A Study of Driver Variability in Car Following and Open Road Driving

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This research investigated the variability of driver velocity control when operating a vehicle under eight different treatment conditions. The following three variables were considered: (a) an instruction for normal or best control, (b) presence or absence of a leading vehicle, and (c) presence or absence of a speedometer.

•DURING THE past few years, many studies have been made of the car following situation. The majority of these have dealt with a situation in which a vehicle is operated in a relatively strange and hostile environment, frequently under traffic density conditions which can hardly be considered typical. Other studies have dealt with normative data consisting of relatively few measures on each of a large number of vehicles. The first type of study does not necessarily produce results applicable to the vast majority of highway driving situations. The second type is viewed as being unable to deal adequately with any time-dependent aspect of car following on other than a macroscopic level.

The intent of this study has been to provide detailed microscopic information on both car following and open road driving for a reasonably large sample of drivers, based on extended periods of driving. Information was sought with regard to the following specific questions:

1. Does a given driver's velocity pattern when engaged in car following differ from that when engaged in open road driving?
2. Is a driver's velocity pattern stable and repeated under similar situations?
3. What is the limit of an individual's ability to control his velocity pattern?
4. Does relative headway affect the velocity pattern of a given driver?
5. To what extent need a driver rely on a speedometer when engaged in car following or open road driving?

EXPERIMENTAL METHOD

Sixteen subjects were employed in this study. Each subject drove the research vehicle for approximately 15 miles of familiarization driving plus eight times over the test highway before participating in the experiment. The test highway, a 14-mile section of I-71 north of Columbus, Ohio, was selected on the basis of geometry to minimize any possible highway effects.

The variables employed in this study were presence or absence of a speedometer, presence or absence of a leading vehicle, and an instruction to drive normally (N) or to drive with best control (B). The eight treatment combinations obtained from these variables, as shown in Table 1, were administered to the subjects randomly. Table 1 also gives the instructions corresponding to each treatment.

The LC+N instruction was intended to produce the type of car following that is frequently observed on the highway where one vehicle will follow another with a headway that apparently is great enough to minimize the influence of the leading vehicle on the

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TABLE 1

TREATMENTS AND CORRESPONDING INSTRUCTIONS EMPLOYED

Instruction Type	Lead Vehicle Present (LC)		Lead Vehicle Absent	
	Speedometer		Speedometer	
	Present (Sp)	Absent	Present (Sp)	Absent
Normal (N)	Sp+LC+N "Follow the lead car as you normally would if it just happened to be in front and you did not want to pass. You will have your speedometer."	LC+N "Follow the lead car as you normally would if it just happened to be in front and you did not want to pass. You will not have your speedometer."	Sp+N "On this run, I want you to drive as you normally would on the open highway. You will have your speedometer. Try to hold your speed down to 65mph."	N "On this run, I want you to drive as you normally would on the open highway. You will not have your speedometer. Try to hold your speed down to 65mph."
Best (B)	Sp+LC+B "Follow the lead car as if he were leading you somewhere and you did not want to get lost. You will have your speedometer."	LC+B "Follow the lead car as if he were leading you somewhere and you did not want to get lost. You will not have your speedometer."	Sp+B "On this run, I want you to drive maintaining a constant velocity of 65mph as best you can. You will have your speedometer."	B "On this run, I want you to drive maintaining a constant velocity of 65 mph as best you can. You will not have your speedometer."

following vehicle. The LC+B instruction was intended to produce a somewhat shorter headway than the LC+N condition without producing the obvious bias that would result if the subject were instructed to follow at a specific distance. It was hoped that these instructions, through their open-ended phrasing, would produce reasonably typical driving behavior.

The N and B instructions for open road driving were intended to produce results that were analogous to the LC+N and LC+B conditions. It was thought that the N instruction would produce behavior characteristic of normal open road driving and the B instruction would produce results indicative of the maximum velocity control a driver could exhibit without training.

The presence or absence of the vehicle speedometer was crossed with each of the four treatments outlined, to give the eight treatments employed in this study. This variable was included to gain an indication of the normal reliance a driver places on this device as a source of information feedback. Extreme deterioration of a driver's velocity control when operating without the speedometer would imply a reliance on this source of feedback information.

Figure 1. Instrumented and leading vehicles.

Two research vehicles were employed (Fig. 1). The subject drove the rear vehicle during each treatment and the front vehicle was operated as the leading vehicle only during the four treatments requiring it. The leading vehicle was operated at an indicated speed of 65 mph. A prior study has shown that the experimenters were able to control the lead vehicle velocity with a variance of less than 0.9 mph^2.

Although the highway used in this study was open to traffic, other vehicles interacted only rarely with the research vehicles. When an interaction did occur, the run was repeated.

The leading vehicle was equipped with a lapse-time camera (Fig. 2) operating at the rate of one frame every two seconds. Headway was derived geometrically from this film for each run which involved the lead vehicle. The vehicle driven by the subject contained an oscillograph recorder which provided an analog record of the velocities driven.

DATA ANALYSIS

The data for the 16 subjects consisted of oscillograph records for each of the eight treatments with photographic data for four treatments. Both types of records were transposed into numerical form by an oscillograph reader having both printed and punched card output. Each frame of the film data was read to obtain relative headway. The corresponding velocity point was also read. A sampling interval of two seconds was used in the reduction of both sets of data; approximately 350 points were read from each type of data for each treatment.

Figure 3 is a plot of the velocity patterns for a randomly selected subject's (No. 8) runs when no lead vehicle was present. Each trace was constructed by plotting the data points read from the oscillograph record. The increased variability in the two

Figure 2. Lead vehicle with camera.

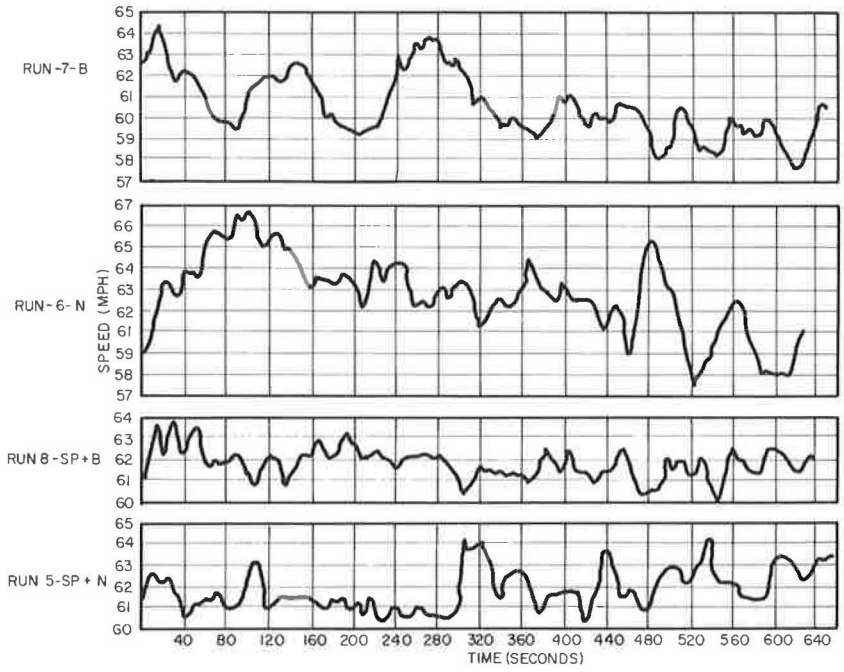

Figure 3. Velocity traces for Subject 8 under no-lead-vehicle condition.

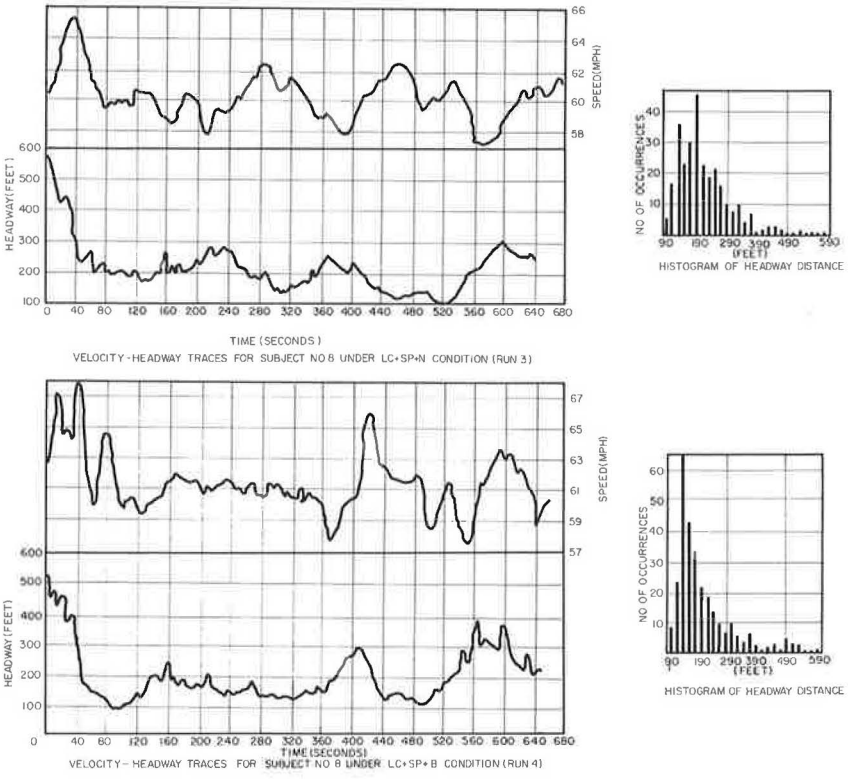

Figure 4.

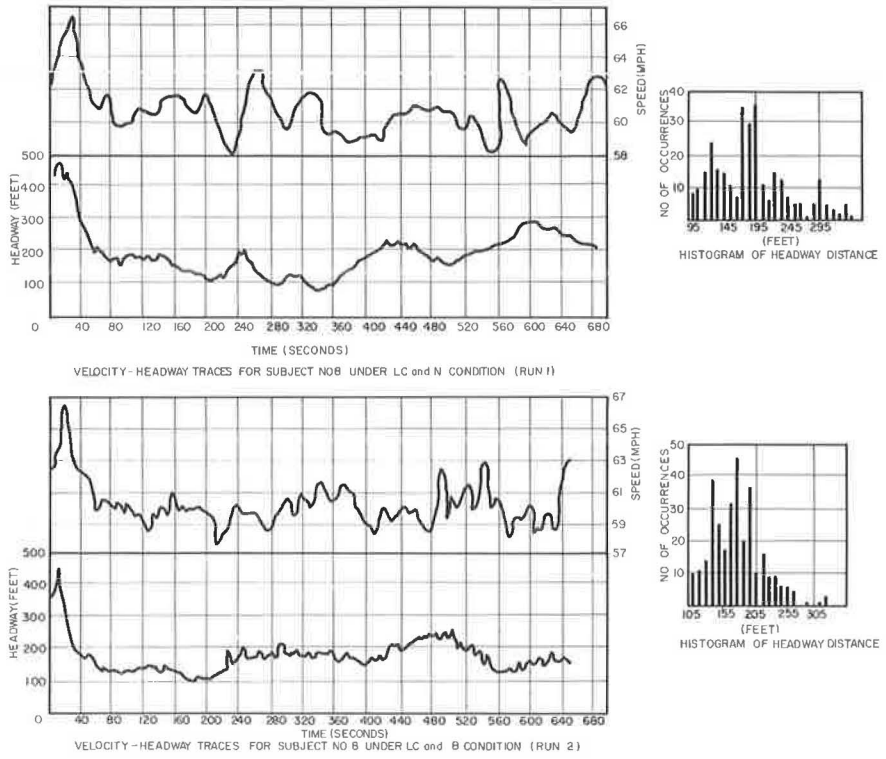

Figure 5.

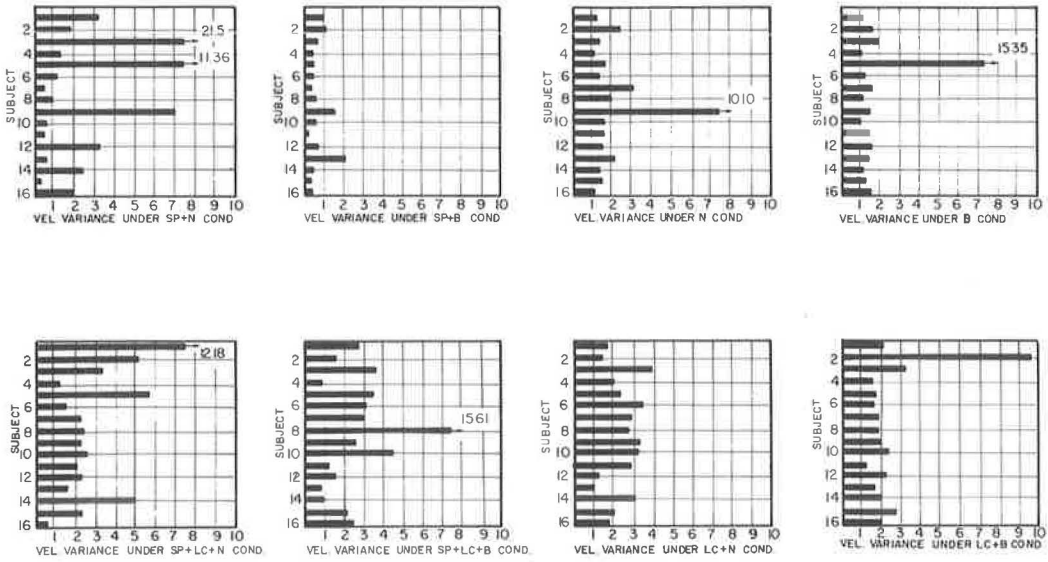

Figure 6. Plot of velocity variance for each condition for all subjects.

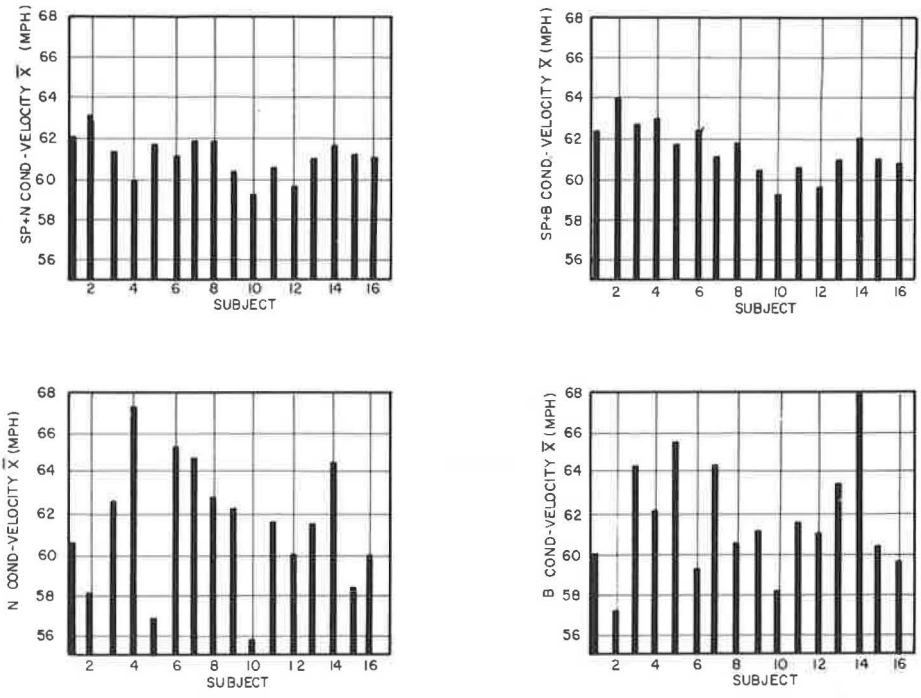

Figure 7. Plot of velocity $\overline{X}$ for each subject for runs without lead vehicle.

runs without speedometer (Runs 6 and 7), compared to those (Runs 5 and 8) with speedometer, is strikingly obvious.

Figures 4 and 5 are graphs of the velocities and headways for Subject 8's four runs with the lead vehicle present. To the right of each graph is a histogram of the headway for that run. In each graph the bottom trace represents headway and the upper trace represents speed. It is apparent from these two graphs that the presence or absence of the speedometer had little effect on this subject's performance when car following.

TABLE 2

ANALYSIS OF VARIANCE

Source	df	Mean Square		F Ratio		Level of Significance (%)	
		$\overline{V}$	6^2_V	$\overline{V}$	6^2_V	$\overline{V}$	6^2_V
Sequences	7	7.55	16.31	1.30	1.44	-	-
Runs	7	6.86	6.19	2.60	0.81	5	-
TREATMENTS:							
SP	1	0.89	1.55	0.338	0.204	-	-
LC	1	56.39	1.44	21.36	0.190	5	-
I	1	0.74	24.81	0.280	3.28	-	10
SP+LC	1	0.11	27.68	0.042	3.66	-	10
SP+I	1	0.05	11.57	-	1.53	-	-
LC+I	1	2.04	24.16	0.771	3.19	-	10
SP+LC+I	1	0.15	10.68	-	1.14	-	-
Residual	42	3.37	10.85	1.27	1.43	-	-
Ss/Seq.	8	5.81	11.28	2.20	1.49	10	-
Ss/Runs/Seq.	56	2.64	7.57	-	-	-	-

Also the difference can be seen between the N and B conditions, with respect to velocity, for the two runs with (Fig. 4) and the two runs without (Fig. 5) the speedometer.

Figure 6 presents the velocity variance of the eight runs of each subject plotted on the basis of instructions. Figure 7 presents the average velocity for runs which did not involve the lead vehicle; runs involving the lead vehicle were not included because their average velocities are effectively the same because of the constant lead vehicle velocity.

Several attempts have been made to analyze the velocity data in terms of repeatable patterns over a period of time. A Fourier analysis was conducted on the data for each run. In each case, the analysis was continued to 40 coefficients with approximately equal values resulting for all coefficients. Attempts have been made, with no positive results, to smooth the data on the basis of fixed-interval averaging.

Table 2 presents the results of an analysis of variance of the mean velocity and velocity variance for each of the 16 subjects' runs. The order in which the subjects performed their eight runs and the presence of the lead car had significant effect on average velocity at the 5 percent level. The treatment instructions and the treatments SP+LC and LC+I significantly affected velocity variance at the 10 percent level. The significance of the run order indicated that some transfer took place when particular treatments occurred before others or that some temporal factor influenced the performance. It would be reasonable to assume that if a subject's first four runs involved a lead vehicle, his velocity maintenance on runs not involving a lead vehicle and speedometer would be better than if runs without the lead vehicle were made first.

On the basis of the initial analysis of this study, two additional studies will be conducted. The first will be designed to investigate further the effect of instructions on the subject's performance. The study will consist of four factors, rather than eight, through the omission of the speedometer variable. The second study will investigate the effects of variable lead vehicle velocity. Further analysis of the data collected in the present study is being continued with particular emphasis on possible time-dependent aspects.

ACKNOWLEDGMENT

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