons with disabilities who are qualified drivers have placed great emphasis on identifying factors that can compromise behind-the-wheel driving (Avolio, Kroeck, & Panek, 1985).

One line of research has specifically focused on identifying deficits in drivers' physical, perceptual, cognitive, and psychological abilities and skills that cause human errors in driving and jeopardize driving safety (Owsley, Ball, Sloane, Roenker, & Bruni, 1991; Porvin, Guibert, & Loiselle, 1993; Shinar, McDonald, & Treat, 1978; Smith & Kirkham, 1982; van Zomeren, Brouwer, & Minderhoud, 1987). For example, many studies have demonstrated a relationship between driver performance and

- *sensory deficiencies*, for example, defects in visual and auditory acuity, glare and contrast sensitivity, motion perception, and visual field perception (Evans & Ginsburg, 1985; Hills, 1980; Johnson & Keltner, 1983; Owsley et al., 1991; Shinar, 1977; Staplin, Breton, Haimo, Farber, & Byrnes, 1987; Staplin & Lyles, 1992);
- *motoric difficulties*, for example, loss of or reduction in strength, coordination, and reaction speed (Ball & Owsley, 1991; Marottoli & Drickamer, 1993; Stelmach & Nahom, 1992);
- *cognitive impairments*, for example, problems in attention, scanning, information-processing speed, visuospatial perception, and decision making (Avolio et al., 1985; Beattie, Tuokko, & Tallman, 1993; Cerella, 1985; Galski, Bruno, & Ehle, 1992, 1993; Galski, Ehle, & Bruno, 1990; Jones, Giddens, & Croft, 1983; Mihal & Barrett, 1976; Odenheimer, Beaudet, & Grande, 1991; Shinar, 1993; Sivak, Olson, Kewman, Won, & Henson, 1981; Stelmach & Nahom, 1992); and
- *personality or behavioral disturbances*, for example, accident-proneness, anxiety, and impulsivity (Galski et al., 1992, 1993; Shaw, 1971).

Another line of research has centered around the situational determinants of accidents, such as the effects of road designs and highway surfaces. Results of this research have shown that accidents tend to occur in

- specific *locations*, for example, intersections (Ball & Owsley, 1991);
- under certain *conditions*, for example, glare (Evans & Ginsburg, 1985); and
- during certain *operations*, for example, left turning and right-of-way decisions (Gebers, Romanowicz, & McKenzie, 1993; Staplin & Fisk, 1991; Staplin

& Lyles, 1992; Zador, Stein, Shapiro, & Tannoff, 1985).

Generally, findings from these studies suggest that accidents are not a homogenous group of events (Barmack & Payne, 1961; Smith & Kirkham, 1982), and, therefore, the context in which a driver operates the vehicle is an important determinant of driving safety.

Although efforts to understand the variables that affect driving safety have tended to focus on personal and situational factors separately, the complex interaction of both human (personal) and situational (contextual) factors may also affect safety. Therefore, it may be worthwhile to explore how drivers who possess varying degrees of driving skills and abilities might make errors in meeting the demands of specific situations, each of which requires different degrees of these skills and abilities. Although human factors researchers recognize that there are subtle interactions between drivers and their environment (Waller, 1992)—and there is some evidence that even slight increases in driving task demands can significantly increase accidents (e.g., speeding up signal changes) (Zador et al., 1985)—a need still exists to explore the nature of the person–situation interaction in driving.

This research was designed to determine, in the view of experts, (a) whether various driving situations seem to require different driving skills and abilities and (b) whether experts can identify the relative demands of specific perceptual, cognitive, psychological–behavioral, and operational skills and abilities in different driving situations. Results were expected to lead to improvement in the accuracy of driver evaluations and the relevance of recommendations about driving.

## Method

### *Participants*

One hundred twenty-five driver evaluators and trainers were randomly selected from a nationwide roster (Transportation Research Board/National Research Council, 1994) and asked to participate in the study. All were occupational therapists or trainers who currently or historically worked in rehabilitation settings. Of 101 professionals who agreed to participate, approximately 62% ( $n = 63$ ) completed and returned study material; another 7% ( $n = 7$ ) returned material too late for inclusion in the data analysis. The 63 participants averaged  $7.52 \pm 6.47$  years of experience (range = .25–29.00 years).

### *Materials and Procedure*

Photographs of various driving scenarios were prepared for this study by covarying three factors: road type (i.e., highway, city, residential), traffic condition (i.e., heavy, light), and weather condition (i.e., sunny, inclement).

Twelve representative 5-in.  $\times$  7-in. pictures resulted from the following combination of factors: (a) highway-heavy traffic-sunny weather, (b) highway-heavy traffic-inclement weather, (c) highway-light traffic-sunny weather, (d) highway-light traffic-inclement weather, (e) city-heavy traffic-sunny weather, (f) city-heavy traffic-inclement weather, (g) city-light traffic-sunny weather, (h) city-light traffic-inclement weather, (i) residential-heavy traffic-sunny weather, (j) residential-heavy traffic-inclement weather, (k) residential-light traffic-sunny weather, and (l) residential-light traffic-inclement weather. The photograph sets were collated for distribution without variation in order of presentation.

Each photograph was affixed to the upper portion of a portrait-oriented 8.5-in.  $\times$  14.0-in. sheet of paper. Rating scales for the physical, perceptual, cognitive, and behavioral dimensions were printed below each photograph for ease of use by participants. Participants were asked to estimate the magnitude of the abilities and skills required for safe driving in each pictured driving scenario; a seven-point ordinal scale (1 = lowest demand, 7 = highest demand) was used for ratings. These dimensions, shown in previous research to be important determinants of driving performance (Galski et al., 1990; Galski et al., 1992, 1993), were defined on a separate sheet for reference and included in the package of materials.

### *Data Analysis*

A total score, which served as a basis for comparing estimates of the overall demands for driving skills and abilities, was calculated for each participant by summing the 25 ratings for each scenario (maximum total score = 175). With the total score as the dependent variable, a factorial (3 [road type]  $\times$  2 [traffic condition]  $\times$  2 [weather condition]) analysis of variance (ANOVA) was performed to evaluate the overall demands for driving skills and abilities in the various driving scenarios. Significant main and interactive effects were predicted for the independent variables (i.e., road type, traffic condition, weather condition).

To facilitate interpretation of main effects for the total scores over levels of the independent variables, a number of a priori predictions were generated for planned comparisons. Specifically, several predictions were made for road type: (a) city driving would be more demanding than highway driving, (b) city driving would be more demanding than residential driving, and (c) highway driving would be more demanding than residential driving. Bonferroni-corrected values were used to maintain the error rate at a reasonable level ( $p < .02$ ). With regard to traffic condition and weather condition, heavy traffic was predicted as more demanding than light traffic and inclement weather as more demanding than sunny weather.

These comparisons were tested against the critical  $F$  at the routine level of significance.

No comparisons were planned for interactions. However, the more exacting level for significance of findings was set for post hoc analyses of significant results ( $p < .02$ ).

On the basis of the possibility that the overall demands of driving could be similar in different situations while varying significantly in the specific demands or patterns of demands for driving in each situation, the significance of individual physical, perceptual, cognitive, and behavioral factors was evaluated across conditions. A factorial (3  $\times$  2  $\times$  2) multivariate analysis of variance (MANOVA) was performed on the following 25 dependent variables: visual acuity, auditory acuity, right peripheral vision, left peripheral vision, depth perception, scanning, attention and concentration, information-processing speed, visuospatial perception, short-term memory, long-term memory, anticipation and planning, problem solving, self-awareness, psychomotor speed, strength, motor coordination, lane and road use, steering, passing, speed control, stopping and braking, road knowledge, emotionality, and perception of riskiness. Independent variables were entered in the following order: road type, traffic condition, and weather condition. Pillai's trace statistic was used to evaluate these data for multivariate significance because it is robust to violations of assumptions for multivariate analyses (Olson, 1979).

Follow-up of multivariate significance involved the use of multiple univariate ANOVAs for each dependent variable. Additionally, multivariate contrasts were performed to simultaneously compare the conditions over sets of dependent variables. As protection against errors from multiple testing, a more stringent significance level was determined by a Bonferroni adjustment ( $p < .002$ ) and used as a basis for interpretation of results. All data analyses were performed with SYSTAT, version 5.0 (Wilkinson, 1990).

### **Results**

A maximum total score of 175.00 was possible for every driving scenario (i.e., the summation of experts' ratings for skills and abilities in each scenario). Total scores averaged 76% of the maximum possible score (i.e., 133.84) and ranged from 70% of the maximum score for the least demanding scenario (i.e., 123.09 for highway-light traffic-sunny weather) to 83% for the most demanding scenario (i.e., 145.14 for city-heavy traffic-sunny weather).

The ANOVA using the total score as the dependent variable resulted in significant main effects for road type,  $F(2,683) = 10.93$ ,  $p < .001$ , and traffic condition,  $F(1,683) = 29.37$ ,  $p < .001$ , but not for weather condition. Evaluation of the planned comparisons for the main

effects of road type revealed, as predicted, that highway driving,  $F(1,683) = 15.92, p = .000$ , and city driving,  $F(1,683) = 16.85, p = .000$ , were rated as significantly more demanding than residential driving. Contrary to prediction, however, no significant differences in demand characteristics were found between city and highway driving. Regarding the main effects for traffic condition, the prediction was confirmed that estimates of the overall demands were significantly greater for driving in heavy traffic than in light traffic,  $F(1,683) = 29.37, p = .000$ . Evaluation of the main effect for weather condition revealed that there was no significant difference in overall driving demands between inclement and sunny weather conditions.

Additionally, significant interaction effects were found for road type by weather condition,  $F(2,683) = 10.20, p < .01$ , and traffic condition by weather condition,  $F(1,683) = 6.80, p < .01$ . However, no significant interaction effects were found for road type by traffic condition or for road type by traffic condition by weather condition. With regard to the interaction effects of road type by weather condition, post hoc analyses revealed that the total scores for road type differed across levels of weather. Specifically, highway driving was rated as significantly more demanding in inclement weather than in sunny weather,  $F(1,683) = 20.31, p = .000$ , whereas, counterintuitively, city driving,  $F(1,683) = 21.25, p = .000$ , and residential driving,  $F(1,683) = 14.51, p = .000$ , were rated as significantly more demanding in sunny weather than in inclement weather. Furthermore, with regard to the interaction effects for traffic condition by weather condition, it was found that driving in heavy traffic was rated as significantly more demanding in sunny weather than in inclement weather, whereas light traffic was found to be significantly more demanding in inclement weather than in sunny weather. These results, including the cell and marginal means and standard deviations for the total scores, are summarized in Table 1.

The MANOVA, which used the 25 physical, perceptual, cognitive, and behavioral ratings as a basis for assessing the effects of the independent variables, revealed significant main effects for road type,  $F(50,1320) = 6.267, p < .001$ ; traffic condition,  $F(25,659) = 2.679, p < .001$ ; and weather condition,  $F(25,659) = 3.264, p < .001$ . Significant interaction effects were also found for road type by weather condition,  $F(50,1320) = 2.470, p < .001$ ; road type by traffic condition,  $F(50,1320) = 1.550, p < .01$ ; and road type by traffic condition by weather condition,  $F(50,1320) = 1.424, p < .05$ . Nonsignificant interaction effects were found for traffic condition by weather condition.

For the significant main effects, univariate analyses revealed that 9 dimensions, or demand characteristics,

differentiated the three levels of road type, 16 differentiated the two levels of traffic condition (the same 9 dimensions that differentiated the levels of road type plus 7 additional dimensions), and only 1 differentiated the two levels of weather condition. Post hoc contrasts revealed that highway driving was significantly differentiated from city driving by greater demands for information-processing speed, passing, and stopping and braking. Highway driving was significantly differentiated from residential driving by greater demands for attention and concentration, anticipation and planning, lane and road use, and passing. City driving was also found to be significantly more demanding than residential driving in the need for attention and concentration, information-processing speed, anticipation and planning, lane and road use, passing, speed control, emotionality, and perception of riskiness. Moreover, driving in heavy traffic was rated as significantly more demanding than driving in light traffic on 16 dimensions: depth perception, scanning, attention and concentration, information-processing speed, visuospatial perception, anticipation and planning, problem solving, self-awareness, psychomotor speed, lane and road use, steering, passing, speed control, stopping and braking, emotionality, and perception of riskiness. Stopping and braking was revealed as the only factor that rendered driving in inclement weather as significantly more demanding than driving in sunny weather.

For the significant interactive effects, six demand characteristics differentiated road type by weather condition: depth perception, attention and concentration, anticipation and planning, psychomotor speed, steering, and stopping and braking. There were no significant univariates for road type by traffic condition or road type by traffic condition by weather condition, even though the MANOVA was significant. Moreover, although the interaction between traffic condition by weather condition was not significant in the omnibus MANOVA, stopping and braking emerged as a significant univariate.

Table 2 summarizes the significant univariates for MANOVA main and interactive effects. Table 3 summarizes the means of demand characteristics that differentiate levels of the significant univariates.

## Discussion

Ratings of the various driving scenarios by knowledgeable and experienced professionals confirmed the view that (a) driving is a demanding task that requires a person to possess and use many cognitive-perceptual skills and abilities at generally higher levels of intensity in all conditions, and (b) driving is regarded as more demanding overall in some situations than in others, depending on contextual determinants, such as type of driving (road type [i.e., highway, city, residential]) and density of the

**Table 1**  
**Cell and Marginal Means and Standard Deviations for the Analysis of Variance of Total Scores**

Weather	Traffic	Road Type			
		Highway <i>M (SD)</i>	City <i>M (SD)</i>	Residential <i>M (SD)</i>	<i>M</i>
Sunny	Heavy	139.24 (17.53)	145.14 (17.44)	136.05 (20.71)	140.12 (18.90)
	Light	123.09 (24.00)	133.53 (22.43)	125.33 (20.50)	127.32 (22.68)
	<i>M</i>	131.16 (22.16)	139.29 (20.86)	130.69 (21.21)	133.70 (21.81)
Inclement	Heavy	144.97 (18.02)	134.40 (21.81)	129.29 (23.36)	136.22 (22.06)
	Light	138.21 (18.54)	133.36 (21.60)	123.60 (25.04)	131.72 (22.60)
	<i>M</i>	141.59 (18.52)	133.88 (21.62)	126.45 (24.28)	133.97 (22.41)
	Heavy	142.10 (17.93)	139.77 (20.41)	132.67 (22.24)	138.16 (20.60)
	Light	130.65 (22.66)	133.45 (20.93)	124.47 (22.80)	129.52 (22.71)
	<i>M</i>	136.38 (21.18)	136.57 (21.37)	128.57 (22.85)	133.84 (22.10)

traffic (traffic condition). In addition to implying that the overall demands for driving abilities are affected by the context, this study also showed that experts regarded context as the determinant of specific abilities and behaviors needed to drive in different situations. For example, compared with residential driving, highway and city driving demanded significantly more intense degrees of specific cognitive abilities—the kind that call for paying attention and concentrating over a period of time, rapidly and accurately processing information, and being able to anticipate—as well as operational skills, such as passing, controlling the speed of the automobile, and braking, and emotional restraint in situations perceived as risky. At the same time, although highway and city driving were not significantly different from each other in terms of overall demands, they were significantly differ-

ent in that driving on the highway demanded significantly greater speed and accuracy in information-processing and passing skills, whereas city driving demanded greater stopping and braking skills.

Interestingly, it was found that weather condition was not an important factor in and of itself but only affected the demands for driving in combination with other determinants and then only in specific ways that were sometimes counterintuitive. This finding may suggest a lack of clarity among the experts about the importance of weather as a primary situational determinant; reflect the experts' view that there are inherent hazards in both weather conditions used in this study (e.g., sunny weather = glare, inclement weather = slipperiness), which are roughly equal in level of demand; or reveal a failure of the photographs to clearly depict differences in weath-

**Table 2**  
**Significant Univariates for MANOVA Main and Interactive Effects**

Variable	RT	WrCn	TrCn	RT x WrCn	RT x TrCn	TrCn x WrCn	RT x WrCn x TrCn
Visual acuity			**				
Auditory acuity	**						
Right peripheral vision							
Left peripheral vision							
Depth perception			*	*			
Scanning			*	**			
Attention and concentration	*		*	*			
Information-processing speed	*		*				
Visuospatial perception			*				
Short-term memory			**				
Long-term memory							
Anticipation and planning	*		*	*			
Problem solving			*				
Self-awareness			*				
Psychomotor speed			*	*			
Strength							
Motor coordination			**				
Lane and road use	*		*				
Steering			*	*			
Passing	*		*				
Speed control	*		*				
Stopping and braking	*	*	*	*		*	
Road knowledge							
Emotionality	*		*	**			
Perception of riskiness	*		*				

Note. MANOVA = multivariate analysis of variance; RT = road type; WrCn = weather condition; TrCn = traffic condition.

\* $p < .002$ . \*\* $p = .002-.003$ .

**Table 3**  
**Significant Mean Differences Between Dependent Variables for Significant MANOVA Univariates**

Variable	Road Type				Traffic Condition		Weather Condition			
	HWY > CTY		CTY > RES		HWY > RES		HVY > LGT		INCL > SUN	
Attention and concentration			6.31	5.99	6.267	5.99	6.360	6.01		
Information-processing speed	6.09	5.68			6.164	5.79	6.159	5.83		
Anticipation and planning			6.06	5.74	6.125	5.74	6.173	5.78		
Lane and road use			6.05	5.51	6.142	5.51	6.032	5.77		
Passing	5.52	4.67	4.67	3.53	5.522	3.53	4.859	4.29		
Speed control					6.086	5.52	5.914	5.61		
Stopping and braking	5.66	6.05					6.035	5.62	5.99	5.66
Emotionality					5.332	4.89	5.369	4.81		
Perception of riskiness					5.457	4.89	5.427	4.92		
Depth perception							5.902	5.53		
Scanning							6.343	6.03		
Visuospatial perception							5.928	5.62		
Problem solving							5.859	5.43		
Self-awareness							5.432	5.05		
Psychomotor speed							5.746	5.36		
Steering							5.738	5.42		

Note. MANOVA = multivariate analysis of variance; HWY = highway; CTY = city; RES = residential; HVY = heavy; LGT = light; INCL = inclement; SUN = sunny.

er condition for some scenarios. Before concluding that weather condition is not an environmental factor with direct influence on the demands for driving, future research should try to improve the representation of differences in weather conditions and reassess its importance.

In terms of behind-the-wheel performance, these findings suggest by inference that (a) drivers can avoid errors in operation (i.e., accidents) only if they possess a sufficient magnitude of abilities and skills to meet the overall and specific demands of the situations in which they operate their automobiles and that (b) drivers could have a base level of abilities to meet the demands of one or more situations but not others. For example, a person may possess abilities (e.g., attentional capacity) to a degree sufficient to safely drive in a relatively easy situation (e.g., residential area–light traffic–sunny weather total score = 125.33) but insufficient to safely drive in another situation (e.g., highway–heavy traffic–inclement weather total score = 144.97).

Furthermore, these results, which emphasize the importance of the person–situation interaction in driving, have important practical implications for driving evaluators. First, evaluators can use them to develop guidelines for conducting individualized assessments that are based on a person’s needs and abilities. For example, they can use knowledge of the interaction between a person’s abilities and certain driving situation demands as a basis for (a) determining whether a person has ubiquitous driving capacity (i.e., fit to drive in any situation) or only situation-specific driving capacity (i.e., fit to drive in some situations) and (b) making appropriate recommendations that range from unconditional motor vehicle operation to stipulated driving (in which a person is restricted to a situation(s) for which he or she has requisite abilities) to complete abstinence from driving. Evaluations conducted

along these lines can be particularly helpful in dealing with the tendency of some persons to overestimate their driving abilities.

Second, the results can be used as a foundation for developing training programs that, unlike generic training courses offered in many driver education programs, take individual differences into account. For example, individualized training programs can be designed to ameliorate the unique pattern of deficits that allow a person to drive anywhere (i.e., deficit-specific training) or to focus on applying preserved skills and abilities in the unique situation(s) in which a person is expected to drive (i.e., situation-specific training). Another advantage of the development of such programs is that trainers can start instructions at a baseline level identified through proper evaluation and gradually progress through specific situations with increasing degrees of difficulty or complexity. This is a more systematic approach to driver training than the traditional method of taking a driver onto a protected course or into traffic and expecting that coached practice would improve driving ability without clear knowledge of what abilities are being ameliorated or how the training applies to the person’s real-life driving patterns.

Additionally, the findings lend themselves to further research, particularly to developing a compendium of perceptual, cognitive, and other relevant abilities and skills required to drive in specific situations (e.g., city intersection during rush-hour traffic at dusk). Such a compendium, which can list many scenarios and their requisite skills and abilities, could serve as a reference for comparing the results of individual drivers’ evaluation. Further, on the basis of the notion that a mismatch between the demands of situations and a person’s skills produces driving errors, researchers may be able to derive a mathematical equation to predict accident-prone drivers. Confir-

mation of the mismatch hypothesis would provide impetus for developing a taxonomy of accidents that is based on differences between drivers' abilities and the demand characteristics of various driving situations that would be meaningful to professionals who evaluate and train drivers, the drivers themselves, and society.

Finally, although the results of this study contribute to an understanding of the relationship between drivers and the contexts in which vehicles are driven, conclusions are based on the opinions and views of selected experts who, because they work in the field of driver evaluation and training, may distort results by deliberately or unwittingly overestimating the importance of skills and abilities in driving. Such a criticism has merit; however, despite the possible bias in selecting participants whose careers are invested in and dependent on a view of driving as complex and demanding, they were considered an appropriate choice to provide the kind of knowledgeable and experience-based information about driving situations that was required in this study. ▲

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