UPPSALA UNIVERSITET

Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Social Sciences 10

The Prediction of Traffic Accident Involvement from Driving Behavior

ANDERS AF WÅHLBERG

ACTA UNIVERSITATIS UPSALIENSIS
UPPSALA
2006

ISBN 91-554-6443-2
urn:nbn:se:uu:diva-6296

Dissertation presented at Uppsala University to be publicly examined in 1022, Gårdshuset, Uppsala, Tuesday, February 21, 2006 at 13:15 for the degree of Doctor of Philosophy. The examination will be conducted in English.

Abstract
af Wåhlberg, A. 2006. The Prediction of Traffic Accident Involvement from Driving Behavior. *Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Social Sciences* 10. 44 pp. Uppsala. ISBN 91-554-6443-2.

The aim of the studies was to predict individual traffic accident involvement by the quantification of driving style in terms of speed changes, using bus drivers as subjects. An accident database was constructed from the archives of the bus company whose drivers were used as subjects. The dependent variable was also discussed regarding whether responsibility for crashes should be included, and what time period to use for optimal prediction. A new theory was constructed about how accidents are caused by driver behavior, more specifically the control movements of the driver, i.e. all actions taken which influence the relative motion of the vehicle in a level plane when v>0. This theory states that all traffic safety related behavior can be measured as celerations (change of speed of the vehicle in any direction of a level plane) and summed. This theoretical total sum is a measure of a person's liability to cause accidents over the same time period within a homogenous traffic environment and a similarly homogenous driving population. Empirically, the theory predicts a positive correlation between mean driver celeration behavior and accident record. The theory was tested in three empirical studies. The first tested equipment and methods, the second studied the question whether driver celeration behavior is stable over time. Celeration behavior turned out to be rather variable between days, and repeated measurements were therefore needed to stabilize the measure. In the third study, a much larger amount of data brought out correlations of sizes sufficient to lend some credibility to the theory. However, the predictive power did not extend beyond two years of time. The reported results would seem to imply that the celeration variable can predict accident involvement (at least for bus drivers), and is practical to use, as it is easily and objectively measured and semi-stable over time.

Anders af Wåhlberg, Department of Psychology, Box 1225, Uppsala University, SE-75142 Uppsala, Sweden

ISBN 91-554-6443-2
urn:nbn:se:uu:diva-6296 (http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-6296)

This thesis is dedicated to those who did not make it this far;
Per-Arne Rimmö, Elsa Sjöberg, and my father.

The present work is based upon the following papers;

Study I: af Wåhlberg, A. E. (submitted). Driver celeration behavior and accidents – an analysis.

Study II: af Wåhlberg, A. E. (2000). The relation of acceleration force to traffic accident frequency: A pilot study. Transportation Research Part F: *Traffic Psychology and Behaviour, 3,* 29-38.

Study III: af Wåhlberg, A. E. (2004). The stability of driver acceleration behavior, and a replication of its relation to bus accidents. *Accident Analysis and Prevention, 36,* 83-92.

Study IV: af Wåhlberg, A. E. (submitted). Driver celeration behavior and the prediction of traffic accidents.

Contents

Introduction

> Unless one can predict accidents, in some sense, above the chance level, one cannot meaningfully claim to understand the processes involved in accidents.
>
> Levonian, Case & Gregory, 1963, p. 50.

The problem

The prediction of traffic accident liability has been an ongoing endeavor for close to a hundred years. No great success has ensued, despite early and many claims to the contrary (see for example Baker, 1932). Actually, already in 1946, Johnson published a scathing criticism of more than a hundred studies whose authors he deemed had overrated the predictive power of the available tests, something which is closely related to the study of what variables are associated with accident liability. Not much has changed since then; in the beginning of the new millennium it was possible to list more than a hundred studies on psychological predictors of accident liability from the past fifty years, and find that an overwhelming majority was of low methodological quality (af Wåhlberg, 2003a).

Some new principles, and better methodology, are obviously needed to better tackle the problem of predicting[1] who is a dangerous driver before accidents start to pile up. In the present work, one of the leading rules of thumb was to measure as close to the accidents as possible. This means that a host of methods usually employed by psychologists were ruled out as being too unreliable, and probably invalid, because they measure variables with doubtful relations to the traffic situation, like intelligence (e.g. Larson & Merritt, 1991; Smith & Kirkham, 1982) or personality (e.g. Shoham, Rahav, Markovski, Chard & Baruch, 1984; Pestonjee & Singh, 1980; Arthur & Graziano, 1996; Furnham & Saipe, 1993).

It would seem that few researchers have taken seriously the variation in human behavior that is present in driving (as pointed out by Stewart, 1958), and what this means for the prediction of accidents; exceedingly few test the stability over time of their predictor variables (af Wåhlberg, 2003a). Many seem instead to take for granted that a bad driver at one time is a bad driver

[1] 'Prediction' is in the present work mainly intended to denote methodology, not statistics.

all the time. However, some studies have found that accident liability seem to rise when a person is under stress of some kind (Selzer & Vinokur, 1975; Selzer, Rogers & Kern, 1968; McMurray, 1970; Holt, 1982; but see also Isherwood, Adam and Hornblower, 1982), which is not a very stable state for humans. People also adapt (or at least change) their driving to environmental circumstances in many ways (e.g. Fuller, 1981; af Wåhlberg, 2003b). These various sources of variance make it exceedingly difficult to predict traffic behavior in general and especially accidents from small amounts of data, for example tests, when administered only once.

Furthermore, there is also the problem of accidents having many causes, and any number of specific variables being related to them (for reviews see Golding, 1983; Lester, 1991; af Wåhlberg, 2003a). Also, although some people seem to have repeated accidents of the same type, this is not a strong factor (Baker, 1929; Stewart, 1958). The predictive power of any specific variable is therefore rather limited, and apart from the very few multivariate studies on accident predictors (e.g. Häkkinen, 1958; Asher & Dodson, 1971; Harano, Peck & McBride, 1975; McKnight & McKnight, 1999; see further af Wåhlberg, 2003a), any practically useful degree of explained variance has rarely been found[2]. The same has been claimed for the German literature by Noordzij (1990).

Due to the various problems listed here, there would seem to exist a need for variables that have the properties of being stable over time, are easy to measure (so that large amounts of data can be gathered), are general to their nature, and are associated with traffic accident involvement. Taking a different road (so to speak) than most other researchers concerning driver behavior, it could be asked whether there is such a thing as 'driving style', i.e. something which pervades most aspects of what a driver does, or could be said to be a recognizable (preferably measurable) feature in the driver's behavior? This question arises out of the many scattered results in accident research; if predictive power is to be had without having to measure any number of variables, we have to find the common thread of driver behavior. It will here be suggested that this common property is driver celeration[3] behavior, i.e. all changes in speed in the plane of the road.

---

[2] What is practically useful does of course differ between situations, but as no single type of measurement has been accepted by the transport industry or state agencies in many countries, it would seem that at least these organizations do not consider them useful.

[3] There have been some changes in terminology throughout the work presented here. The use of the word 'force' was erroneous in that the intended meaning was not that of force as used by physicists. Also, 'acceleration' was used to denote both negative and positive change in velocity, which might have created some confusion when it was sometimes used for positive change only. The term driver celeration behavior is defined in Study I, and only that meaning is intended. Other uses, within statistics for example, are not intended. In the present work, 'driver celeration behavior' denotes the theory and its implementation, while 'acceleration' and 'deceleration' have no theoretical connotations but are the common physical terms, and are

The dependent variable; accident history

One of the basic problems of traffic accident prediction is the scarcity of crashes; it is very hard to get any statistical power in a sample of western car drivers for the three-year period used by most researchers (af Wåhlberg, 2003a). Most of the subjects will have zero accidents, and the resulting predictive power of any variable very low (Cobb, 1940; Peck, 1993). To further complicate matters, it is close to impossible to get valid accident data for private drivers; police records are notoriously unreliable apart from where deaths are involved, hospitals only record injuries and deaths, and insurance companies only claims made (about this type of problem, see for example Fife & Cadigan, 1989; Hopkin, Murray, Pitcher, & Galasko, 1993; Rosman & Knuiman, 1994; Rosman, 2001; Rosman, Ferrante & Marom, 2001; for a review, Hauer & Hakkert, 1988). And even if these sources were pooled, there would probably still remain a large percentage of incidents where none of these agencies had been notified (Harris, 1990), although comparisons between insurance files and other sources are scarce.

The common solution to this problem is to use self-reported crashes as dependent variable. However, self-reports concerning accidents are not that reliable (correlations with other sources are seldom above .50, af Wåhlberg, 2002b), as they are rapidly forgotten (Chapman & Underwood, 2000; Maycock, Lockwood & Lester, 1991) and in general are badly contorted when reported (Maycock & Lester, 1995; Pelz & Schuman, 1968; but see also Dalziel & Job, 1997[4]), in number and details (af Wåhlberg, 2002b). They also tend to give different results for associated variables as compared to official sources (Smith, 1976; Arthur et al, 2001).

Some have suggested that the way to overcome this problem is by measuring intermediate variables (Shaoul, 1976), like traffic conflicts (e.g. Risser, 1985), which in principle would seem to be a reasonable method. However, no great success seem to have been reported in the international literature, probably because the amounts of data have been too small, and it is kind of hard to study this variable for identified drivers.

There is, however, a source of incident data that is probably much more reliable than any of those mentioned above; transport company records. Given that there is a system for gathering reports and that the records are well kept, a transport company has many advantages when it comes to studying traffic accidents. The accident data used in the present work was therefore collected from the local bus company in Uppsala, Sweden (for details see af Wåhlberg, 2002a; 2004; 2005).

---

used to denote research not guided by the celeration theory, and the pure physical phenomenon of speed changes.

4 The high agreement between self-reports and archival material found by these authors was probably due to methodological peculiarities that are usually not present in other studies; mainly that the drivers were aware that their answers would be checked.

A further problem in the study of traffic accidents is that of causation, or culpability. Many researchers do not make any distinction between accidents which a person has caused and those which he or she has had no part in as an active part (see af Wåhlberg, 2003a, for a review). However, apart from the theoretical problems of predicting from your personal characteristics that someone else will hit you, there are also a number of studies in the traffic domain where culpable accidents have been shown to have stronger associations with diverse individual differences variables (apart from exposure) (e.g. Lajunen, Corry, Summala & Hartley, 1997; Gully, Whitney & Vanosdall, 1995; Arthur & Graziano, 1996; Rajalin, 1994; see also Garretson & Peck, 1982).

The final issue discussed here regards what time period should be used in a study for calculating frequency (or number) of accidents, another issue that has rarely been raised by traffic researchers (af Wåhlberg, 2003a; see McKenna, 1983, and Ball, Owsley, Sloane, Roenker & Bruni, 1993, for discussions of this problem). Consider that accidents do not correlate well between short time periods but better for longer periods (Häkkinen, 1958; Schuster, 1968; Burg, 1970; Bach, Bickel & Biehl, 1975; Miller & Schuster, 1983; McKenna, Duncan & Brown, 1986; French, West, Elander & Wilding, 1993; Peck, 1993). What does this mean? Possibly that the accident variable really is not very stable over time, or that the risk is so low that we cannot achieve any true measure of its reliability without using decades of data. But this in its turn mean that the time period used as dependent variable must be chosen with care, because different time periods might yield vastly different answers to your questions. This is especially evident if you consider that behavior changes over time, which mean that any measurement has limited predictive power over time. What you measure today may simply not be representative for what things were like a few years ago. For accidents, you therefore get two contrary effects; a longer time period will give you a more stable dependent variable with better statistical properties, but it will also probably give you a declining predictive power of the independent variable.

The independent variable; driver behavior

As there are many sources of variance in the traffic environment apart from the individual driver, one of the main problems of psychological traffic research is to sort out what could be said to be due to individual preferences and abilities, and what is (for the purpose of the research) environmental noise. For example, speed choice studies have the problem of deciding what distance to other vehicles can be accepted as proof of volitional behavior, unrestricted by other road users (e.g. Haglund & Åberg, 2000). Headway research has similar problems (e.g. Evans & Wasielewski, 1982; 1983).

Concerning speed changes, and especially given the way that celeration behavior is conceptualized and measured in the present work, there are probably differences between driving in dense versus light traffic and city versus rural areas. It is therefore important to try to hold such factors constant when trying to establish individual differences on this variable. In this respect too, transport companies are very advantageous to study, especially bus companies who run regular public services. In fact, a bus running on a route is very much a moving laboratory, where the researcher has automatic control of many factors (or at least they are held constant). For example, the roads used are the same, and so is often the vehicle. If time of day is deemed to be of importance, statistical and/or methodological controls can be used, there is a steady stream of more or less willing subjects (for the present work the drivers, for other purposes the passengers, see af Wåhlberg, in press, a), and research can often be totally covert. Also, many drivers and passengers will return and can be measured again, with obvious advantages for the zealous scientist. Most important though, drivers can be identified and various background data gathered from the company.

Previous research

Several areas of research may be noted as predecessors of the present work. In the most general sense, all studies, which have tried to predict traffic accident involvement for individual drivers, may be noted. At least 150 papers fall into this category (for reviews see Signori & Bowman, 1974; McGuire, 1976; Golding, 1983; Hansen, 1988; Lester, 1991; Elander, West & French, 1993; Peck, 1993; Arthur, Barrett & Alexander, 1991; af Wåhlberg, 2003a). Predictive power has usually been very low for such studies, which can be illustrated by the multivariate study of Harano, Peck and McBride (1975); out of 27 variables entered into a regression, 15 turned out significant at $p<.10$, yielding an R of .69. However, this was a contrasted sample, so the predictive power was somewhat inflated. Also, R shrank to .47 at cross-validation.

A sub-group of these studies are those which have used variables that may be interpreted in terms of speed changes, i.e. celeration, for example close following (Evans & Wasielewski, 1982; 1983), sudden lane changing (Gully, Whitney & Vanosdall, 1995), speed (Kloeden, McLean, Moore & Ponte, 1997) and abrupt stops (Babarik, 1968). See also Quenault (1968a; 1968b), who reported that drivers convicted of careless driving carried out more unnecessary maneuvers than other drivers, and Edwards, Hahn and Fleishman (1977), who found a correlation between accident record and some type of vaguely described braking variable in a simulator environment.

A further few have tried predicting accidents with an explicit acceleration variable; Lajunen and Summala (1997), Lajunen, Karola and Summala, (1997)[5], and Quimby, Maycock, Palmer and Grayson (1999). None of these studies succeeded in showing any good evidence in favor of an acceleration-accident association. Also, Malfetti and Fine (1962) included various accelerations in their study of extremely safe drivers (and found them to be low). Finally, there is the peculiar case of Robertson, Winnett and Herrod (1992), who analyzed driver acceleration behavior in mathematical detail, and stated that this type of variable should be associated with accidents, but did not test the hypothesis or develop it beyond this basic statement. It might also be added that none of the studies that explicitly tested acceleration as predictor of crashes stated any reason for this, apart from mentioning the Robertson et al study.

Very few researchers have explicitly used accelerations as a measure of driver behavior, in terms of individual differences[6]. Apart from the accident predictor studies above, Lewis (1956) studied the stability of driver behavior on a test-track, concerning how they approached corners and similar obstacles, while Aschenbrenner and Biel (1994) used acceleration and deceleration patterns for the study of possible behavior changes due to ABS brakes, and Godley, Triggs and Fildes (2002) validated aspects of a driving simulator.

Regarding bus drivers, most research on this population has been about stress and various medical conditions (e.g. Bartone, 1989; Duffy & McGoldrick, 1990; Evans, 1994), although some have tried to predict their accidents (e.g. Bacqueyrisse, 1935; Brandaleone & Flamm, 1955). However, many of these studies used only age and experience (e.g. Cornwall, 1962; Blom, Pokorny & van Leeuwen, 1987) as independent variables, and they do not explain a lot of variance. Instead, the dissertation of Häkkinen (1958) remain the seminal work in this area; bus and tram drivers were studied for a long period of time regarding a large number of physiological and psychological variables in relation to their accident rate (with a follow-up two decades later; Häkkinen, 1979).

Study I: Theory

The first paper included in the present thesis describes the theory, one prediction of which is tested in the other papers. It concerns the prediction of accident record by an objective, quantitative measure of driving style; celeration behavior. The first part of the theory describes this driver behavior variable. The word 'style' implies certain characteristics that are important for the understanding of the celeration behavior theory; it is a general, not

[5] The two studies by Lajunen et al seem to use the same set of data.
[6] Instead, technicians often seek some kind of mean behavior (across subjects) for the establishment of driving cycles etc (e.g. Booth, 2002).

specific behavior, like speed choice or mistakes. It is instead the common part of a number of different driver behaviors, which all add up to a single measure. As in principle all behavior of importance for safety in traffic concerns vehicle control behavior, directly or indirectly, it would seem natural to interpret this as changes in speed in various directions. In this way, many different driver behaviors can feed into a common variable (see Figure 1), which is easily measured. The relation between celeration behavior and other vehicle control variables can be exemplified by speed; a positive correlation is expected to exist, but it is not necessarily high.

It is important to point out that celeration behavior is not just the volitional acts of the driver, like speeding, but also for example reactions that are forced upon him/her by bad planning (failing to foresee a change to red at an intersection) or vigilance (failing to notice another road user) and therefore having to brake hard. Another way of conceptualizing this variable is as a measure of conflicts with the driving environment and other road users. The theoretical specification of celeration behavior is described in Formula 1.

Formula 1: Theoretical specification of all speed changes undertaken by a driver during movement of vehicle, from start of driving to end. Under the condition of v>0, where Δv=a, the following formula describes driver celeration behavior over a specified time of driving;

$$C = \int_{t_0}^{t_n} |a(t)| dt$$

where

C = total (individual) driver celeration behavior for the designated time period

a = acceleration (positive and negative) in the plane of the road

dt = the time difference between two speed samplings

t_0 = time for start of driving

t_n = time for end of driving

The second part of the theory concerns the relation of this summed behavior to accidents. Many of the behavior variables found to be associated with accidents in the previous section can be interpreted in terms of celerations, and would thus feed into the general measure, as well as they add to the risk for an incident. Therefore, a driver with a high level of celeration behavior will also have a high level of accidents, given all else equal.

More specifically, the driver celeration behavior theory states that the standardized celeration behavior value of a driver driving in a homogenous driving environment for a very long time will be the same as his standardized number of culpable accidents within a homogenous population driving in the same environment during the same time period. This relation is specified in Formula 2.

Formula 2: Theoretical specification of the relation between a driver's celeration behavior and his number of accidents for a very long time period in a homogenous driving environment and driving population.

$$\frac{I-\mu_I}{\sigma_I} = \frac{C-\mu_C}{\sigma_C} \Rightarrow \mathrm{I} = \frac{(C-\mu_C)\times\sigma_I}{\sigma_C} + \mu_I$$

where
I = expected total number of culpable traffic incidents
C = total amount of celeration behavior, as defined in Formula 1
μ = the mean in the population
σ = the standard deviation in the population

The homogeneity of the environment concerns the average risk encountered by the driver that is not due to his own behavior, and the influence of the environment on his celeration behavior. If the average on these variables are fairly equal for the drivers in the specified population, homogeneity can be said to exist. This means that homogeneity is really a relation between the population and the environment; if all drivers are equally exposed for all parts of a driving environment, this environment can be said to be homogenous, despite it being very different between parts. Variables that can be suspected to influence the risk and/or celeration behavior are type of vehicle, weather, type of road and traffic density.

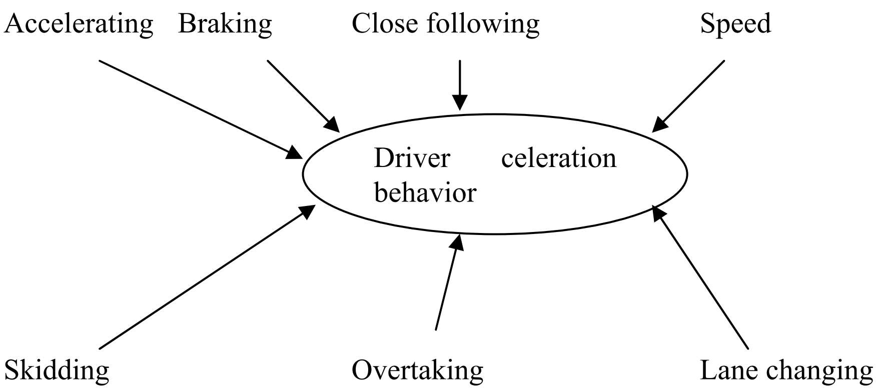


Figure 1. Some of the many behaviors that add to the mean celeration behavior value of a driver.

It is important to point out that celeration behavior is only in existence when the vehicle is moving (v>0), and data should therefore not be collected from standstills. Furthermore, the total of celerations (over a specified stretch of road) is the value that should be correlated with accidents, due to the logic behind; every behavior that causes a change in speed also carries an infinitesimal risk of accident, and these add up to a sum total, which should be the total number of accidents experienced. However, for methodological reasons, the mean over a specified stretch of road is used instead of the total.

A limitation of the theory and the predictive power of the celeration variable may be the information-processing capabilities (in a very wide sense) of the driver. For example, a half-blind person may have accidents that another person could have evaded during the same circumstances. However, it would also seem probable that this type of situation would be more frequent for the weak-of-eye driver, but avoided with the use of more forceful maneuvers, thus contributing to a higher celeration value. In the end, it is therefore uncertain which force will get the upper hand.

Methodology

General

Three studies were undertaken to test the main prediction of the theory; there is a positive correlation between celeration behavior and accident record. The method used was basically the same throughout all studies, but the differences will be described in detail. None of these make the data incomparable. Data was gathered from one bus route in Uppsala. Study II was mainly a testing of the methods involved. In general, it can be said that there were no unsurpassable problems, although the measuring equipment used meant riding buses 12 hours a day. In this and Study III, the data came in three variants; longitudinal (Gas/Brake), lateral (Left/Right) and resultant acceleration.

As Study II did not yield any clear results, another (Study III) was undertaken to gather more data, to calculate how stable the celeration variables are over time, and to test a correction procedure for traffic density; holding celeration constant for time for standstill along the route, a variable that should be closely associated with number of passing cars.

In Study IV, celeration behavior was measured automatically from the speedometer by a hidden computer, resulting in a change in variables. In this study, (longitudinal) celeration is the same as the Gas/Brake in the previous projects, while Left/Right and the resultant were dropped. Instead, the longitudinal variable was split into three; acceleration, deceleration and even speed (actually percent time for zero acceleration). This was due to technical limitations and the finding in Study III that almost all the variation in the resultant was contributed by the longitudinal acceleration variable.

Accident data

Incident reports were available from the bus company's records. All such where some physical damage (including injuries) resulted, apart from very minor scratches and accidents within the company's grounds, were coded into a database (see af Wåhlberg, 2002a; 2004; 2005). In the first two studies, two variants of accident variable were used; All and Responsible, while in the last paper only Responsible were included. The criterion for being responsible was that the bus driver behavior had in some way contributed to the accident, something that was often very hard to ascertain (inter-rater reliability 70 percent, see af Wåhlberg, 2002a). Some error variance is therefore bound to have crept in to the calculations from this source. In Table 1 can be seen the mean number of accidents in one of the samples used, as well as that of the population at that time.

Subjects

All studies were carried out at the bus company Gamla Uppsalabuss in Uppsala, Sweden. The subjects were drivers who drove route number eight and happened to turn up when measurement was being undertaken, making the samples semi-random. This includes a majority of all drivers, as number eight was the busiest route, and the duties scattered among several of the subgroups[7] of drivers. Drivers were identified by their working schedule in the first two studies, and thereafter from passenger data registered by the vehicles (this includes logging into the system by the driver). In Table 1 can be seen some descriptive data on the summed samples in Study III. The population values tend to change very little, despite there being a large turnover rate. As any sample used was also a substantial part of the population (>10%), the differences on any variable were always small. However, one persistent and unavoidable difference concerned the number of hours worked. Drivers who worked more time were more likely to be included, as they turned up more frequently, and all samples therefore had more hours of driving than the population. Furthermore, this lead to some systematic differences on other parameters, especially accidents. As incidents are positively associated with exposure, the samples also had more accidents on record per year. Similarly, as drivers with non-Swedish names tend to work more, they also had a slightly higher incidence in the samples.

Procedure and technical equipment

In Studies II and III, the data were gathered by a researcher traveling on a bus, using an accelerometer equipment from Valentine Research, measuring speed changes with 10 Hz in two variables; longitudinal and lateral if placed along the center line of the vehicle. The data was sent to a laptop computer, and the whole equipment was hidden in a suitcase. The researcher would enter the bus at the end stop as any passenger and place the case on a flat

[7] A subgroup work on a specific so-called list, rotating between 10-20 different duties involving different routes and times of the day. However, these duties tend to have something in common; all can be early, midday or late or even weekends only. Weekend data has not been included in the present work, as it is not known whether the driving environment might be different (traffic density tend to be lower, and the time table is different).

surface at the end of the bus and start the measurement. In Study II, the measurements ended at the center of town, while in Study III they were from terminus to terminus. Drivers were identified from the duty schedule.

Table 1: Descriptive data on the sample in Study III and the population of bus drivers. The means, maximums, minimums and standard deviations of age (years), number of responsible accidents and hours worked in the full sample and in the population (bus drivers at Gamla Uppsalabuss) in 1999. Age computed as of 1999-05-01. Sample A traveled from south to north of Uppsala, B the other way.

Sample A+B, N=125, 1999			
Variable	Age	Number of accidents	Hours worked
Mean	43.9	0.320	1438.0
Maximum	59.6	3	2258.6
Minimum	21.4	0	288.3
Std	9.27	0.590	462.7
Population, N=416, 1999			
Variable	Age	Number of accidents	Hours worked
Mean	43.8	0.209	1167.2
Maximum	68.1	3	2258.6
Minimum	21.2	0	3.0
Std	10.6	0.473	635.0

In Study IV, vehicle computers were installed in five buses, measuring continuously whenever the electricity was turned on. The signal from the rear axle to the speedometer was tapped, and speed calculated with 10 Hz. Thereafter, acceleration was calculated with 2.5 Hz (see Appendix). Drivers were identified by the use of ticket data, as they have to log into the system.

The use of different measurement systems may have added some error in terms of different absolute levels of celeration between studies (see Table 11, where the values of Study III are much higher than all other, possibly due to an erroneous or forgotten calibration procedure). However, this is of no consequence for the present research, as these data are not compared between samples. Positive correlations between measurements of the same drivers at different times have also been noted (af Wåhlberg, 2003b), although those between Study II and III tended not to be significant. However, these intercorrelations increase strongly when data are aggregated (af Wåhlberg, in press, b; submitted).

Mathematical treatment of data

The raw data is a string of values over time. The celeration behavior theory states that it is the sum of all such behavior that gives the total accident risk and should be the best predictor of accidents during the same time period. However, as it is only possible to sample behavior in very small amounts, it is necessary to estimate the total by calculating a mean of celeration behavior during movement over a specified stretch of road, under the assumption that amount of exposure is fairly uniform, and multiplying for the exposure of the time period for which accidents are predicted. A long measurement is thus condensed into a single value, a data point.

However, if behavior is variable between measurements, it is necessary to use several data points for the estimate, taking the mean of these. Out of this procedure, it is also possible to make an estimate of how well the total has been estimated by calculating the standard error over data points. If the value is large, there is not yet enough data gathered to predict the accident frequency of this individual.

Statistical methods

The association between accidents and celeration behavior can be analyzed in a number of ways. The method of choice in the present work is Pearson correlations, as this computation gives a single value which directly tells how much variance can be explained, which is of prime importance, and also a regression equation for the prediction of one variable from the other (which is not used here). The alternatives used by traffic researchers include Poisson regressions (e.g. West & Hall, 1995), phi coefficients (e.g. Kunce, 1967), logistic regression/odds ratio (e.g. Violanti & Marshall, 1996) and percentages (e.g. Stradling, Parker, Lajunen, Meadows & Xie, 1998). However, this is mainly due to the use of short time periods for accident frequencies and car drivers as subjects, resulting in a Poisson distribution, i.e. the majority of drivers have zero crashes. The bus drivers in the present work have much higher accident frequencies (see Table 1). Another method sometimes used is that of contrasted groups, comparing drivers with no accidents and those with several (e.g. Quenault, 1968a).

A large number of correlations were computed in the present work, and it might be argued that some sort of correction method (i.e. Bonferroni) should have been used in such a situation. However, this is only applicable if a number of different variables are used, and conclusions drawn from the few significant correlations that show up. This is not what was done in these studies. Instead, the theory predicts that celeration is the best possible predictor; all others (including similar ones) should be inferior. However, a number of variants of the accident variable were tested, as it is unknown which is the optimal time period to use for calculation of the dependent variable.

Results

Study II: Pilot

Associations were computed between Responsible accidents and All accidents for time periods of two to five years on one hand, and longitudinal, lateral and resultant acceleration on the other. Correlations ranged from .51 to -.11, with lateral (Left/Right) acceleration as the best predictor[8], as can be seen in Table 2. In general, the results were inconsistent.

Table 2: The Pearson correlations between the three acceleration variables, Driving time and the two accident variables for the four time periods used. N=47. Measurement was from the south terminus to center of town only, equaling stretch A1 in Study III.

Variable	All accidents				Responsible accidents			
Time period	1997-98	1996-98	1995-98	1994-98	1997-98	1996-98	1995-98	1994-98
Resultant	-.08	.12	.04	.18	-.24	.22	.11	.19
Gas/Brake	-.08	-.06	-.11	-.02	-.24	-.02	-.07	-.01
Left/Right	-.06	.38*	.25	.40*	-.15	.51**	.36*	.44*
Driving time	-.05	-.20	-.22	-.36*	.24	-.16	-.21	-.28

* p<.02, ** p<.001.

Study III: Methodological development

It was found that split-half correlations for the three variables (i.e. variants of mean celeration behavior for half of the measuring stretch correlated with the other half of the same run) were in the range of .37-.64, while two measurements with a mean of 36 days between them ranged .33-.57, with the resultant achieving the strongest association in the latter calculation, while in the first it was similar.

The associations between celeration behavior and accidents were inconsistent between the two samples, where one had correlations from -.05 to .32, while the others were essentially zero. This situation was switched, however, when a correction procedure was used (values divided by time for total standstill to hold constant the influence of traffic density), see Table 3.

[8] In all cases where Left/Right was significant, it was also the only significant predictor in a forward stepwise multiple regression (when Resultant and Gas/Brake were included).

Table 3: The correlations between the number of Responsible accidents for time periods of one up to eight years and the three acceleration variables in sample A corrected for (divided by) total time of standstill. Sample A traveled from south to north of Uppsala, B the other way.

Time period	1999-00	1998-00	1997-01	1996-01	1995-01	1994-01
N	55	47	42	41	41	40
corrected Resultant	.25	.31*	.35*	.37*	.30	.27
corrected Gas/Brake	.26	.32*	.36*	.36*	.29	.25
corrected Right/Left	.24	.29	.33*	.38*	.31*	.28

* p<.05, ** p<.01

The stability of celeration behavior over environment and time was also studied, by correlating drivers' behavior in different measurements. The first calculation was a split-half, associating the behavior during the drive from the terminus to city with the rest of the route (city to other terminus). Thereafter, behaviors on drives from terminus to terminus about a month apart were correlated. As can be seen in Tables 4 and 5, all correlations were fairly strong.

Table 4: The Pearson correlations between mean driver acceleration behavior on stretches A1 versus A2 and B1 versus B2. Overlap between samples was 19 subjects. Sample A traveled from south to north of Uppsala, B the other way, with 1 designating the first part of the drive (from terminus to the center of town).

Sample	Resultant	Gas/Brake	Right/Left
A1/A2 (N=81)	.61***	.62***	.64***
B1/B2 (N=65)	.43***	.39***	.37***

*** p< .005

Table 5: The Pearson correlations between mean driver acceleration behaviors of first measurement versus second measurement on stretches A and B pooled. Overlap between samples was 3 subjects. Mean time between measurements 36.6 days. Sample A traveled from south to north of Uppsala, B the other way, with 1 designating the first part of the drive (from terminus to the center of town).

Sample	Resultant	Gas/Brake	Right/Left
A/A+B/B (N=31)	.57 ***	.54 ***	.33 ***

*** p< .003

Study IV: Enlargement

In this study, drivers were measured repeatedly over more than three year's time. Data was split into samples gathered in three time periods (fall, winter, spring[9]), see Table 6. Correlations with accidents for differing time periods

[9] Summertime data was excluded, due to there being very little traffic and few accidents, thus violating the theoretical axiom of homogeneity of driving environment.

were run, but only two-year periods yielded associations of any practically useful strength, and only those are shown in Tables 7-9.

Table 6: The grouping of data in samples. The first sample of each period contains the first measurement of all drivers who yielded any data during that time, the second and third are repeated measurements on those in the first, which leads to a shrinking N within any sampling period. Not all of these samples were used in the present paper, due to very small N's.

Samples	Time period	Season
1-3	August-December 2001	Fall
4-6	December 2001-February 2002	Winter
7-9	March-June 2002	Spring
10-15	August-December 2002	Fall
16-18	January-March 2003	Winter
19-21	April-June 2003	Spring
22-26	August-December 2003	Fall
27-28	January-March 2004	Winter

Table 7: The Pearson correlations between the celeration variables and the number of Responsible accidents in 2001-2002 for drivers in samples 1-9. In the last column, the mean of these correlations, calculated as the square root of the mean of the squared correlations, unweighted for N.

Sample	1	2	3	4	5
N	203	142	80	169	81
Celeration	.125	.203*	.311**	.232**	.106
Acceleration	.112	.152	.310**	.223**	.094
Deceleration	-.094	-.226**	-.247*	-.227**	-.085
Sample	6	7	8	9	**Mean 1-9**
N	54	163	107	70	**118.8**
Celeration	.197	.175*	.193*	.332**	**.220**
Acceleration	.181	.179*	.206*	.355**	**.217**
Deceleration	-.217	-.139	-.163	-.235	**-.191**

* p<.05, ** p<.01, *** p<.001

It can bee seen that although the correlations differ quite a lot between samples, the mean in all three groupings is fairly similar, indicating a level of association of about .20 at this level of calculation refinement. Also, the celeration variable consistently comes out as the best predictor, in accordance with theory.

The celeration data could also be analyzed as differences between groups of drivers specified by their accident record. This is shown in Table 10. It would seem that the increase in mean celeration level is fairly low at first, with the last group (very highly accident liable drivers) differing to a much larger amount. However, as this group is very small, the observation needs some further corroboration. It is of some theoretical importance, as it implies non-linearity of the effect.

Table 8: The Pearson correlations between the celeration variables and the number of Responsible accidents in 2002-2003 for drivers in samples 11-21. In the last column, the mean of these correlations, calculated as the square root of the mean of the squared correlations, unweighted for N. Samples 10 and 18 excluded due to too few cases.

Sample	11	12	13	14	15	
N	145	71	174	143	108	
Celeration	.290***	.146	.139	.294***	.231*	
Acceleration	.274***	.079	.161*	.252**	.203*	
Deceleration	-.280***	-.226	-.102	-.240**	-.236*	
Sample	16	17	19	20	21	**Mean 11-21**
N	149	93	130	73	40	**112.6**
Celeration	.250**	.185	.225**	.151	.266	**.225**
Acceleration	.246**	.193	.200*	.119	.207	**.216**
Deceleration	-.232**	-.140	-.189*	.009	-.211	**-.197**

* p<.05, ** p<.01, *** p<.001.

Table 9: The Pearson correlations between the celeration variables and the number of Responsible accidents in 2002-2003 for drivers in samples 22-27 (sample 28 excluded due to too few cases). In the last column, the mean of these correlations, calculated as the square root of the mean of the squared correlations, unweighted for N.[10]

Sample	22	23	24	25	26	27	**Mean 22-27**
N	181	149	123	100	78	80	**118.5**
Celeration	.193**	.246**	.261**	.129	.150	.173	**.198**
Acceleration	.187*	.247**	.214*	.146	.067	.120	**.174**
Deceleration	-.154*	-.192*	-.247**	-.078	-.177	-.222*	**-.186**

* p<.05, ** p<.01.

Table 10: The difference in mean celeration (m/s^2) levels (aggregated over samples) among groups of drivers with differing numbers of accidents during 2001-2002 (1-9) and 2002-2003 (11-27). Analysis of variance calculated.

Number of accidents	0	1	2	3-4	F	Significance
N	159	53	23	8		
Mean celeration 1-9	0.526	0.531	0.553	0.575	4.08	p<.01
N	143	57	16	8		
Mean celeration 11-21	0.491	0.500	0.518	0.548	3.45	p<.01
N	121	48	12	6		
Mean celeration 22-27	0.475	0.483	0.494	0.537	3.58	p<.05

In Table 11 are shown the Ns and mean longitudinal celeration behavior for some samples in the three empirical studies reported on here. It can readily be seen that IIIA and IIIB deviates strongly from all other values. The only explanation would seem to be that the measurement equipment had not been properly calibrated.

[10] In Table 9, each of the three predictors turned out to be strongest two times out of the six samples when forward stepwise multiple regressions were run.

Table 11: The Ns and means of longitudinal celeration behavior in the some of the samples of the three empirical studies, with the roman numbers denoting study.

Sample	II	IIIA	IIIB	IV1	IV2	IV3
N	47	65	54	208	144	81
Mean	0.511	0.578	0.608	0.530	0.531	0.531
Sample	IV4	IV5	IV6	IV7	IV8	IV9
N	171	82	55	166	108	70
Mean	0.519	0.519	0.532	0.533	0.519	0.521

General discussion

From the data in the three empirical studies presented here it may be concluded that there is some support for the driver celeration behavior theory, despite the mainly weak correlations found, and some unresolved questions. However, most of the problems involved would seem to be fairly logical, and possible to overcome. They also lead to testable hypotheses about driver behavior and its measurement. It is therefore argued that the main reason that associations are low are due to methodological problems involving mainly the variability of driver celeration behavior.

However, some conclusions may be drawn from the existing results. It should be fairly clear from the last study that the time frame used for prediction is fairly short, obviously due to the instability of driver celeration behavior over time. As accidents too are fairly unstable during such a short time frame, this is not an argument against the theory presented in this work.

Regarding limitations of conclusions, it could be argued that the present results are only applicable to bus driving, as this is were the results have been found. However, the theory predicts the same kind of relationship for all vehicle users (actually, maybe even all road users); the use of bus drivers as subjects of study is due to the methodological advantages of this population. Therefore, it is claimed that significant associations[11] would be found for other vehicle drivers too, given that a reasonably valid accident history could be found, and driving behavior was sampled repeatedly (>10) over at least a year.

The results in the last study would seem to differ somewhat from the previous two regarding the optimal accident prediction time frame. No really satisfactory explanation for this state of affairs has been found, although it is possible that the change of method for gathering data could be suspected. In the first two studies, measuring was done with the same apparatus, not totally unobtrusive, while in the last, data was gathered from the systems of five different vehicles, possibly with some differences in their calibrations. These latter measurements were also totally undetectable for the drivers. However, no clear differences between vehicles could be ascertained, and no further predictive power could be had by analyzing data from each bus separately. This does not exclude the possibility of some small amount of

[11] The preferred measure of Pearson correlations in the present work would probably not be optimal for low-accident groups like car drivers.

error having its source in the change of method, but it does not seem to be big enough to explain the differences mentioned.

Some other possible confounding differences between the studies are daylight and weather, as the last study used data from a wider range of circumstances. However, tentative trials did not show any clear effects, and this question remains to be explored. It would seem probable that here too it would be possible to reduce error variance somewhat, the other chief target being traffic density.

The celeration behavior theory is mainly about the relation between measurable driver behavior and traffic accidents, i.e. why high-celeration behavior is dangerous. This is all that is necessary for the prediction of crashes. However, some further speculations may be useful for clarifying the wider picture. It is possible that people have some kind of preferred or highest acceptable level of celerations during their driving. This has so far mainly been expressed as stability of behavior, i.e. an observational term, but for any stability to exist there must be some type of internal control which compares the experienced levels of celeration (and possibly anticipates those that will be experienced in the near future due to current maneuvers) to some type of internal benchmark. Although this type of thinking may be more familiar (and acceptable) to psychologists in general, it does not add much to the more basic statement about traffic behavior. It is possible that such a level could be established, but this would not be very useful, if it did not predict accident involvement, or could lead to some way of changing people's acceptable level towards something safer.

In connection with the above statements about possible mechanisms behind driver celeration behavior it could be of some interest to discuss the principle of testing hypotheses by the use of association measures and similar statistical techniques. Unfortunately, the falsification principle of Popper (1968) seems to have had little impact in psychology and related disciplines (Hirsch, 1980; 1981a; 1981b; Hecht, 1996; af Wåhlberg, 2001). Some would perhaps argue that we have not yet reached such a level of knowledge that we can make exact, testable statements, and that falsification is not a working scientific principle for us. However, the basic tenet of falsification, that a theory that can explain any outcome but not actually predict anything is scientifically worthless, would still seem to hold good.

However, how can this be applied to correlations and other association measures? Taking the present work as example, the theory predicts a positive correlation between celeration behavior and accidents, but it does not specify an acceptable range. Does this mean that any positive correlation, however low, could be interpreted as corroborating the theory? In principle yes, as so far the theory only excludes negative associations. This kind of situation does not seem to have been anticipated by Popper, and therefore need some further rule. For the present work, the principle suggested is that of practical use; if the correlations found can predict accident involvement to a practically useful degree, and also betters the predictions made from other data sources (violations, previous accidents, sex, age etc), the theory is valuable. If not, it may be scrapped, because however correct it may be at a low level of association, it is of little practical interest (this view is similar to that of Lakatos, 1978).

These observations and statements lead to another area of interest; how can the celeration measure be further developed, theoretically and methodologically? Starting with the stability of the celeration variable, further tests of environmental influences would seem to be a primary area for study. It is not known how or how much various aspects of the traffic environment add or subtract from the celeration measure. Weather would seem to have some effect (af Wåhlberg, 2003b), as does possibly darkness. Any number of other variables could also be tested; type of vehicle, number of passengers, time pressure etc. However, at this moment, intra-individual variables would seem to be the chief suspects as the source of variation in celeration behavior. Mathematically, the use of means as predictor may seem crude, and this could possibly be developed, especially when a long series of measurements is available. Many different variants of celeration measurements have been suggested through the years by colleagues and reviewers; the top ten percent of values (extreme behavior), selected parts of the route (for example corners), or deceleration (less restricted values than acceleration). However, apart from the last suggestion (which was tested in Study IV and found erroneous), these ideas all have two things in common; they are mathematically or methodologically more advanced than the current method, and they have no theoretical underpinnings.

The associations found so far are not very impressive, and it may be doubted whether the celeration measure is practically useful in its present state, explaining possibly five percent of accidents only, for a two-year period. However, small effects is the rule in accident prediction (e.g. Smith & Heckert, 1998; Stradling, Parker, Lajunen, Meadows & Xie, 1998; Jonah, Thiessen & Au-Yeung, 2001), while strong associations (>.30 correlations) are rare if only one predictor variable is used (Williams, 1977, is among the few exceptions). However, comparisons are hard to make, due to the differing statistical methods used by various researchers, as discussed in the method section. Anyway, the low predictive power in the present material does not preclude substantial improvement, something that has begun to materialize (af Wåhlberg, submitted).

Apart from the main goal of predicting accident involvement, the celeration measure would probably be useful in various research and practical settings as a general measure of driver behavior (for example af Wåhlberg, 2002c). So far, only a few seem to have hit upon this idea, as referenced in the introduction, although variables with some similarity to celeration, for example the standard deviation of speed, are sometimes used.

However, the best use of the celeration measure would probably be in professional settings, where a surveillance system would monitor behavior and automatically detect drivers who stray from the safe path, giving direct and long-term feedback. Incidentally, this would probably also have a positive effect on fuel consumption (i.e. it would decrease), as these variables are correlated (af Wåhlberg, 2002c). The problem of driver variability would also be countered, as monitoring would be continuous.

It should also be noted that there is a vast difference in effect between selection procedures based on a variable measured once, and the continuous monitoring of driving and feedback. In the first instance, a strong relationship between variables is needed, unless the selection is very strong (i.e. very few are chosen). For the continuous situation, it does not matter if most of the behaviors targeted are perfectly safe, because the feedback does not have any adverse effect. This is fairly apparent concerning the case of speed limits; all are affected, not only those few who really need interference. By applying a rather weak predictor, a fair safety effect can be had anyway (Baum, Wells & Lund, 1991; Farmer, Retting & Lund, 1999) because all drivers are included. Incidentally, celeration behavior probably has a higher predictive power than speed (af Wåhlberg, in press, b), as predicted.

It could seem that this way of predicting accident involvement is a bit cumbersome, with measurement apparatus, downloading data, identifying drivers etc. However, as compared to a number of other studies utilizing various predictors this is not so. Actually, many variables are so hard to measure (e.g. Andersson, Nilsson & Henriksson, 1970; Avolio, Kroeck & Panek, 1985; Arthur, Barrett & Doverspike, 1990; Maag, Vanasse, Dionne, & Laberge-Nadeau, 1997) or so many are used (e.g. Häkkinen, 1958; Harano, Peck, & McBride, 1975; De Raedt & Ponjaert-Kristoffersen, 2001) that they would not be feasible for practical use. Similarly, instrumented cars usually have much more advanced setups than what is actually needed to measure celeration behavior (e.g. Wilson & Greensmith, 1983), especially the longitudinal variable. Also, today many new vehicles are already equipped with electronic systems that can be tapped for information which can be transformed into celeration data. Celeration measurement may therefore actually be a very practical alternative, yielding continuous data in large quantities, with the amount of manual work involved inversely related to the quality of the technical system. Also, given that the influence of the driving environment is small (which may be suspected from af Wåhlberg, 2003b), this kind of measurement would even work for private drivers.

Apart from accidents, it can also be noted that a number of other variables should be correlated with driver celeration behavior, as noted in the theory section. These are testable statements; for example, close following could be measured continuously along with celeration. Actually, any variable which is related to (responsible) accidents should have a similar association to celeration behavior.

In the present work, accidents for which the driver was considered at least partially responsible have been used as dependent variable. However, this is not necessarily the optimal way of constructing an accident index, although the present state of the art has no directions to give regarding this problem. For example, one possible way of tackling this problem is to give accidents different weights due to their severity. Very little such research has been undertaken on this topic, however, and there is no theory about how and why such weighting should be undertaken. Those who have employed such methods include Hartley and El Hassani (1994) (composite index of different aspects of violation and accident history), Smith and Heckert (1998) (near-accidents), and Kahneman, Ben-Ishai and Lotan (1973) (summed ratings of the severity of the error of the driver in each accident). Unfortunately, none of these papers discussed their choice of methods. Furthermore, it is uncertain whether accidents of different severity are predicted by different variables, as the results differ between studies (Garretson & Peck, 1982; Begg, Langley & Williams, 1999).

The use of company accident data and measurements unknown by the drivers might be viewed as unethical by some. However, the activities of bus drivers are not private; anyone buying a ticket may observe them (and reach similar conclusions about a driver as the measurement equipment, as shown in af Wåhlberg, in press, a). Furthermore, the work for the last paper was commissioned by the bus company, and the union representatives were informed beforehand.

At the end of this work, several conclusions of a general nature might be drawn. For some reason, few traffic researchers seem to use instrumented vehicles for the gathering of ecologically valid data, i.e. non-experimental setups where the subjects are unaware of the study. Although these requirements in unison are a bit hard to satisfy, there are good reasons for advocating them. On a general level, way too many traffic psychologists (and others) rely on questionnaires and fancy statistics to 'test' their hypotheses, while dodging the question of validity. Soft data is the rule. Also, experimental setups, while yielding hard data, often disregard the ecological side; would people really behave this way if left to their own devices?

Given the technology of today, this is somewhat strange. It is therefore suggested that traffic research should aim less at fuzzy 'psychological' concepts and instead target explicit, measurable road user behavior. Celeration is one such measurable behavior, which is still in its infancy as a research concept. Hopefully, the use of such objective variables will give a new impetus and a more practical orientation to psychological traffic research.

The celeration behavior theory is at its present stage fairly well developed; one basic assumption generates several testable predictions, and a set of formulas, which specify the exact relationships expected. The testing of these predictions has only begun, and although the results in the first two empirical studies related here add little to the positive evidence for celeration's impact on accident liability, the third is stronger. Furthermore, aggregation of celeration data does have a positive impact, as expected (af Wåhlberg, submitted), and different variants of speed choice do not seem to predict accidents with more power than celeration behavior (af Wåhlberg, in press, b). Time will show whether this fairly positive start will continue into a substantial scientific backing for the theory of driver celeration behavior.

Acknowledgements

Through the many years I have spent preparing the ground for my doctoral thesis, many organizations and persons have acted in ways that have been instrumental in bringing about the final product. First and foremost are my financial backers; without them this whole endeavor would probably never have gotten very far. In timely order, I would therefore like to thank;
The Swedish House of Nobles - for making my student life more than existence, contributing excessively through my many years of academic wandering.
Svenska Försäkringsföreningen - for their totally unwarranted faith in my competence at that time.
The Swedish Road Administration - for their large funds.
The Transport and Communications Research Board (nowadays merged into VINNOVA) - for their inadvertent oversight concerning my being non-eligible for funding.
The Swedish Institute - for letting me have some productive vacation in Edinburgh.

From the feeble start around 1995, the people I have interacted with in different parts of research and life have contributed to the development of me and my research, some of them probably in quite surprising ways to themselves, if they would happen to know them. These persons would include (but not exclude anyone in particular);

The personnel at Gamla Uppsalabuss; the drivers who have (more or less voluntarily) been my subjects, and all the others who have helped me out in various ways, only a very few of which will be mentioned specifically (in no particular order); Hans Lerne, Jan Burström, Björn Bostrand, Cilla Franzén, Yngve Näslund, Tage Wiippola, and last but certainly not least, Kent-Åke Eriksson.

Lennart Sjöberg, professor of psychology, Center for Risk Research, Stockholm School of Economics: Two years of mopping up what others had left behind and plunging head first into unchartered waters, constructing reports about things of which I had had no knowledge some weeks before, made valuable experience. Furthermore, Lennart's view concerning nasty referees was very illuminating and useful; "I think they're bluffing". He also taught me how to handle troublesome Norwegians...

Lars Åberg, professor of psychology, Dept. of Psychology, Uppsala University: Although we never seemed to agree on anything, even about if we were agreeing or not, this interaction taught me things which I will never forget, and was thus as useful as anything else.

Lennart Melin, professor of psychology, Dept. of Psychology, Uppsala University: Although a late starter as my supervisor (and not a traffic researcher), Lennart caught up fast, and provided the practical and insightful criticism that was needed for my work to progress and develop. Always knowledgeable, helpful and entertaining, work has been a lot of fun in his presence.

Mats Haglund, Rickard Nilsson and Per-Arne Rimmö, late[12] PhDs, Uppsala University; the interaction with the tricolor of traffic psychology of the Dept of Psychology made for a social as well as scientific environment. Although they might not believe it, I actually heeded some of their advice...

Leo Poom, perpetual perceptual researcher, Dept. of Psychology, Uppsala University; sharing an office with Leo through the years is only part of a journey of friendship and scientific discussions which started in the dim under-graduate past. Being a-social, fond of drinking and hamburgers, he has made perfect company for years, and probably will for years to come.

Gunnar Jansson, Dept. of Psychology, Uppsala University; he taught me by personal example the meaning of scientific integrity and objectivity coupled with relentless conviction when Leo and I attacked him mercilessly in class about his theoretical basis.

Professor Stephen Stradling at the Transport Research Institute, Napier University, Edinburgh; who gave me advice concerning grant applications; "Think big!".

My energetic and competent assistant during 2001-2004, Hanna Skagerström, who grasped the concepts of traffic psychology faster than I could explain them, and worked faster than I could provide work.

Johan Göthe, computer nerd and measurement techniques expert; constructing and building the equipment I needed for the last study was only

[12] This inadvertent pun was written before P-A sadly died a very premature death.

a part of the very fruitful cooperation that rapidly developed alongside a mutual interest in explosives, locusts and various bizarre trivialities.

Sven Södergren (PhD in physics and hypnotizer of hens[13]), who helped me develop the formulas describing the celeration behavior theory, as well as the conceptual understanding of the whole thing.

Charlotte Frycklund, who proofread various manuscripts, developing my English from the mediocre to the... not so mediocre.

My wife Åsa, who never told me to get a proper job. You might also understand why I argue with such unrelenting force if you have had a discussion with her...

Then there are Barbro and Kjell Bondestad, who kept me in touch with quite different venues in life, like culture, politics, and the humanistic way of arguing and thinking.

Finally, my parents, who taught me a practical view of life. Without that, I might have become a (inappropriate comment about other university discipline deleted)...

[13] And I do not mean women.

References

Andersson, A. L., Nilsson, A., & Henriksson, N. (1970). Personality differences between accident-loaded and accident-free young car drivers. *British Journal of Psychology, 61,* 409-421.

Arthur, W. Jr., Barrett, G. V., & Alexander, R. A. (1991). Prediction of vehicular accident involvement: A meta-analysis. *Human Performance, 4,* 89-105.

Arthur, W. Jr., Barrett, G. V., & Doverspike, D. (1990). Validation of an information-processing-based test battery for the prediction of handling accidents among petroleum-product transport drivers. *Journal of Applied Psychology, 75,* 621-628.

Arthur, W., & Graziano, W. G. (1996). The Five-factor model, conscientiousness, and driving accident involvement. *Journal of Personality, 64,* 593-618.

Arthur, W. Jr., Tubre, T. C., Day, E., Sheehan, M. K., Sanchez-Ku, M. L., Paul, D. S., Paulus, L. E., & Archuleta, K. D. (2001). Motor vehicle crash involvement and moving violations: Convergence of self-report and archival data. *Human Factors, 43,* 1-11.

Aschenbrenner, K. M., & Biehl, B. (1994). Improved safety through improved technical measures? In R. Trimpop and G. Wilde (Eds.) *Challenges to accident prevention. The issue of risk compensation behaviour,* pp. 81-89. Groningen: Styx.

Asher, W., & Dodson, B. (1971). Automobile accidents in the year following highschool: The predictive value of 377 unobtrusive variables. *Behavioral Research in Highway Safety, 2,* 107-122.

Avolio, B. J., Kroeck, K. G., & Panek, P. E. (1985). Individual differences in information-processing ability as a predictor of motor vehicle accidents. *Human Factors, 27,* 577-589.

Babarik, P. (1968). Automobile accidents and driver reaction pattern. *Journal of Applied Psychology, 52,* 49-54.

Bach, H., Bickel, H., & Biehl, B. (1975). Validierung von Testverfahren zur Fahrer-Auslese am Unfallkriterium. *Zeitschrift fur Verkehrssicherheit, 21,* 27-38.

Bacqueyrisse, L. (1935). Psychological tests in Paris tramway and omnibus services. *Human Factor, 9,* 231-234.

Baker, J. S. (1929). Do traffic accidents happen by chance? *National Safety News, 20,* 12-14.

Baker, J. S. (1932). What can we do for high-accident drivers? *National Safety News, 25,* 19-20, 63.

Ball, K., Owsley, C., Sloane, M. E., Roenker, D. L., & Bruni, J. (1993). Visual attention problems as predictor of vehicle crashes in older drivers. *Investigative Ophthalmology and Visual Science, 34,* 3110-3123.

Bartone, P. T. (1989). Predictors of stress-related illness in city bus drivers. *Journal of Occupational Medicine, 31,* 657-663.

Baum, H. M., Wells, J. K., & Lund, A. K. (1991). The fatality consequences of the 65 mph speed limits. *Journal of Safety Research, 22,* 171–177.

Begg, D. J., Langley, J. D., & Williams, S. M. (1999). A longitudinal study of lifestyle factors as predictors of injuries and crashes among young adults. *Accident Analysis and Prevention, 31,* 1-11.
Blom, D. H., Pokorny, M. L., & van Leeuwen, P. (1987). The role of age and experience in bus drivers' accidents. *International Journal of Epidemiology, 16,* 35-43.
Booth, A. S. (2002). *Measurement and modelling of vehicular driving cycles and their impact on emissions.* Unpublished doctoral thesis, Napier University, Edinburgh, UK.
Brandaleone, H., & Flamm, E. (1955). Psychological testing: Effect on the accident frequency of bus operators. *Industrial Medicine and Surgery, 24,* 296-298.
Burg, A. (1970). The stability of driving record over time. *Accident Analysis and Prevention, 2,* 57-65.
Chapman, P., & Underwood, G. (2000). Forgetting near-accidents: The roles of severity, culpability and experience in the poor recall of dangerous driving situations. *Applied Cognitive Psychology, 14,* 31-44.
Cobb, P. (1940). The limit of usefulness of accident rate as a measure of accident proneness. *Journal of Applied Psychology, 24,* 154-159.
Cornwall, C. J. (1962). The accident experience of London bus drivers. *Annuals of Occupational Hygiene, 5,* 69-82.
Dalziel, J. R., & Job, R. F. (1997). Motor vehicle accidents, fatigue and optimism bias in taxi drivers. *Accident Analysis and Prevention, 29,* 489-494.
De Raedt, R., & Ponjaert-Kristoffersen, I. (2001). Predicting at-fault accidents of older drivers. *Accident Analysis and Prevention, 33,* 809-819.
Duffy, C., & McGoldrick, A. (1990). Stress and the bus driver in the UK transport industry. *Work and Stress, 4,* 17-27.
Edwards, D. S., Hahn, C. P., & Fleishman, E. D. (1977). Evaluation of laboratory methods for the study of driver behavior: Relations between simulator and street performance. *Journal of Applied Psychology, 62,* 559-566.
Elander, J., West, R. J., & French, D. J. (1993). Behavioral correlates of individual differences in road-traffic crash risk: An examination of methods and findings. *Psychological Bulletin, 113,* 279-294.
Evans, G. W. (1994). Working on the hot seat: Urban bus operators. *Accident Analysis and Prevention, 26,* 181-193.
Evans, L., & Wasielewski, P. (1982). Do accident-involved drivers exhibit riskier everyday driving behavior? *Accident Analysis and Prevention, 14,* 57-64.
Evans, L., & Wasielewski, P. (1983). Risky driving related to driver and vehicle characteristics. *Accident Analysis and Prevention, 15,* 121-136.
Farmer, C. M., Retting, R. A., & Lund, A. K. (1999). Changes in motor vehicle occupant fatalities after repeal of the national maximum speed limit. *Accident Analysis and Prevention, 31,* 537-543.
Fife, D., & Cadigan, R. (1989). Regional variation in motor vehicle accident reporting: Findings from Massachusetts. *Accident Analysis and Prevention, 21,* 193-196.
French, D. J., West, R. J., Elander, J., & Wilding, J. M. (1993). Decision-making style, driving style, and self-reported involvement in road traffic accidents. *Ergonomics, 36,* 627-644.
Fuller, R. G. (1981). Determinants of time headway adopted by truck drivers. *Ergonomics, 24,* 463-474.
Furnham, A., & Saipe, J. (1993). Personality correlates of convicted drivers. *Personality and Individual Differences, 14,* 329-336.

Garretson, M., & Peck, R. C. (1982). Factors associated with fatal accident involvement among California drivers. *Journal of Safety Research, 13,* 141-156.
Godley, S. T., Triggs, T. J., & Fildes, B. N. (2002). Driving simulator validation for speed research. *Accident Analysis and Prevention, 34,* 589-600.
Golding, A. P. (1983). *Differential accident involvement: A literature survey.* Council for Scientific and Industrial Research Reports, PERS 356: 44.
Gully, S. M., Whitney, D. J., & Vanosdall, F. E. (1995). Prediction of police officers' traffic accident involvement using behavioral observations. *Accident Analysis and Prevention, 27,* 355-362.
Haglund, M., & Åberg, L. (2000). Speed choice in relation to speed limit and influences from other drivers. *Transportation Research Part F, 3,* 39-51.
Hansen, C. P. (1988). Personality characteristics of the accident involved employee. *Journal of Business and Psychology, 2,* 346-365.
Harano, R. M., Peck, R. C., & McBride, R. S. (1975). The prediction of accident liability through biographical data and psychometric tests. *Journal of Safety Research, 7,* 16-52.
Harris, S. (1990). The real number of road traffic accident casualties in the Netherlands: A year-long survey. *Accident Analysis and Prevention, 22,* 371-378.
Hartley, L. R., & El Hassani, J. (1994). Stress, violations and accidents. *Applied Ergonomics, 25,* 221-230.
Hauer, E., & Hakkert, A. S. (1988). Extent and some implications of incomplete accident reporting. *Transportation Research Record, 1185,* 1-10.
Hecht, H. (1996). Heuristics and invariants in dynamic event perception: Immunized concepts or nonstatements? *Psychonomic Bulletin & Review, 3,* 61-70.
Hirsch, P. M. (1980). The "scary world" of the nonviewer and other anomalies: A reanalysis of Gerbner et al.'s findings of cultivation analysis Part I. *Communication Research, 7,* 403-456.
Hirsch, P. M. (1981a). On not learning from one's own mistakes: a reanalysis of Gerbner et al.'s findings on cultivation analysis, Part II. *Communication Research, 8,* 3-37.
Hirsch, P. M. (1981b). Distinguishing good speculation from bad theory. Rejoinder to Gerbner et al. *Communication Research, 8,* 73-96.
Holt, P. C. (1982). Stressful life events preceding road traffic accidents. *Injury: The British Journal of Accident Surgery, 13,* 111-115.
Hopkin, J. M., Murray, P. A., Pitcher, M., & Galasko, C. S. (1993). *Police and hospital recording of non-fatal road accident casualties: A study in Greater Manchester.* TRL Research Report 379. Crowthorne: Transport Research Laboratory.
Häkkinen, S. (1958). *Traffic accidents and driver characteristics.* Unpublished doctoral dissertation, Finland's Institute of Technology, Finland.
Häkkinen, S. (1979). Traffic accidents and professional driver characteristics: A follow-up study. *Accident Analysis and Prevention, 11,* 7-18.
Isherwood, J., Adam, K. S., & Hornblower, A. R. (1982). Life event stress, psychosocial factors, suicide attempts and auto-accident proclivity. *Journal of Psychosomatic Research, 26,* 371-383.
Johnson, H. M. (1946). The detection and treatment of accident-prone drivers. *Psychological Bulletin, 43,* 489-532.
Jonah, B. A., Thiessen, R., & Au-Yeung, E. (2001). Sensation seeking, risky driving and behavioral adaptation. *Accident Analysis and Prevention, 33,* 679-684.
Kahneman, D., Ben-Ishai, R., & Lotan, M. (1973). Relation of a test of attention to road accidents. *Journal of Applied Psychology, 58,* 113-115.

Kloeden, C. N., McLean, A. J., Moore, V. M., & Ponte, G. (1997). *Travelling speed and the risk of crash involvement. Volume 1: Findings.* Federal Office of Road Safety Rep. No. CR 172. Australia: Department of Transport and Regional Development. Available at http://raru.adelaide.edu.au/speed/

Kunce, J. T. (1967). Vocational interests and accident proneness. *Journal of Applied Psychology, 51,* 223-225.

Lajunen, T., Corry, A., Summala, H., & Hartley, L. (1997). Impression management and self-deception in traffic behaviour inventories. *Personality and Individual Differences, 22,* 341-353.

Lajunen, T., Karola, J., & Summala, H. (1997). Speed and acceleration as measures of driving style in young male drivers. *Perceptual and Motor Skills, 85,* 3-16.

Lajunen, T., & Summala, H. (1997). Effects of driving experience, personality, driver's skill and safety orientation on speed regulation and accidents. In T. Rothengatter & E. Carbonell Vaya (Eds.), *Traffic and Transport Psychology, Theory and Application,* pp. 283-294. Amsterdam: Pergamon.

Lakatos, I. (1980). *Philosophical papers Methodology of Scientific research Programmes.* Cambridge: Cambridge University Press.

Larson, G. E., & Merritt, C. R. (1991). Can accidents be predicted? An empirical test of the Cognitive Failures Questionnaire. *Applied Psychology: An International Review, 40,* 37-45.

Lester, J. (1991). *Individual differences in accident liability: review of the literature.* TRRL Research Report 306. Crowthorne: Transport and Road Research Laboratory.

Levonian, E., Case, H. W., & Gregory, R. (1963). Prediction of recorded accidents and violations using non-driving predictors. *Highway Research Record, 4,* 50-61.

Lewis, R. E. (1956). Consistency and car driving skill. *British Journal of Industrial Medicine, 13,* 131-141.

Maag, U., Vanasse, C., Dionne, G., & Laberge-Nadeau, C. (1997). Taxi drivers' accidents: How binocular vision problems are related to their rate and severity in terms of the number of victims. *Accident Analysis and Prevention, 29,* 217-224.

Malfetti, J. L., & Fine, J. L. (1962). Characteristics of safe drivers: A pilot study. *Traffic Safety Research Review, 6,* 3-9.

Maycock, G., & Lester, J. (1995). Accident liability of car drivers: follow-up study. In G. B. Grayson (Ed.) *Behavioural Research in Road Safety V,* pp. 106-120. Crowthorne: Transport Research Laboratory.

Maycock, J., Lockwood, C., & Lester, J. F. (1991). *The accident liability of car drivers.* TRRL Research Report No. 315. Crowthorne: Transport and Road Research Laboratory.

McGuire, F. L. (1976). Personality factors in highway accidents. *Human Factors, 18,* 433-442.

McKenna, F. P. (1983). Accident proneness: A conceptual analysis. *Accident Analysis and Prevention, 15,* 65-71.

McKenna, F. P., Duncan, J., & Brown, I. D. (1986). Cognitive abilities and safety on the road: a re-examination of individual differences in dichotic listening and search for embedded figures. *Ergonomics, 29,* 649-663.

McKnight, A. J., & McKnight, A. S. (1999). Multivariate analysis of age-related driver ability and performance deficits. *Accident Analysis and Prevention, 31,* 445-454.

McMurray, L. (1970). Emotional stress and driving performance: The effect of divorce. *Behavioral Research in Highway Safety, 1,* 100-114.

Miller, T. M., & Schuster, D. H. (1983). Long-term predictability of driver behaviour. *Accident Analysis and Prevention, 15,* 11-22.
Noordzij, P. (1990). *Individual differences and accident liability: a review of the German literature.* Contractor Report 195/SA. Crowthorne: Transport and Road Research Laboratory.
Peck, R. C. (1993). The identification of multiple accident correlates in high risk drivers with specific emphasis on the role of age, experience and prior traffic violation frequency. *Alcohol, Drugs and Driving, 9,* 145-166.
Pelz, D. C., & Schuman, S. H. (1968). Dangerous young drivers. *Highway Research News, 33,* 31-41.
Pestonjee, D. M., & Singh, U. B. (1980). Neuroticism-extraversion as correlates of accident occurrence. *Accident Analysis and Prevention, 12,* 201-204.
Popper, K. R. (1968). *The Logic of Scientific Discovery.* Second edition. London: Hutchinson.
Quenault, S. W. (1968a). *Dissociation and driver behaviour.* Report No. LR 212. Crowthorne: Road Research Laboratory.
Quenault, S. W. (1968b). *Driver behaviour - safe and unsafe drivers. Part II.* TRRL Report No. LR 146. Crowthorne: Transport and Road Research Laboratory.
Quimby, A., Maycock, G., Palmer, C., & Grayson, G. B. (1999). *Drivers' speed choice: an in-depth study.* TRL Report 326. Crowthorne: Transport Research Laboratory.
Rajalin, S. (1994). The connection between risky driving and involvement in fatal accidents. *Accident Analysis and Prevention, 26,* 555-562.
Risser, R. (1985). Behavior in traffic conflict situations. *Accident Analysis and Prevention, 17,* 179-197.
Robertson, D. I., Winnett, M. A., & Herrod, R. T. (1992). Acceleration signatures. *Traffic Engineering and Control, 33,* 485-491.
Rosman, D. L. (2001). The Western Australian Road Injury Database (1987-1996): ten years of linked police, hospital and death records of road crashes and injuries. *Accident Analysis and Prevention, 33,* 81-88.
Rosman, D. L., Ferrante, A. M., & Marom, Y. (2001). A linkage study of Western Australian drink driving arrests and road crash records. *Accident Analysis and Prevention, 33,* 211-220.
Rosman, D. L., & Knuiman, M. W. (1994). A comparison of hospital and police road injury data. *Accident Analysis and Prevention, 26,* 215-222.
Schuster, D. H. (1968). Prediction of follow-up driving accidents and violations. *Traffic Safety Research Review, 12,* 17-21.
Selzer, M. L., Rogers, J. E., & Kern, S. (1968). Fatal accidents: The role of psychopathology, social stress, and acute disturbance. *Journal of Psychiatry, 124,* 1028-1036.
Selzer, M. L., & Vinokur, A. (1975). Role of life events in accident causation. *Mental Health, 2,* 36-54.
Signori, E. I., & Bowman, R. G. (1974). On the study of personality factors in research on driving behavior. *Perceptual and Motor Skills, 38,* 1067-1076.
Shaoul, J. E. (1976). The use of intermediate criteria for evaluating the effectiveness of accident counter-measures. *Human Factors, 18,* 575-586.
Shoham, S. G., Rahav, G., Markovski, R., Chard, F., & Baruch, I. (1984). "Anxious" and "reckless" drivers. *Deviant Behavior, 5,* 181-191.
Smith, D. I. (1976). Official driver records and self-reports as sources of accident and conviction data for research purposes. *Accident Analysis and Prevention, 8,* 207-211.

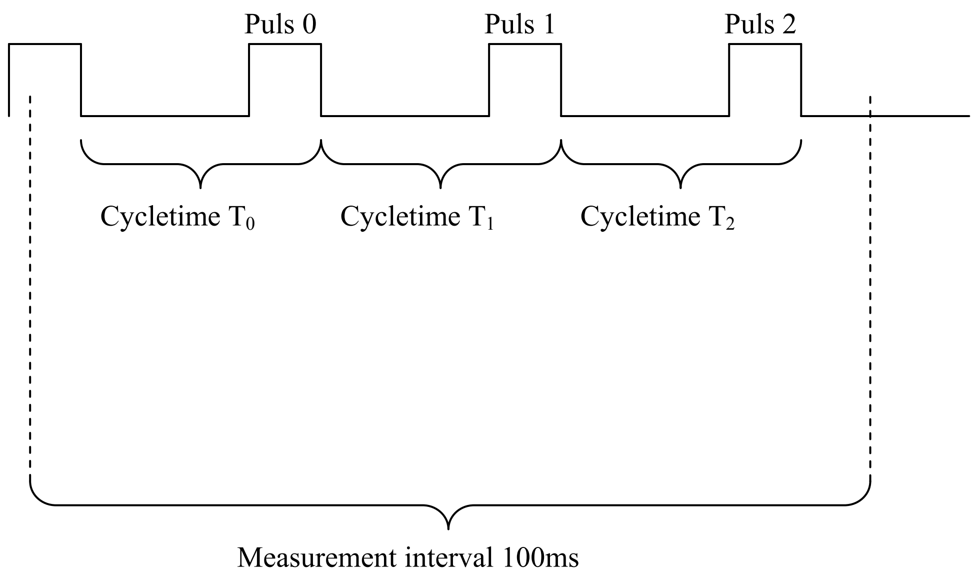
Smith, D. I., & Kirkham, R. W. (1982). Relationship between intelligence and driving record. *Accident Analysis and Prevention, 14,* 439-442.
Smith, D. L., & Heckert, T. M. (1998). Personality characteristics and traffic accidents of college students. *Journal of Safety Research, 29,* 163-169.
Stewart, R. G. (1958). Can psychologists measure driving attitudes? *Educational and Psychological Measurement, 18,* 63-73.
Stradling, S. G., Parker, D., Lajunen, T., Meadows, M. L., & Xie, C. Q. (1998). Drivers' violations, errors, lapses and crash involvement: International comparisons. Bergisch Gladbach: Paper presented at the 9th International Conference on Road Safety in Europe.
Violanti, J. M., & Marshall, J. R. (1996). Cellular phones and traffic accidents: An epidemiological approach. *Accident Analysis and Prevention, 28,* 265-270.
West, R., & Hall, J. (1995). Predicting accident risk in novice drivers. In G. B. Grayson (Ed.) *Behavioural Research in Road Safety V,* pp. 97-105. Crowthorne: Transport Research Laboratory.
Williams, J. R. (1977). Follow-up study of relationships between perceptual style measures and telephone company vehicle accidents. *Journal of Applied Psychology, 62,* 751-754.
Wilson, T., & Greensmith, J. (1983). Multivariate analysis of the relationship between drivometer variables and drivers' accident, sex, and exposure status. *Human Factors, 25,* 303-312.
af Wåhlberg, A. E. (2001). The theoretical features of some current approaches to risk perception. *Journal of Risk Research, 4,* 237-250.
af Wåhlberg, A. E. (2002a). Characteristics of low speed accidents with buses in public transport. *Accident Analysis and Prevention, 34,* 637-647.
af Wåhlberg, A. E. (2002b). On the validity of self-reported traffic accident data. Manama: E140 Proceedings of Soric'02.
af Wåhlberg, A. E. (2002c). Fuel efficient driving training - state of the art and quantification of effects. Manama: E141 Proceedings of Soric'02.
af Wåhlberg, A. E. (2003a). Some methodological deficiencies in studies on traffic accident predictors. *Accident Analysis and Prevention, 35,* 473-486.
af Wåhlberg, A. E. (2003b). Stability and correlates of driver acceleration behaviour. In L. Dorn (Ed.) *Driver Behaviour and Training*, pp. 45-54. First International Conference on Driver Behaviour and Training. Stratford-upon-Avon 11-12 November, 2003.
af Wåhlberg, A. E. (2004). Characteristics of low speed accidents with buses in public transport. Part II. *Accident Analysis and Prevention, 36,* 63-71.
af Wåhlberg, A. E. (2005). Differential accident involvement of bus drivers. In L. Dorn (Ed.) *Driver Behaviour and Training*, pp. 383-391. Second International Conference on Driver Behaviour and Training. Edinburgh 15-17 November, 2005.
af Wåhlberg, A. E. (in press, a). Short-term effects of training in economical driving; passenger comfort and driver acceleration behavior. *International Journal of Industrial Ergonomics,*
af Wåhlberg, A. E. (in press, b). Speed choice versus celeration behavior as traffic accident predictor. *Journal of Safety Research,*
af Wåhlberg, A. E. (submitted). Aggregation of driver celeration behavior data: Effects on stability and accident prediction.

Appendix: Technical specification of measurement equipment and ordering of measurements in Study IV

Technical specification

All predictor variables in Study IV came from the same data; measurement of pulses from the speedometer system of the buses. These pulses signify that a certain length of road has been traveled (for the buses in the present study 1/6900 of a kilometer). By counting the number of pulses for a time period (given by the internal clock of the measurement system), it is possible to calculate speed during this time period.

Example



Example
$t = T_0 + T_1 + T_2$
$n = 3$

The speed signal is tapped from the vehicle's speedometer with a frequency of 10Hz, an interval of 100 ms. During this interval, the number of complete puls-cycles is counted, and speed and acceleration calculated with the formulas below.

Speed calculation formula
$v = ((n/t)/w)*1000$
where
v= speed (m/s)
n= number of pulses from the speedometer
t= time for n pulses to accumulate (seconds)
w= pulses per kilometer

Acceleration calculation formula
$a_{(4n)} = ((v_{(4n)} + v_{(4n+1)} + v_{(4n+2)} + v_{(4n+3)})/4 - (v_{(4n)} + v_{(4n-1)} + v_{(4n-2)} + v_{(4n-3)})/4) / 2{,}5$
where
a= acceleration (m/s^2)
v= speed (m/s)
n= number of acceleration measurement points

Ordering of measurements

As measuring was operative during several years, drivers who worked a lot, and on certain duty rotation lists, tended to be measured several times, while others were rarely so. To utilize as much data as possible, but still retain a data arrangement that was ordered in time, these repeated measurements were ordered into samples within time periods. One such period can be seen in the first table below (where numbers designate measurement order, i.e. 1 is the first measurement of this driver). It can be seen that the driver Nilsson was measured three times during the fall season. These three measurements were easily ordered into the three samples of this period. Driver Jonsson, on the other hand, was only measured twice, and he is therefore absent from the third sample. Note also that despite that the first measurements of Nilsson and Jonsson are a month apart, these will still both be ordered into the first sample. Finally, although Andersson was among the last to be measured during this period, his single value will still be put with other first measurements in Sample 1.

When the season was finished (decided by the weather), a new grouping would start, in the example below winter, with three new samples (4-6), where the first measurement of each driver this season was ordered into sample 4, and so on.

Driver	August	September	October	November	December
Nilsson	1		2		3
Jonsson		1	2		
Pettersson			1	2	3
Andersson					1

Driver	Sample 1	Sample 2	Sample 3
Nilsson	1	2	3
Jonsson	1	2	
Pettersson	1	2	3
Andersson	1		

Acta Universitatis Upsaliensis

Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Social Sciences 10

Editor: The Dean of the Faculty of Social Sciences

A doctoral dissertation from the Faculty of Social Sciences, Uppsala University, is usually a summary of a number of papers. A few copies of the complete dissertation are kept at major Swedish research libraries, while the summary alone is distributed internationally through the series Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Social Sciences. (Prior to January, 2005, the series was published under the title "Comprehensive Summaries of Uppsala Dissertations from the Faculty of Social Sciences".)

Distribution: publications.uu.se
urn:nbn:se:uu:diva-6296

ACTA
UNIVERSITATIS
UPSALIENSIS
UPPSALA
2006