In-Traffic Driver Behavior: Development of Measures and Evaluation of Differences Between Finland and Michigan

JUHA LUOMA

A study was designed (a) to develop an initial set of measures to observe driver behavior in different countries and (b) to compare driver behavior in Finland with driver behavior in Michigan by using these measures. Development of the measures emphasized equating environmental factors and traffic rules. For such conditions the study produced a reliable research tool providing potentially valuable results. The measures were applied in one middle-sized city in both regions, Lahti in Finland and Ann Arbor in Michigan. The results indicated the following main differences in driver behavior. Drivers in Lahti (compared with those in Ann Arbor) signaled more frequently before the lane change or turning and came to a full stop at intersections with a stop sign more frequently. The following trends were found: drivers in Lahti exceeded the speed limit more frequently but decreased the speed earlier while approaching the intersection from the secondary road, accelerated more slowly after turning onto the secondary road, and accepted slightly longer gaps when entering the main road. The following aspects of driver behavior did not differ in the two cities: the variance of the speed in free-flow traffic, the proportion of short headways in car-following situations, the frequency of no stops compared with rolling and full stops at intersections with a stop sign, and yielding to pedestrians at intersections. The differences that were found differences are likely consequences of differences in values and norms.

The need for measures that can be used to collect descriptive and comparable data on actual driver behavior to improve traffic safety has been recognized for at least 20 years. Smeed (*1*) argued the following: "A knowledge of standards of driver behaviour would help to determine which aspects of such behaviour especially need to be improved. If these standards were assessed periodically, it would be possible to assess whether driver behaviour was or was not improving and assess the effects of policies directed to the improvement of driver behaviour. If the standards were assessed in different countries or in different parts of the same country, the results would be of value in explaining differences in accident rates in the countries or parts of the same country concerned."

Until recently, there has been no cross-national or longitudinal study on driver behavior that has collected data by (a) using a broad and unobtrusive set of measures and (b) matching or controlling environmental factors and traffic volumes properly. For example, Benjamin (*2*) reported drivers' close-following and speed behaviors on motorways in 11 countries. However, the sites varied substantially in terms of the posted speed limits and traffic volumes. Only two behaviors were compared in a study that investigated vehicle speeds while approaching an intersection from a secondary road and gap acceptance at one English and two German rural intersections (*3*). Traveling speeds on highways, drivers' visual scanning behaviors at intersections, and pedestrians' crossing behaviors at red traffic signals were compared in Canada, Japan, and Korea (*4*). However, that study did not attempt to match the road and traffic conditions.

Longitudinal studies have also collected data on many driver behaviors in different parts of the same city or country. Drivers' speed behavior, running red lights, use of turn signal when turning, and yielding to pedestrians were studied in Stockholm (*5*). In Finland several measures of driver behavior were obtained (*6*): speed behavior, headways of vehicles driving in car-following situations, use of safety belt, use of daytime running lights, use of turn signal while turning, proportion of drunk drivers, use of bicycle helmet, crossing on red lights by pedestrians, and use of retroreflectors by pedestrians. More specific definitions and control of traffic volumes for each measure would improve the comparability of the results of these studies with those of other studies.

The present study [based on a detailed technical report (*7*)] was designed (a) to develop an initial set of measures that can be used to observe driver behavior unobtrusively in different countries (or in different parts of a given country or in longitudinal studies) and (b) to investigate driver behavior in Finland and Michigan.

METHODS

Measures

The following measures were included in the study: Measure 1, speed behavior in a free-flow traffic situation; Measure 2, headways in car-following situations; Measure 3, use of turn signals before a lane change; Measure 4, speed while approaching an intersection from a secondary road; Measure 5, speed after turning onto a secondary road; Measure 6, use of turn signals before turning; Measure 7, stopping behavior at intersections with a stop sign; Measure 8, gap acceptance when entering a main road; and Measure 9, yielding to pedestrians at intersections.

The underlying logic in the selection of measures was that these measures would show different aspects of driver behavior that have potential safety consequences. Measures 1, 3, 6, 7, and 9 focused primarily on obeying a specific traffic rule. Measures 2, 4, 5, and 8 focused on behavior in situations with a general rule for safe driving. However, most of the measures have many aspects. Speed behavior includes two major aspects: speed deviation and exceeding the speed limit. Short headways mean that drivers have less time to react if the lead vehicle suddenly brakes. Speed while approaching an intersection from a secondary road and, especially,

The University of Michigan Transportation Research Institute, 2901 Baxter Road, Ann Arbor, Mich. 48109-2150.

gap acceptance when entering a main road were expected to reveal possible differences in safety margins. Speed after turning onto a secondary road shows how rapidly (aggressively) drivers accelerate. Use of a turn signal either before a lane change or before turning indicates that the driver obeys specific traffic rules and also how well drivers show their intentions to other road users. Stopping behavior at intersections with a stop sign primarily indicates whether the driver obeys traffic rules, but perhaps also provides information about safety margins. Yielding to pedestrians at intersections indicates how well drivers give a right-of-way to vulnerable road users, as well as how well they obey a particular rule.

It is acknowledged that in most cases the safety effects of a particular driver behavior are only potential. For example, one cannot quantify the safety effects of violating a specific traffic rule. In general, however, the violation of rules means a negative attitude toward traffic safety, an unwillingness to be concerned with other road users, or a willingness to accept a smaller safety margin.

Sites

The measures were applied in middle-sized cities in both countries, Lahti in Finland and Ann Arbor in Michigan. The population of each city is about 100,000. Measures 1, 3, 6, 8, and 9 were obtained from two sites in each city, whereas Measures 4 and 5 were measured at one site each, and Measure 7 was measured at three sites each (Table 1).

The study attempted to match the environment type and function, as well as sight distances, number and width of lanes, curvature, and gradient (7). The surface was dry asphalt that was in good or fairly good condition. Atmospheric conditions were good, with no rain, snow, or fog.

Equipment

All data except speed and headways were collected by video recording or note taking. Speed and headways were measured by a traffic counter connected to detector loops (Measures 1 and 2) or photocell pairs (Measures 4 and 5).

Drivers

The number and characteristics of the drivers for each measure are given in Table 2. The study focused on driver behavior, and thus the study excluded pedestrians and bicyclists, as well as police cars, ambulances, fire engines, taxicabs, cars driven by student drivers, motorcycles, mopeds, buses, and trucks. It is noteworthy that the minimum age for a driver's license is 18 years in Finland and 16 years in Michigan.

Vehicle Population

It is assumed that differences in vehicle populations are relatively minor and that they do not have a major impact on the behaviors studied. The most substantial difference is that cars in Finland are generally equipped with manual transmissions, whereas automatic

TABLE 1 Road and Traffic Conditions at Sites of Measures

		Speed Limit (km)		Number of Lanes for Observed Vehicles		Traffic Volume (Vehicles per Hour)	
Measure (Site)	Environment	Lahti	Ann Arbor[a]	Lahti	Ann Arbor	Lahti	Ann Arbor
Speed behavior (1a) and headways (2a)	Suburban streets	70	64	2	2	360	510
Speed behavior (1b) and headways (2b)	Suburban streets	70	72	2	2+1[b]	670	1,160
Use of turn signals before a lane change (3a, b)	Urban and suburban streets	50 or 60	48 or 56	2 or 3	2 or 2+1[b]	400-1,000	600-1,000
Speed while approaching an intersection (4), speed after turning (5), stopping behavior (7c), and gap acceptance (8a)	Suburban intersections with a stop sign	50 80[c]	56 72[c]	1	1	140 390[c]	140 650[c]
Use of turn signals before turning (6a) and stopping behavior (7a)	Urban intersections with a stop sign	50 50[c]	48 48[c]	1	1	60 80[c]	30, 40 90[c]
Use of turn signals before turning (6b), stopping behavior (7b), and gap acceptance (8b)	Suburban intersections with a stop sign	50 80[c]	40 72[c]	1	1	80 540[c]	80 550[c]
Yielding to pedestrians (9a, b)	Controlled downtown intersections	50 50[c]	48 48[c]	1	1	80, 140	60, 100

[a] converted from miles per hour.
[b] a center lane for left-turning vehicles because of a residential cross-street to the left.
[c] a crossing street (volumes in both directions).

TABLE 2 Number and Characteristics of Drivers for Each Measure

Measure (Site)	Number of Drivers		Male Drivers (%)		Estimated Driver's Age (%)					
					<25	25-65	>65	<25	25-65	>65
	Lahti	Ann Arbor	Lahti	Ann Arbor	Lahti			Ann Arbor		
Speed behavior (1a)	1,153	1,458	-	-	-	-	-	-	-	-
Speed behavior (1b)	380	106	-	-	-	-	-	-	-	-
Headways (2a, b)	1,485	1,665	-	-	-	-	-	-	-	-
Use of turn signals before a lane change (3a)	303	225	-	-	-	-	-	-	-	-
Use of turn signals before a lane change (3b)	281	285	-	-	-	-	-	-	-	-
Speed while approaching an intersection (4)	164	170	85.7	63.5	13.0	86.3	0.6	5.6	90.6	3.8
Speed after turning (5)	199	209	-	-	-	-	-	-	-	-
Use of turn signals before turning (6a)	110	115	72.8	71.6	21.9	70.2	7.9	5.9	93.1	1.0
Use of turn signals before turning (6b)	248	267	87.8	62.4	11.4	86.2	2.4	13.3	84.7	2.0
Stopping behavior (7a)	248	183	73.7	67.1	20.2	67.6	12.1	4.9	92.0	3.1
Stopping behavior (7b)	62	79	85.2	55.1	14.8	82.0	3.3	17.9	80.8	1.3
Stopping behavior (7c)	100	91	89.9	64.4	14.1	84.8	1.0	6.9	88.5	4.6
Gap acceptance (8a)	89	127	81.5	65.4	11.1	88.9	0.0	3.8	91.4	4.8
Gap acceptance (8a)	117	164	85.4	60.0	12.5	83.3	4.2	14.6	83.1	2.3
Yielding to pedestrians (9a, b)	154	165	70.5	69.5	17.9	76.9	5.1	25.0	73.5	1.5

- data are unavailable

transmissions are the norm in Michigan. Also, cars are generally smaller in Finland than in Michigan.

Rules and Enforcement

Measures were taken in traffic situations and environments where similar rules applied (Table 1). The risk of being caught while violating the rules was assumed to be similar. In both countries drivers may believe that they are more likely to get a ticket because of exceeding the speed limit than because of an incomplete stop at an intersection with a stop sign. Furthermore, they may believe that they are even less likely to get a ticket because of failure to use a turn signal or because of not yielding to pedestrians. No objective data on the magnitude of the enforcement were collected, because these indicators were considered not to be directly comparable. For example, the same number of hours of enforcement in different regions is unlikely to mean the same strength of enforcement.

Procedure

Data were collected between 9 a.m. and 4 p.m. on Tuesdays through Thursdays in May 1993 (Lahti) and September and October 1993 (Ann Arbor). The observation car was a standard car or van parked in a normal manner. However, while investigating the use of turn signal before a lane change, the observation car was moving. For all measures that involved the use of the video recording, drivers were not able to see the camera before or while the behavior occurred.

To compare driver behavior it was appropriate to select only certain drivers for further analysis or to classify behaviors into categories (Table 3).

RESULTS

Speed Behavior in Free-Flow Traffic

Bartlett's test was performed to test the difference of variances (Table 4). The test was computed between the cities and between the first sites that included the majority of data. No significant differences were found between the two cities in either case.

The proportion of the drivers exceeding the speed limit was different at the two sites in Ann Arbor [$\chi^2(1) = 29.5, p < .00001$], but not in Lahti. At each site in Ann Arbor the proportion of the drivers exceeding the speed limit was smaller than the average in Lahti [for the first Ann Arbor site, $\chi^2(1) = 7.02$ and $p < .008$; for the second Ann Arbor site, $\chi^2(1) = 47.4$ and $p < .00001$]. There was no significant difference between the cities in the proportions of drivers exceeding the speed limit by more than 15 km/hr, but the difference between the sites was significant in each city [for Lahti, $\chi^2(1) = 25.5$ and $p < .0001$; for Ann Arbor, $\chi^2(1) = 19.7$ and $p < .001$].

Headways in Car-Following Situations

This analysis was performed for combined sites for each city by traffic volume, which varied between 200 and 899 vehicles per hour. The proportions of drivers with a short headway varied between 15 and 25 percent in Lahti and between 15 and 30 percent in Ann Arbor. There were no systematic differences in the proportion of short headways for a given traffic volume. However, the proportion of short headways was smaller in Lahti than in Ann Arbor when the traffic volume was 200 to 299 vehicles per hour [$\chi^2(1) = 5.26, p < .03$]. None of the other differences was significant.

TABLE 3 Selection of Drivers and Classification of Behavior

Measure	Selection of Drivers	Classification of Driver Behavior
Speed behavior in a free-flow traffic situation	Vehicles with a minimum headway of 10 s between the actual vehicle and the vehicle ahead	
Headways in car-following situations	Vehicles with a maximum headway of 5 s and the maximum speed difference of 10 s between the actual vehicle and the vehicle ahead	A short headway < 1 s
Use of turn signals before a lane change	(a) A vehicle was observed before a lateral movement or signalling (b) Other traffic travelling in the same direction as the observed car	A driver was categorized as using a turn signal if he/she signalled before crossing a lane marking.
Speed while approaching an intersection, and speed after turning onto a secondary road	(a) Vehicles with a minimum headway of 20 s from a vehicle ahead (b) Only turning drivers were included	
Use of turn signals before turning		A driver was categorized as using a turn signal if he/she signalled before the wheels began to turn or the vehicle stopped.
Stopping behavior at intersections with a stop sign	(a) Vehicles with a minimum headway of 20 s between an approaching vehicle and a vehicle ahead (b) No oncoming vehicles, pedestrians, or bicyclists that affected driver behavior (c) Drivers who accepted the first gap of the traffic flow on the main road	(a) Full stop = the wheels of the vehicle did not roll (b) Rolling stop = the vehicle speed was about the same as the walking speed (c) No stop = the vehicle speed was constant or might be reduced, but the speed was higher than in a rolling stop
Gap acceptance when entering a main road	(a) Vehicles with a minimum headway of 20 s in front of them (b) Vehicles that approached the stopping line in a situation when a gap (lag) on the main road was 10 s or less	
Yielding to pedestrians at intersections	Left-turning drivers (and pedestrians who had a green phase at the same time) when no oncoming vehicles or bicycles	For drivers: (a) Drove on (b) Reacted (braked, weaved, or stopped) For pedestrians: (a) Walked on (b) Reacted (slowed down, stopped, ran, or retreated)

Use of Turn Signals Before Lane Change

As shown in Figure 1, drivers in Lahti signaled more frequently than those in Ann Arbor [$\chi^2(1) = 19.7$, $p < .0001$]. The differences between the two routes were not statistically significant in either city.

Speed While Approaching an Intersection from a Secondary Road

The mean initial speed at a distance of 120 m before the intersection was 58.6 km/hr in Lahti and 64.2 km/hr in Ann Arbor, reflecting the differences in the posted speed limits. The proportions of drivers exceeding the speed limit initially (82.9 percent in Lahti and 81.4 percent in Ann Arbor), right-turning drivers, and drivers accepting the first gap when entering the main road were not significantly different.

Figure 2 shows for each city the mean approach speed at distances of 120, 90, 60, and 30 m before the intersection. On average the speed change (in comparison with the initial speed at 120 m) was greater in Lahti than in Ann Arbor at 90 m [4.1 versus 0.6 km/hr; $F(1,324) = 51.9$, $p < .0001$] and at 30 m [20.4 versus 18.0 km/hr; $F(1,309) = 7.38$, $p < .02$), but not at 60 m (9.1 versus 9.0 km/hr). In Ann Arbor (but not in Lahti) there was a

TABLE 4 Speed Behavior in Free-Flow Traffic by Site

	Lahti		Ann Arbor	
Aspect	a	b	a	b
Mean and median speed (km/h)	80	77	73	75
Standard deviation (km/h)	9	7	9	9
85-percentile of the speed, v_{85} (km/h)	89	84	82	85
Exceeding speed limit (%)	88.3	84.5	84.0	63.2
Exceeding speed limit by more than 15 km/h (%)	24.6	12.1	23.2	4.7

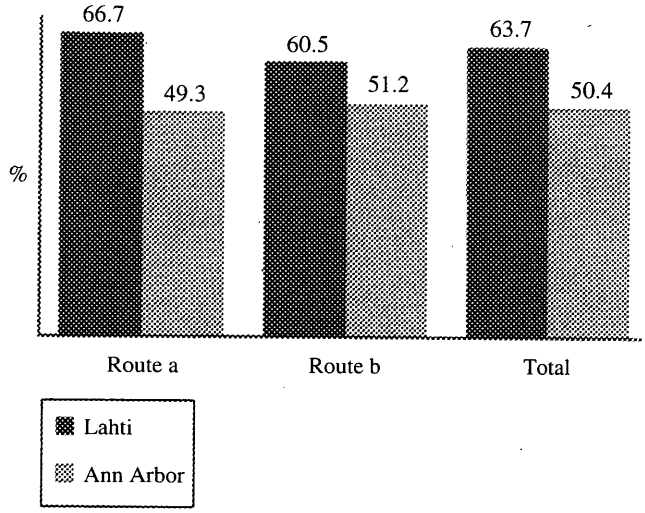

FIGURE 1 Proportion of drivers using turn signal before lane change by route.

slight incline uphill that helped to decrease speed. Consequently, the results suggest that the drivers in Lahti approached the intersection from the secondary road slightly more cautiously than the drivers in Ann Arbor. The standard deviations of the speed distributions at different distances from the intersection varied between 5.9 and 9.7 km/hr in Lahti and between 5.9 and 8.3 km/hr in Ann Arbor.

The speeds at the four locations were submitted to an analysis of variance by using the following three main factors: city, sex, and acceptance of the first gap while entering the main road. The effect of city was significant, mostly because of the higher initial speed. More interestingly, the effect of gap acceptance was significant at each distance: 120 m [$F(1,286) = 7.09, p < .01$], 90 m [$F(1,286) = 6.89, p < .01$], 60 m [$F(1,286) = 5.63, p < .02$], and 30 m [$F(1,286) = 12.9, p < .001$]. Drivers accepting the first gap drove faster at each location, with a tendency for this difference to be greater in Lahti than in Ann Arbor. The effect of sex was not significant (as in all of the following measures in which sex was recorded), as were all interactions.

Speed After Turning onto Secondary Road

The drivers in Lahti tended to accelerate more slowly than those in Ann Arbor (Figure 3). However, the result must be interpreted cautiously because of the higher speed limit and the slight incline downhill in Ann Arbor. The standard deviation of the speed was 5.6 to 6.4 km/hr in Ann Arbor and 4.7 to 6.1 km/hr in Lahti. The last speed measurement at a distance of 120 m from the intersection showed that 69.3 percent of the drivers in Lahti and 56.5 percent of the drivers in Ann Arbor exceeded the speed limit [$\chi^2(1) = 7.24, p < .01$].

Use of Turn Signals Before Turning

Drivers in Lahti signaled more frequently than those in Ann Arbor (Figure 4). This was the case at the urban intersections [for left turn, $\chi^2(2) = 22.9$ and $p < .00001$; for right turn, $\chi^2(2) = 16.3$ and $p < .00001$] and at the suburban intersections [for left turn, $\chi^2(2) = 2.05$ and p was not significant; for right turn, $\chi^2(2) = 16.3$ and $p < .0001$]. The effect of the turn direction was not significant at each intersection.

One could assume that there might be drivers who signaled only if they saw other traffic in the vicinity. Furthermore, the suburban intersection in Ann Arbor had traffic from only one secondary road, whereas the other intersections had traffic from two directions. Therefore, the effect of other traffic was computed by each turn direction at urban intersections. The results revealed that drivers tended to signal more frequently if no traffic was in the vicinity. However, none of the four pairwise differences was significant.

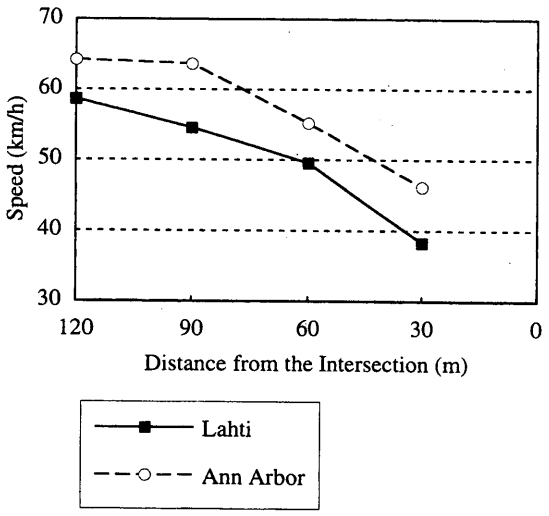

FIGURE 2 Mean speed while approaching an intersection from a secondary road.

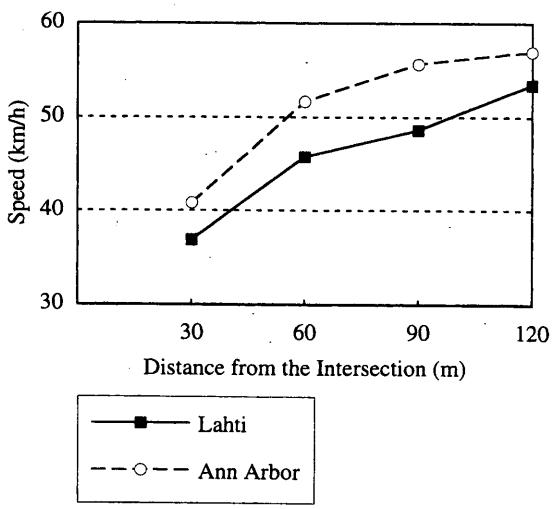

FIGURE 3 Mean speed after turning onto secondary road.

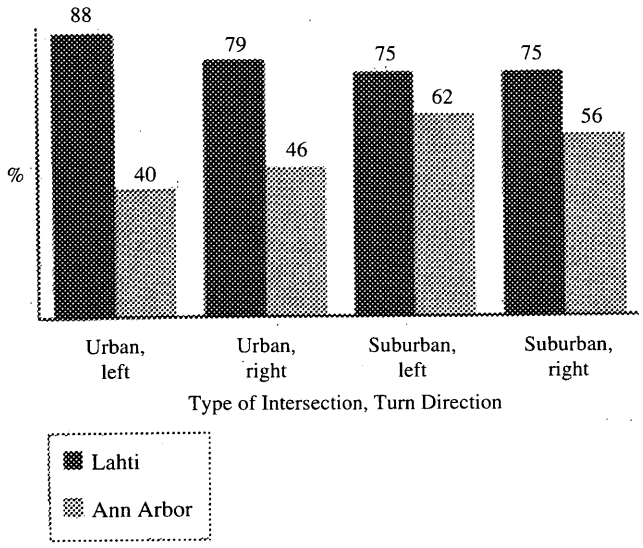

FIGURE 4 Percentage of drivers using turn signals before turning, by turn direction.

Stopping Behavior at Intersections with a Stop Sign

Stopping behavior by intersection and turn direction is presented in Figure 5. The following two hypotheses were tested for each turn direction and between each pair of intersections.

Is there a cross-national difference in the proportion of full stops? A comparison of the corresponding traffic streams showed that at each intersection right-turning drivers in Lahti came to a full stop more frequently than those in Ann Arbor [for urban intersections, $\chi^2(1) = 11.1$ and $p < .001$; for the first suburban intersections, $\chi^2(1) = 5.39$ and $p < .03$; for the second suburban intersections, $\chi^2(1) = 23.5$ and $p < .00001$]. The through-traveling drivers were investigated at urban intersections only. As in the case of the right-turning drivers, drivers in Lahti came to a full stop more frequently than those in Ann Arbor [$\chi^2(1) = 13.6, p < .001$]. Comparison of the left-turning drivers showed that at the second suburban intersections the difference was significant [$\chi^2(1) = 7.77$, $p < .01$], but the difference was not significant at the urban intersection. (At the first suburban intersection the test of significance was not performed because of the small number of left-turning drivers.)

Is there a cross-national difference in the proportion of no stops? Only the difference for the across-traveling drivers at urban intersections was significant [$\chi^2(1) = 4.26$, $p < .04$], with drivers in Lahti coming to no stops more frequently than those in Ann Arbor.

Gap Acceptance When Entering a Main Road

Overall, there was no significant difference between the cities in the durations of the first gap (accepted or rejected). Critical gaps, that is, the gap size that 50 percent of the drivers accepted, were computed for drivers who rejected the first gap (only the durations of the first rejected and accepted gaps were measured). In each case the critical gap was longer in Lahti than in Ann Arbor (Figure 6). Unfortunately, the results based on the long time separations (because of the small numbers of drivers) allowed only the order of the critical gaps, but not their absolute values, to be defined.

The durations of the first gaps that were accepted were submitted to an analysis of variance by using city and turn direction as factors. The two main effects and their interaction were not statistically significant.

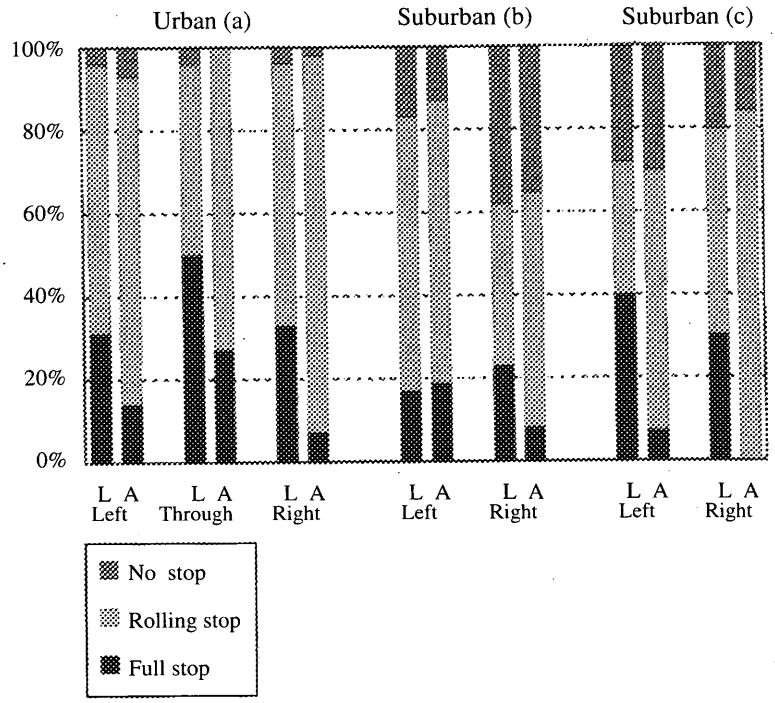

FIGURE 5 Stopping behaviors at three intersections in each city, by turn direction (L = Lahti, A = Ann Arbor).

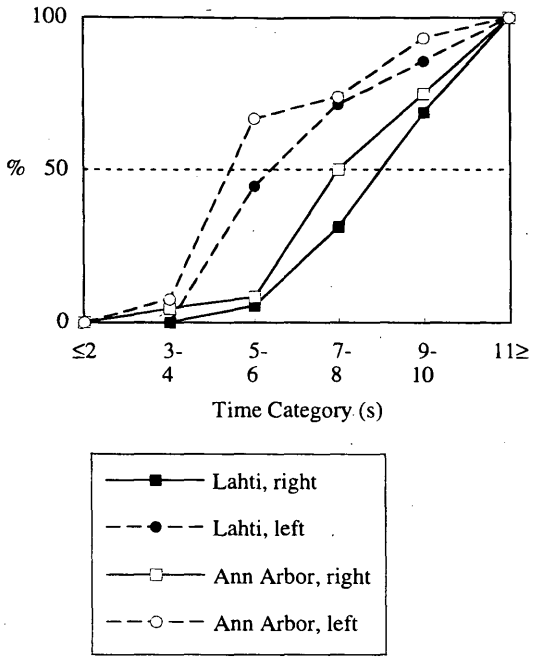

FIGURE 6 Critical gaps at both intersections, by turn direction.

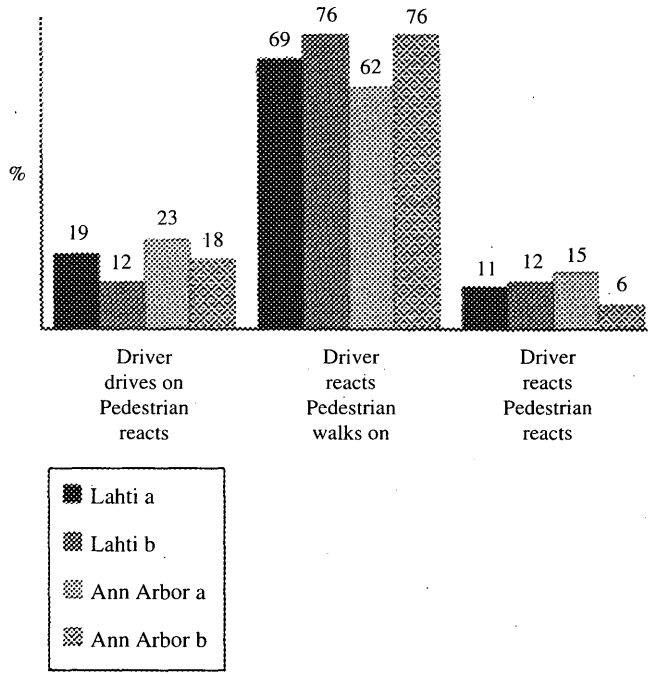

FIGURE 7 Proportions of different type of interactions.

Yielding to Pedestrians at Intersections

The results in Figure 7 indicate no significant difference in the proportions of the interactions between cities or between intersections in each city. Driver behavior, cross-tabulated by the number of pedestrians in the interaction, showed that if one to two pedestrians were in interaction, there were some instances of drivers in each city who did not yield to pedestrians (the difference between the cities was not significant). However, when there were three to four pedestrians, that happened only in Ann Arbor [18 and 23 percent; $\chi^2(1) = 8.66, p < .01$].

DISCUSSION OF RESULTS

The goals of the present study were (a) to develop a set of measures that could be used to observe driver behavior in different countries, different parts of a country, or longitudinal studies and (b) to compare driver behavior in Finland with driver behavior in Michigan. The results of the study will be discussed in terms of these two goals.

Development of Set of Measures

The comparison made between Finland and Michigan showed that each of those measures was usable. Given that, the following are essential questions: How reliable and valuable are the results that these measures provide? The problem of reliability includes three broad areas: (a) techniques of data collection and interpretation of the data, (b) matching of environmental factors and specific rules, and (c) numbers of drivers.

Techniques of Data Collection and Interpretation of Data

The speed and headway data collected by the traffic counter are reliable (*6*). Data collection by the video recording technique provides the possibility of examining every event carefully and replaying it if necessary. In addition, the video recording technique provides the possibility of counting actual traffic volumes. However, the data have room for interpretations. The most evident interpretation problem of the present study was the separation of rolling and no stops at intersections with a stop sign. The separation was based on the comparison of walking and driving speeds, but it may involve systematic bias if several people estimate the speed. In the present study, however, one person interpreted all of the data.

Matching of Environmental Factors and Specific Rules

The lists of selections and definitions show the limited scope of the study. However, it is emphasized that these selections and definitions must be explicit to show how much caution must be taken while generalizing the results. On the other hand, the limitations of the study do not invalidate the results, because the goal of the study was to collect basic information on driver behavior.

If one estimates how well the match succeeded in the comparisons that were performed, some shortcomings can be seen. First, in the comparison of speed behavior and headways, the second site in Ann Arbor seemed to be different because there were intersections. In addition, the similarity of the 85th percentile of the speed but a lower percentage of drivers exceeding the speed limit suggests that the speed limit was relatively high. The second major concern was that the traffic volumes on the main road were substantially different for Measures 4 and 8a (Table 1). However, this presumably did not influence the comparisons unduly because the results showed

that drivers who accepted or rejected the first gap decreased their speeds similarly in both cities. The comparison of gap acceptance behavior was based on critical gaps, ruling out a major influence of different volumes on the main road.

Number of Drivers

In studies like the present one the question about the number of drivers is always connected to the amount of time that is allowed for data collection. Especially in the case of measures such as speed while approaching an intersection and gap acceptance, attention should be paid to this question, because only a small amount of data is usable for further analysis. Perhaps it would be possible to collect these data with loop detectors, providing possibilities for collecting a substantial amount of data.

The study was not based on data collection at a random sample of sites in two cities, because the goal was to develop and test the set of measures. If the goal is to obtain a general picture from one or two countries, special attention must be paid to the selection of the sites to cover the target area without any bias.

Value of Results

The question of the value of the comparison of driver behavior is difficult to answer on the basis of this individual comparison. However, the question is worth discussing. It was assumed that the measures would show different aspects of driver behavior that have potential safety effects. As indicated earlier, it is not known whether this is the case. It is hoped that further research will show the possible connections by comparisons of driver behavior and traffic accidents. The main difficulty of this approach has been the lack of a sound methodology for investigating driver behavior. Therefore, the study produced a research tool. Also, this kind of tool may be necessary when similar technical applications are intended for use in different countries or within a large country. Of course, it is possible to add other measures to this set of measures: the use of safety belts, the use of motorcycle and bicycle helmets, and the proportion of drunk drivers, for example (*6,8*).

Comparison of Driver Behavior in Finland and Michigan

The results of the study suggest that, overall, driver behaviors are rather similar in Lahti and Ann Arbor, and most of the differences are minor. This main finding was expected because the patterns of road accidents in Finland and the United States are relatively similar (*9*). Although no comparison of road accidents in Finland and Michigan has been conducted, there is no reason to believe that the patterns are more different than those between Finland and the United States. In addition, there is evidence that drivers assess risks connected to traffic similarly (*10*).

However, there were substantial differences in the proportion of drivers who used turn signals and in the proportion of full stops at intersections with a stop sign. These differences suggest that Finnish drivers obey specific traffic rules more often than Michigan drivers, which may reflect differences in societal values and norms. This conclusion is supported by two arguments. First, it is well known that individual freedom is more emphasized in the United States than in Europe and, especially, in Scandinavia (*11*). In traffic research this aspect has been frequently evident in the rates of usage of safety belts, with safety belt use rates being higher in Europe than in the United States (*12*). This difference also applies for Finland versus Michigan (*7*). Second, given that minimum driver training is more extended in Finland than in Michigan (*7*) it can be assumed that both the perceived behavioral differences and the mandatory duration of driver training reflect the values and norms of the society. In addition, the training may directly improve the frequency of obeying specific rules, because the applicants usually concentrate on learning rules (*13*). On the other hand, the conclusion concerning obeying traffic rules cannot be generalized to all specific rules, because drivers in Lahti tended to exceed the speed limit more frequently than drivers in Michigan, and yielding to pedestrians and the proportion of full stops were not different. Also, differences in behavior may be influenced by general differences in traffic control or trip length. For example, Michigan drivers may be more unwilling to come to a full stop than Finnish counterparts because of more frequent stop signs instead of yield signs and longer average trips.

The present results did not support the assumption that some positive indication of the longer history of motorized transportation in the United States would be detected. In contrast, compared with drivers in Lahti, drivers in Ann Arbor tended to decrease speed later while approaching the intersection from a secondary road, to accelerate more rapidly after turning onto the secondary road, and to accept slightly smaller gaps while entering the road.

ACKNOWLEDGMENTS

This study was conducted as a joint project of the Technical Research Centre of Finland (VTT) and the University of Michigan Transportation Research Institute (UMTRI). Appreciation is extended to the Academy of Finland and the Henry Ford Foundation for support of this research. The author thanks the following people for their contributions: Veli-Pekka Kallberg, Risto Kulmala, and Erkki Ritari (VTT); Martti Niskanen (city of Lahti, Finland); Masami Aoki, Michael Sivak, and Eric Traube (UMTRI); Bob Stegink (University of Michigan); and Nancy Greenleaf Gibson and Richard Watkins (city of Ann Arbor).

REFERENCES

1. Smeed, R. J. Research into Driver Behaviour. *Proc., Meeting of the International Statistics Institute*, Vienna, 1974.
2. Benjamin, T. *A Fifteen-Country Study of Some Factors Influencing the Number and the Severity of Road Accidents—Drivers' Risk-Taking, Speed Behaviour and Accidents on Motorways*. International Drivers' Behaviour Research Association, Arcueil, France, 1980.
3. Leutzbach, W., et al. *Vergleich der Verkehrssicherheit in der Bundesrepublik Deutschland und Grossbritannien* [Comparison of Traffic Safety in Federal Republic of Germany and Great Britain]. Lfd. 183. Bundesanstalt für Strassenwesen, Bergisch Gladbach, Germany, 1988.
4. Nagayama, Y. International Comparison of Traffic Behavior and Perceptions of Traffic. *IATSS Research*, Vol. 13, No. 1, 1989, pp. 61–69.
5. Slätis, A. *Hur Mäter Man Trafikmoralen—Studier av Trafikbeteenden i Stocholm* [How to Measure Traffic Responsibility—Studies on Traffic Behavior in Stockholm]. Report 57. Traffic Safety Association in Stockholm, Stockholm, 1990.

6. Heino, J. *Liikennekäyttäytymisen Seuranta 1993* [Follow-up Study on Road-User Behavior 1993]. Research Notes 69. The Central Organization for Traffic Safety, Helsinki, 1994.
7. Luoma, J. *Toward a Methodology for Field Observations of Driver Behavior: A Comparison of Finland and Michigan.* Report UMTRI-94-16. The University of Michigan Transportation Research Institute, Ann Arbor, 1994.
8. Streff, F. M., D. W. Eby, L. J. Molnar, H. C. Joksch, and R. R. Wallace. *Direct Observation of Safety Belt and Motorcycle Helmet Use in Michigan: Fall 1993.* Report UMTRI-93-44. The University of Michigan Transportation Research Institute, Ann Arbor, 1993.
9. Luoma, J., and M. Sivak. *Traffic Accidents in Finland and the U.S.A: A Cross-Cultural Comparison of Associated Factors.* Report UMTRI-92-26. The University of Michigan Transportation Research Institute, Ann Arbor, 1992.
10. Luoma, J. Driver Risk Assessment in Finland and Michigan. Report UMTRI-95-15. The University of Michigan Transportation Research Institute, Ann Arbor, 1995.
11. Hofstede, G. Cultures and Organizations. Software of the Mind. Intercultural Cooperation and Its Importance for Survival. McGraw-Hill Book Company, London, 1991.
12. Campbell, B. J., and F. A. Campbell. Seat Belt Law Experience in Four Foreign Countries Compared to the United States. AAA Foundation for Traffic Safety, Falls Church, Va., 1986.
13. Luoma, J. Autokoulu ei Opeta Tunnistamaan Vaaroja [Driving school does not improve recognition hazards]. *Liikennevilkku*, Vol. 31, No. 4, 1984, pp. 22–24.

Publication of this paper sponsored by Committee on Vehicle User Characteristics.