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RELATION OF INDIVIDUAL DIFFERENCES IN INFORMATION-PROCESSING ABILITY TO DRIVING PERFORMANCE

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ABSTRACT

Fifty subjects ranging in age from 30 to 83 participated in a closed-course driving test and in laboratory tests of information processing. Driving tests included responding to traffic signals, selection of routes, avoidance of moving hazards, and judgment at stationary gaps. Lab tests included measures of perceptual style, selective attention, reaction time, visual acuity, perceptual speed and risk-taking propensity. Analyses were conducted to determine how well lab measures predicted driving performance. Results revealed different patterns of correlations for different age groups. For younger drivers (30-51), lab measures generally showed no association with measures of driving performance. For older drivers (74-83), measures of information-processing were associated with overall rated driving performance, while measures of reaction time showed strong correlations with objective driving measures. The results suggested that different mechanisms are utilized by drivers of different ages, and that the slowing of reaction time associated with aging has effects on driving skills related to vehicle control.

INTRODUCTION

Considerable research effort has been directed at predicting motor-vehicle accident rates with laboratory measures of information-processing skills. Barrett, Alexander and Forbes (1973), presented a conceptual analysis of pre-crash maneuvers related to accident causation and concluded that three categories of information-processing are relevant to predicting driving accidents. These categories (perceptual style, selective attention and perceptual-motor reaction time) have been the basis of a number of subsequent research studies (cf., Mihal and Barrett, 1976; Avolio, Kroeck and Panek, 1985). While much of this work has demonstrated positive results, correlations between lab measures and accident records are generally not strong. According to McKenna, Duncan and Brown (1986), this is due to the fact that accident causes may reflect chance factors as well as many different personal characteristics and psychological abilities or processes.

The stability of accident rates has been investigated by Miller and Schuster (1983), who found that past accident history is not a good predictor of future accident involvement and thus may not be a valid indicator of current or future driving competency. The need for an alternative measure of driving proficiency was asserted by McKenna et al. (1986), who concluded that detailed investigations of component skills would lead to better understanding of differences in driving performance than reliance on a single criterion such as accident rate. These authors concluded that "research should concentrate on specific skill deficiencies and their contribution to human error, rather than more immediately attempting to predict overall accident liability." Finally, practical considerations about the availability and quality of accident data, which rarely contain information in sufficient detail for research purposes, underscore the need for alternative ways of evaluating driving competency.

In response to these concerns, a battery of driving tasks was developed which focuses on the decision making and judgment involved in everyday suburban driving. The driving tasks were implemented on a half-mile closed course, which allows drivers to use their own vehicles. Use of drivers' own vehicles avoids problems of differential adaptation to unfamiliar research apparatus such as simulators and instrumented vehicles. In addition, a battery of laboratory tasks, including information-processing tasks which have been shown to be related to accident rates, was developed. The overall objective of the research program is the development of a safe driving capability profile, including both driving and laboratory tasks, for drivers of all ages. The objectives of the present paper are to: (1) describe the initial development of the driving test, and (2) evaluate the relationship between performance on the driving test and laboratory measures of information-processing.

METHOD

Subjects

Fifty subjects ranging in age from 30 to 83 participated in driving and laboratory tests. Subjects were recruited with newspaper ads and from local senior citizen activity centers. Subjects were paid $8.00 to $10.00 per hour for participation, depending on their responses to performance incentives.

Apparatus

An instrumented driving range, including a half mile of two-lane roadway, a signalized intersection, mobile hazards, and various regulatory and destination signs, was developed to enable drivers to use their own vehicles. The instrumentation and its rationale are discussed in Ranney, Pulling, Roush and Didriksen (1986). Traffic signal timing and data acquisition are controlled by a DEC PDP 11/23 computer which is housed in a van parked alongside the intersection. Spot speed data are obtained with four pairs of inductive loops buried beneath the pavement. The pairs are separated by 36.6 m (120 ft). Three pairs are before the intersection and one pair is beyond it. Time of entry into the intersection is obtained with a single loop in each approach lane located at the stopline. Traffic signal timing is related to the "temporal position", or time to the intersection of the vehicle, which is computed using approach speeds. This compensates for differences in vehicle approach speed.

Driving Test

The driving test consisted of three 30-minute "trips." Each trip, composed of up to twenty laps of the closed course, required the driver to respond to a continuous sequence of driving situations. Primary tasks included responding to traffic signals with varied timing and selection of routes using information presented on traffic signs. A gap-acceptance task required drivers to select one of two routes at a junction on the course. One route was shorter, but required drivers to drive through a variable-sized gap formed by two construction barrels. Drivers' judgments concerning the width of the gap and their willingness to attempt the gap were evaluated with this task. Secondary tasks included avoidance of unexpected moving hazards (such as a rolling ball or simulated baby stroller), responding to regulatory signs (speed limit and stop signs) and executing maneuvers created by cones and barrels.

Both subjective ratings and objective measures of drivers' responses to the driving task situations were recorded. Drivers were rated on the following ten skills:

- Stop/go decision making
- Gap judgment
- Gap execution
- Decision speed
- Route selection
- Speed maintenance
- Vehicle control
- Emergency hazard avoidance
- Time to destination
- Ability to follow instructions

Ratings were made on a three-point scale. Drivers were observed by two or three raters. Following each session ratings were discussed and a single consensus rating was recorded for each driver on each of the ten categories. An overall rating of driving performance was computed as the average of the ten categorical ratings.

Objective driving performance measures included the following:

Measures of intersection performance

- Stopping probability: the proportion of decision trials on which the driver stopped when faced with the yellow traffic signal (STOPPR)
- Stopping accuracy: vehicle placement relative to the stopline on stopping trials (STPACC)
- Intersection clearance margin: the mean difference between the time the vehicle exited the intersection and the onset of the red traffic signal (MARGIN)

Measures of gap performance

- Number of attempts: number of trials where driver attempted to drive through gap (NOATT)
- Number of gap judgment errors: included selection of gaps too small and avoidance of gaps of equal or greater width than the vehicle (JUDGERR)
- Number of gap execution errors: Struck barrels or excessively slow speed (EXERR)

Speed measures

- Intersection approach speed: mean over all trials (SPEED1)
- Intersection approach speed change: mean over all trials (SPDDIF)
- Mean lap time: mean over all trials in one trip (LAPTIME)
- Speed maintenance errors: instances of speeds over 56.3 km/h (35 miles/hour) (FAST35) or under 43.5 km/h (27 miles/hour) (SLOW) in the intersection approach

Measures of vehicle control consistency

Approach speed consistency: standard deviation over all trials of approach speed (SSPD1)

A measure of route selection errors was eliminated due to insufficient data.

Laboratory tasks

Visual acuity (VISION) was measured with a standard Titmus tester, similar to those used for license renewal. Perceptual style was measured with the Embedded Figures Test (EFT) (Witkin, Oltman, Raskin & Karp, 1971). Perceptual speed was measured with three tests of the Cognitive Factors Kit (Ekstrom, French, Harman & Dermen, 1976). The tests required visual search for letters (VSEARCH), matching numbers (NUMBERS), and matching figures (FIGURES). The Digit Symbol Substitution (DSS) test of the Wechsler Adult Intelligence Scale is also a measure of perceptual speed and short-term memory, and has been used widely in studies of information-processing and aging (Salthouse, 1985). Visual selective attention was measured with an analogue of the dichotic listening task (Avolio, Kroeck, and Panek, 1985). The total number of errors (VSATOT) and the number of switching errors (VSATSW) provided a measure of efficiency of switching in attention. Three measures of reaction time, included simple (SRT), simple plus movement (MRT), and movement plus (two) choice (CRT) reaction times. Risk-taking propensity (RISK) was measured by the Choice Dilemmas Questionnaire developed by Kogan and Wallach (1964).

RESULTS

Analyses were conducted to determine: (1) how well lab measures predicted driving performance; and (2) how well objective driving performance corresponded to subjective ratings. To determine how well lab measures predicted overall driving performance, correlations between overall driving performance and lab measures were examined. The correlations ranged from .21 to .61. All correlations except those for choice reaction time (CRT) and risk propensity (RISK) were significant at the .05 level, most at the .01 level. Four measures (DSS, FIGURES, VSATOT, VSATSW) exhibited correlations greater than .55 with overall driving performance. Previous research using accident rates as the criterion suggested that correlations in the range of .3 to .4 would indicate a relatively strong association. The considerably larger correlations for several of the variables, most notably the DSS, which has been used extensively in studies of aging, led us to reconsider our data. According to Salthouse (1984), spurious correlations can arise when samples are not homogeneous with regard to age. Because our sample included a wide range of ages, and the overall driving performance rating was found to be highly correlated with age, it was hypothesized that age was accounting for some of the relatively high observed correlations. Accordingly, the data were reanalyzed, separately for the two main age groups (30-51, 74-83). Results are shown in Table 1.

Table 1

Correlations of Lab Measures with Overall Driving Performance for Two Age Groups

	r	
Lab test	Young (n=21)	Old (n=20)
DSS	.07	.40
EFT	.03	-.41
VSEARCH	.01	.42
NUMBERS	-.11	.26
FIGURES	-.11	.56
SRT	.21	-.57
MRT	.28	-.31
CRT	.17	-.21
VSATOT	-.04	-.24
VSATSW	-.02	-.09
VISION	.02	-.14
RISK	-.17	-.20

The statistical power has been reduced considerably with the separation into two age groups, so that statistical significance is not comparable between the two analyses. For current purposes, correlations of .4 or greater are considered as different from zero. It is apparent that patterns of correlations differ for the two age groups. For the younger drivers, performance on the driving test was not related to any of the lab measures. However, for the older drivers, correlations greater than .4 were evident for several lab measures. Strongest correlations were associated with simple reaction time (SRT) and the figure matching test of perceptual speed (FIGURES). The DSS, EFT, and letter search task (VSEARCH) also exhibited relatively strong correlations with overall driving performance. Attention switching, as measured by the VSAT and risk propensity (RISK) were not related to overall driving performance for either group.

The results of two multiple regression analyses revealed that the lab measures accounted for 52% of the variance in overall driving scores for the younger drivers, and 84% for the older drivers.

Next, analyses were conducted to determine the relation between selected measures of driving performance and lab measures. These results are shown in Table 2.

Table 2

Correlations Among Driving Performance and Laboratory Measures for Two Age Groups

Lab Measures with significant correlations (p <.05)+

Driving Performance Measure	Younger Drivers (30-51)	Older Drivers (74-83)
STOPPR	MRT, CRT	
STPACC	RISK*	(EFT)
MARGIN		MRT*, CRT*, EFT*
NOATT		
JUDGERR	(FIGURES)	DSS, VSATOT
EXERR	VISION*	SRT, MRT, CRT
SPEED 1		SRT*, MRT*, CRT*, RISK
SPDDIF		
LAPTIME	SRT, MRT, CRT* (RISK)	SRT*, MRT,CRT
FAST35	DSS*	RISK
SLOW	(VISION)	SRT, MRT, CRT
SSPD1		SRT*, MRT*, CRT*,FIGURES, RISK*

+Correlations greater than or equal to .40, but not statistically significant at p <.05 are indicated in parenthesis.
*Correlations greater than or equal to .50

As with overall driving performance, the correlations were generally stronger for the older group. Measures of reaction time, especially simple reaction time (SRT), were correlated with a number of driving measures, including measures of speed (SPEED1, LAPTIME, SLOW) and speed consistency (SSPD1). In addition, for the older drivers, the reaction time measures were highly correlated with stopping margin (MARGIN) and execution errors on the gap task (EXERR). The fact that all three reaction time measures behaved similarly is consistent with the generally high correlations observed among the three measures for both age groups. Of interest is that the choice reaction time measure (CRT), which involved movement, was essentially identical (r=.97) to the movement reaction time (MRT) without choice for the older drivers, but not for the younger drivers (r=.87).

With several exceptions, measures of information processing speed were not strongly correlated with driving performance for either age group. Gap task judgment (JUDGERR) exhibited significant correlations with DSS and total VSAT errors for the older group only. Gap judgment for the younger group was related to the FIGURES identification task, although not strongly. For the younger group DSS scores were related to speed exceedances over 35 mph (FAST35).

The embedded figures test (EFT) was related to stopping accuracy (STPACC) and to the clearance margin (MARGIN) at the signalized intersection for the older group only; however, neither correlation was very large. The risk propensity questionnaire (RISK) was related to stopping accuracy (STPACC) and mean lap time (LAPTIME) for the younger drivers, and to two measures of speed (SPEED1, FAST35) for the older drivers.

The results of two regression analyses revealed that the measures of driving performance accounted for 69% of the variance in overall driving scores for the younger drivers and 83% for the older drivers.

DISCUSSION

Perhaps the most significant finding of the current analysis is that correlation patterns were different for different age groups. This is consistent with results of Mihal and Barrett (1976), who used accident rates as the criterion. Their explanation focused on differences between the accident rate distributions for the two age groups. Although such differences do exist for some of the current measures, it is also possible, as suggested by Salthouse (1985), that different patterns of correlations reflect use of different information processes by different-aged drivers.

For the younger drivers, none of the lab measures correlated with overall driving performance. While some of the driving measures exhibited significant correlations with lab measures, the pattern was generally not consistent with predictions of the information processing model of Barrett et al. (1973). It can thus be concluded that for drivers in our younger age group, closed-course driving involved skills different from those measured with lab tasks.

Correlations were generally stronger for the older drivers. Several information processing measures correlated with overall rated driving performance, while measures of reaction time correlated with both overall rated performance and with individual driving measures. The slowing of response time with age is well documented (Salthouse, 1985). The results of the present study indicate that for drivers over age 74, slowing of reaction time has a strong association both with overall driving performance and with specific driving measures, especially those related to vehicle control. Driving measures reflecting judgment and decision making skills were not correlated with reaction time measures.

The results suggest that the driving test was considerably more challenging for the older drivers than for the younger drivers. The absence of correlations for the younger group is consistent with the hypothesis that younger drivers were able to perform driving tasks more automatically, without complex information processing of the types required for the laboratory tasks. For the older drivers, more effortful processing, most notably visual search and identification, in addition to quick responding, were apparently required for the driving test.

Several specific hypotheses were addressed in the analysis. First, it was hypothesized that risk-taking, as measured by the Choice Dilemmas Questionnaire, would be related to drivers' willingness to attempt to negotiate different sized gaps and their decisions to stop or go when confronted with a yellow traffic signal. No such associations were found, however risk propensity scores were associated with several measures of speed, primarily for the older drivers. In this context, the Choice Dilemmas Questionnaire was not a useful predictor of risk-taking behavior.

Because accident causation may reflect different performance failures, it was hypothesized that laboratory tasks would be more highly correlated with individual driving measures than had been found in previous studies which used accident rates as the criterion. Of special interest was the Visual Selective Attention Test (VSAT), since the ability to rapidly switch attention is required in many driving situations. For the older drivers VSAT performance was related to their ability to judge whether their vehicle would fit through the stationary gap. None of the other driving measures was significantly correlated with VSAT performance, leading to the conclusion that rapid switching of attention was not generally required for the current driving test.

The results of regression analyses indicate that neither the lab measures nor the driving measures correspond to all aspects of rated driving performance. With regard to driving measures, they reflect the fact that speed of decision-making in the route selection task, avoidance of emergency hazards, and ability to follow instructions were not measured directly. With regard to the lab tasks, the above-cited correlations between information processing measures and accident rates, have in the past led to the conclusion that complex information processing is involved in accident causation. The current results are not consistent with this reasoning. Whether this reflects inadequacies of the current driving test or whether previous reliance on past accident rates is not valid cannot be determined at this time. Prediction of culpability in future accident involvement would be required for this purpose.

Finally, the analyses support the conclusion that different information processes are utilized by different age groups. They also indicate that lab tests may be more useful predictors of driving performance for older drivers than for younger drivers. If the current driving test represents the requirements of real-world driving, the results suggest that different causes are responsible for accidents of drivers of different ages.

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