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Speed Choice

The Driver, the Road and Speed Limits

BY

MATS HAGLUND

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ABSTRACT

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Speed choice is one of the more characteristic features of driver behaviour. The speed a driver chooses to travel at determines the degree of difficulty he or she operates under. Higher speeds lead to more accidents, higher accident risk and more severe consequences of an accident. The present thesis examines factors that are associated with drivers' speed choice. Repeated measures of drivers' speed showed a reasonably high correlation, but also that stability in speed varied with road layout between measurement sites. Effects of police enforcement were studied on roads with temporary reduced speed limits (from 50 km/h to 30 km/h) during school hours. Lower speeds were found on roads with enforcement and drivers observed on one such road showed a higher perceived probability of detection than did drivers observed on a non-enforced road. However, in a laboratory study higher driving speeds and lower accident risk was associated with enforced roads. Drivers not informed about existing speed limits overestimated the limits to a large extent and chose driving speeds above the limit as did drivers informed about the limits. In an on-the-road survey, fast drivers reported higher driving speed, thought a higher percentage of other drivers were speeding and had a more positive attitude towards speeding than did slower drivers. The results suggest that drivers' travel speed is influenced by road factors, other road users and enforcement. Furthermore, drivers' own judgements of what is an appropriate speed are also important for speed choice.

Key words: Driving behaviour; Speed choice; Risk estimates; Enforcement; Attitudes

Mats Haglund, Department of Psychology, Uppsala University, Box 1225, SE-751 42 Uppsala, Sweden

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INTRODUCTION

Moving from one place to another implies speed, i.e. a distance travelled per unit time. By driving faster, less time is spent on the roads and more time can be allocated to other activities. Travelling too fast has serious shortcomings, however. For instance, travelling rapidly in a vehicle entails a higher risk that a traffic accident will occur. Thus, excess speed is recognised as one of the most common traffic violations (Fildes & Lee, 1993) and is a major factor responsible for persons killed and seriously injured in road traffic accidents (Nilsson, 1981; Kloeden, Ponte & McLean, 2001).

Although it is highly possible to drive at high speeds without any negative consequences and, of course, accidents do occur even at low speeds, the focus of research and traffic safety has chiefly been on high-speed drivers. Excessive speed can be classified into two categories. A driver may travel at a speed over the legal limit or a driver may travel at a speed below the limit but that is still too high with respect to road, traffic and weather conditions. A higher speed leads to a shorter reaction distance and a longer braking distance. High speed also results in other potentially risky behaviours. A higher than average speed often involves other vehicles being overtaken. In addition, high-speed drivers keep shorter headways (Wasielewski, 1984). By choosing a specific speed, the driver determines the degree of difficulty that he or she is willing to operate a vehicle. According to traffic law (Trafikförordning, 1998), a driver should keep a sufficiently low speed under poor driving conditions (e.g., poor weather and bad road conditions), within residential areas, near a pedestrian crossing, at hillcrests and at other places where the driver's view is severely restricted. Thus, in many circumstances it is up to the driver to make judgements about choosing an appropriate speed. Yet, a driver's judgement may not always meet the demands of safe driving as is evidenced by the large number of traffic accidents reported every year.

The present thesis is about how drivers' choose their travelling speed. This multifaceted issue is investigated by studying drivers' speed choice on the road, in the laboratory and via standardised self-report questionnaires.

History of vehicle speed

Throughout the history of the automobile, speed has been an important and hotly debated topic. In the beginning of the 20th century, automobile manufacturers were competing to produce the fastest car and average speeds were continuously increasing in almost every car race (Lacey, 1986). The history of speed limits is almost as old as the history of the automobile. In 1907, the first speed limits were introduced in Sweden (SOU, 1954). On rural roads, private cars were allowed to travel at 25 km/h in daylight and 10 km/h at nighttime. As cars were made safer, a decision was taken to raise speed limits and speed limits were abolished on rural roads in 1930 and in residential areas in 1936. The argument for this decision was that cars had become so much better in terms of safety. A further consideration for abolishing speed limits was that predetermined speed limits would weaken the character of the drivers in the sense that drivers would not take full responsibility for their actions. If there were speed limits, it was thought that drivers would adopt their speed according to the stipulated limit, which might result in higher speeds. Free speed, on the other hand, would sharpen the drivers' attention and increase their sense of responsibility.

Because of an increasing number of cars and higher speeds on the roads, the number of traffic accidents increased rapidly. In Sweden in the early 1950s, when cars became more accessible to people in general, the number of private cars was around 400,000 and the number of road deaths was about 800 (SOU, 1954). In 2000, the number of cars was nearly 4 million and the total number of people killed on the roads was almost 600 (SIKA/SCB, 2001). Many advances in traffic safety can be attributable to the introduction of speed limits, better roads and superior vehicles. For instance, modern cars are equipped with seat belts, energy-absorbing zones, airbags and superior handling characteristics than cars of yesterday. Even if the road traffic accident rate indicates a significant reduction since the middle of the 20th century, the rate is now showing signs of increasing (Jacobs, Aeron-Thomas & Astrop, 2000), especially in areas of the world which may be classified as less motorised countries. Therefore, road traffic accidents are a major problem in most countries (Zaal, 1994).

According to physical law, there is a strong relation between speed and the consequences of a crash. Moreover, there is evidence of a dramatic increase in the risk of involvement in severe and fatal traffic accidents associated with travelling at relatively high speeds. Conversely, there is a lower risk of a traffic accident occurring at lower speeds, and when they do occur, the outcome of such accidents is less severe. The relation between speed and accident rate was examined by Nilsson (1981). Nilsson studied how accidents and casualties change as a function of speed limit. The author asserted that the ratio between median speed after and before a change approximates the ratio of accident rate after and before the speed change. The probability of a police reported accident was found to be proportional to the square of the speed change and the probability of a fatal accident to the fourth power of the speed change. This implies, for example, that a 10% decrease in mean speed will lead to a 34% decrease in the fatality rate. Not surprisingly, a principal aim of traffic safety policy has been to lower mean speeds on the roads.

The driving task

The driving task consists largely of two components: adjusting speed and lateral position. However, this highly simplified view of what the driver has to do results in a large diversity of driving behaviours. In addition to the simple control of steering wheel and accelerator and brake pedals, the driver employs complex perceptual and cognitive systems. McKnight and Adams (1970) identified some 1,500 different perceptual-motor tasks in driving.

Driving may be conceptualised as a closed-loop feedback control system (Evans, 1991) in which the driver makes inputs, receives feedback from these inputs, arrives at decisions about action, makes additional inputs, etc. This process is described in Figure 1.

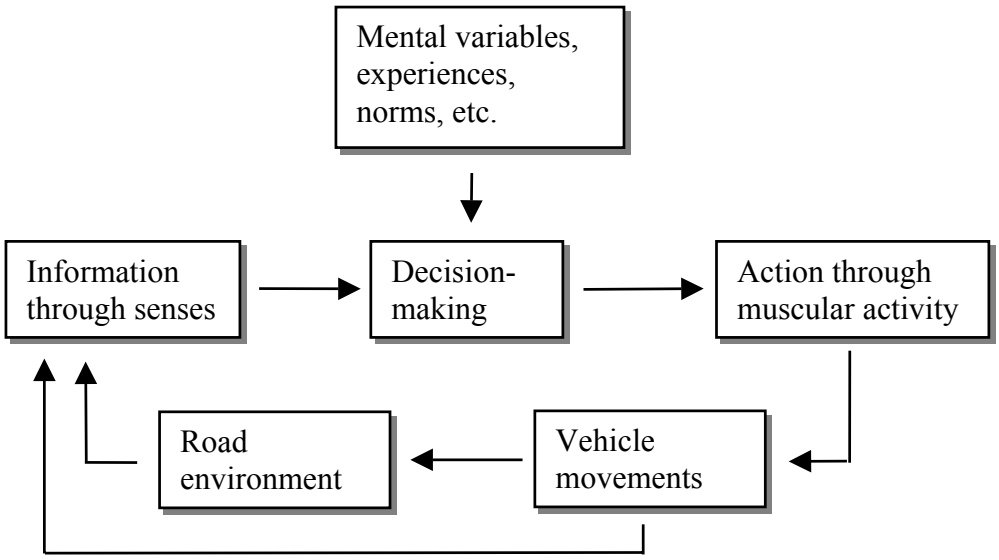

Figure 1. Dynamics of the driving task.

Thus, when the driver perceives the road environment (e.g., road layout, other drivers and road signs), he or she makes a decision to take some action, followed by adjustments in speed or lateral position via pedals and the steering apparatus. The movements of the vehicle alter its position in the road environment. The driver, in turn, perceives these movements, which give rise to new information based on the new position of the vehicle.

Judgement of speed

The information input to the driver is predominantly visual (Evans, 1991; Olson, 1993). When a person is moving in a forward direction in the environment, the image on the retina expands. The rate of this expansion conveys information about the person's velocity (Schrater, Knill & Simoncelli, 2001). In addition, the image of objects close to the observer will move faster across the retina than the image of objects farther away. Accordingly, perception of speed may depend on the distance to objects on the side of the road (Fildes & Lee, 1993). Thus, the perception of how fast one moves can be expected to vary with the combination of circumstances at a given time.

Roadside development is the environment close enough to the road to influence driving (Fildes & Lee, 1993). How the roadside environment affects driving speed was studied in an experiment in which drivers were instructed to keep the same speed without the aid of a speedometer (Shinar, McDowell & Rockwell, 1974). The findings indicated that speeds were lower on a road with trees close by than on a road with open spaces.

A number of investigations have studied how drivers estimate the speed their vehicle is travelling (Evans, 1970; Horne & Reyner, 1997; Horswell & McKenna, 1997; Milošević, 1986). Normally, the driver has a speedometer to keep track of the speed, but even without this speed indicator, the driver can estimate speed within reasonable limits. In studies in which subjects were asked to estimate the speed they were travelling without looking at the speedometer, errors in estimates were within 5 km/h (Evans, 1970; Milošević, 1986). In addition to visual information, auditory cues are important for speed judgement. In the Evans and Milošević studies, subjects were asked to estimate speed with auditory cues withheld. The results of these studies indicated that driving speed was underestimated by about 8 km/h after the removal of normal "car sounds". Effects of sound level in a car on speed was studied by Horswell and McKenna (1997). They found that drivers who were exposed to higher noise levels drove slower than those exposed to low-level noise. It seems that layout and sound reduction in larger, modern cars prevent drivers from obtaining complete feedback about speed (Horne & Reyner, 1997). These findings have implications for how judgement of speed is made in modern cars in which sound is reduced to a minimum. Thus, to give the driver feedback on objective speed the car is equipped with a speedometer. Watching the speedometer is strongly motivated by the need to obey speed limits (Groeger, 2000). After comparing actual with perceived speed, the driver learns the accuracy of the perceptual input (Evans, 1991).

Perception of speed of other vehicles on the road is another problem that may have implications in certain situations, such as overtaking and passing vehicles. When overtaking another vehicle, misjudging the speed of oncoming cars could have disastrous consequences. Björkman (1963) studied drivers' ability to judge the point where two cars driving in opposite directions would meet. Although the purpose was not to study

speed judgement per se, it may be relevant regarding the present discussion. When instructed to estimate the meeting point of the two cars, subjects underestimated the distance to the point when the speed of their own car was greater than the speed of the oncoming car and overestimated the distance when their own car was travelling slower than the other car. The estimates were, on average, halfway between the two oncoming cars. Only when the two cars were travelling at the same speed, did the subjects make correct average estimates. Björkman (1963) interpreted these results as an indication that drivers were subject to systematic errors in their estimations. In contrast to the notion of systematic error, Brehmer (1990) argued that variable errors in the perceptual system could explain Björkman's results. Brehmer concluded that accident rates depend on the distribution of vehicle speeds. Thus, when speed is more homogeneous among cars, drivers will make fewer incorrect judgements about the speed of other vehicles.

How to explain speeding?

The main objective of a journey is to travel from one place to another. This should be done in a safe and reasonably fast manner. Näätänen and Summala (1976) argued that drivers have other motives for driving additional to the need for safe transportation. These motives include goals set up for the journey, including haste, emotions, norms (what is thought of as correct behaviour), showing off, hedonistic objectives and a wish to take risks. Rothengatter (1991) found that speed is determined by four motivational factors: pleasure in driving, traffic risks, travel time and driving costs. Fast and slow drivers differ significantly on all four factors. Speeders believe that driving faster than the speed limit will give more pleasure and will not increase risk. Moreover, fast drivers, in comparison with slow ones, value time more and driving costs less. Rothengatter further argued that the speed limit acts as a factor that influences speed choice in addition to attitude toward speed as such. In summary, a driver's choice of speed is a balance between expedience and safety, and is frequently a subconscious reaction to the environment.

Several attempts have been made to explain driver behaviour. In general, theories have focused on driver errors in an effort to explain why drivers

experience accidents and who these drivers are (Ranney, 1994). Traffic accidents, however, are rare events relative to the individual driver. Thus, because traffic accidents occur so infrequently, research should focus on driver error (Rimmö, 1999). Speeding is often defined as a type of driver error. However, errors can be classified into violations and mistakes. Violations are deliberate errors, whereas mistakes occur when the driver fails in his or her intentions to execute an intended behaviour. Thus, exceeding the speed limit may be a deliberate choice or it may be unintended. Moreover, a driver may intend to drive at the legal speed limit or even below it, but have difficulties in holding the intended speed and thus unintentionally exceed the speed limit.

Although drivers exceed speed limits without deliberate intent, the fact that speed limits are often neglected may be a manifestation of drivers' dissatisfaction with posted speed limits. For instance, some drivers consider the posted speed limit to be too low for certain roads or circumstances. If driving fast (i. e. faster than the legal speed limit) is dangerous, why do drivers fail to recognise this danger? Jobs (1990) suggested that drivers learn to cope with fear through the process of over learning. Long before drivers receive their driver's license, they have travelled as a passenger with parents or other drivers. Most situations that may have been experienced as dangerous never resulted in an accident. Through frequent encounters with risky situations, individuals learn to adapt to these dangerous circumstances and any fear that they had in the beginning diminishes until fear is no longer experienced. This over learning phenomenon to cope with fear, desensitisation, has been used successfully in behaviour therapy to eliminate fears and phobias (Carlson, 1988). It has been proposed that drivers learn to respond late to aversive stimuli which will lead to risky behaviours (Fuller, 1988). When a driver is warned about a hazard on the road, delaying the response may be rewarding (e. g., no loss of speed by braking) because an accident does not occur or the situation is not perceived as hazardous. In their zero-risk theory, Näätänen and Summala (1976) reasoned that drivers normally experience no risk in driving. This means that when a situation becomes more demanding and the experienced level exceeds zero, the driver tries to eliminate the feeling of risk by taking appropriate action, such as reducing speed. The driver may also try to avoid situations that elicit the risky feeling.

Thus, exceeding the speed limit is a common traffic violation and there may be a number of reasons why drivers take the opportunity to drive at high speeds. Some measures against excessive speeds are presented in the next section.

Measures to reduce speed

To reduce drivers' speed several methods have been used. One method, enforcement, is aimed solely at those drivers who exceed the speed limit (Åberg, 1980; Armour, 1984; Rothengatter, 1996). Another method is publicity campaigns in which drivers are informed about the risks of high speed. The primary goal of this approach is to alter drivers' attitudes about speed in general (Englund, Gregersen, Hydén, Lövsund & Åberg, 1998). Another method is the use of perceptual measures. These measures are aimed at manipulating drivers to drive slower by deceiving them into believing that they are driving faster than their actual speed (Fildes & Lee, 1993). In their review, Fildes and Lee noted that physical measures in the environment, such as reducing the road width, are used mainly in urban settings. Of special interest for the present thesis is speed limit, a topic that is addressed in the next section. Each of these methods is related to the driving task in different ways. Environmental measures are aimed at the driver's immediate responses and actions in the car while publicity campaigns should have effect on the driver's decision making and make the driver more considerate.

Enforcement is one of the more efficient strategies in reducing driving speeds (Åberg, 1980; Armour, 1984; Rothengatter, 1996). Enforcement is thought to affect driving speeds and eventually the number of accidents as follows: A given level of enforcement is the actual level of the risk of detection. This risk level affects drivers' perceived level of risk of detection, which, in turn, has an effect on driving speeds. Lower speeds result in lower accident risk. However, the effect of enforcement on driving speeds has been shown to be limited temporally and spatially, i.e. the enforcement is effective for only a few kilometres from the enforcement site and it lasts for only a few weeks after the intervention (Vaa, 1997). Hauer, Ahlin and Bowser (1982) noted that the effect found at the

enforcement site was reduced by half for approximately every 900 m from the site.

Only those drivers who frequently travel a particular road can notice any differences in the levels of enforcement on that same road. Drivers who are unfamiliar with the road may perceive some risk of detection based on prior driving experience on other roads, but they may not be aware of any difference in the level of enforcement. From a review of literature, Østvik (1989) reports that in general an increase of about three times the normal level is needed to have any effect on drivers' perceived risk of detection.

Sanctions for violating traffic rules are used as deterrents. In which way the size of the fine imposed on violators promotes law-abidingness has not been studied to any extent. One obvious assumption is that higher fines serve as a stronger deterrent on drivers' speed choice. Yet, Åberg, Engdahl and Nilsson (1989) reported that doubling fines for speed violations had no effect on drivers' speed choice. This finding does not necessarily mean that fines do not have effect on drivers' behaviour, however, but that it has not been shown how high the penalties have to be before they have an affect on drivers' speeding behaviour.

Publicity campaigns designed to alter drivers' attitudes or behaviour are difficult to evaluate (Englund et al., 1998; Forward, 1994). Changes in attitudes come about slowly, if at all, and the effects of campaigns may not have shown before evaluations were made. Poor understanding of peoples' justifications and lack of any theoretical basis are two explanations to account for the weak results. Public information, in combination with speed enforcement, however, has been found effective (Rothengatter, 1996). Elliot (1989) maintains that limited effects of campaigns can be expected and that campaigns primarily affect people's awareness of a problem and possibly strengthen attitudes and behaviours that already exist. To influence people indirectly through campaigns, i.e. information directed toward peers, have been used with success in Australia (Elliott, 1993).

Perceptual measures to reduce speed are based on assumptions about how drivers use visual information for speed choice. Denton (1973) found that lines painted across the roadway served the purpose of making the driver

perceive higher speed than the actual driving speed. With the lines painted perpendicular to the direction of travel and with decreasing distance between the lines, increasing speed is perceived even though speed is kept constant. Such a measure should make drivers slow down in order to perceive the speed as constant.

Physical measures used to decrease speed include humps, narrowing the roadway, pavement material, etc. In the Netherlands, a road environment in cities called "woonerf" has been introduced. In such an environment, the driver is forced to slow down because of road layout and design, a pattern that also partly informs the driver of the speed zone for that area (Riemersma, 1986). The effects of road humps have been shown, however, to be limited (Karlgren, 2001). On streets with humps, the speed has been shown to be uneven as motorists tend accelerate between the humps.

The above-mentioned measures of reducing speeds have differing desirable effects. The effects, however, may be limited with respect to temporal and spatial factors, such as enforcement and built-in measures in the road environment. That effects are limited points to the possibility that drivers search in the environment for reasons to slow down or speed up. A more general and widely accepted method among researchers and traffic safety authorities to reduce driving speeds is the use and enforcement of speed limits.

Speed limits

In the era before speed limits were introduced, drivers were held fully accountable to determine what speed was correct for a given situation. Because road fatalities have shown an increase (SOU, 1954) and because drivers may misjudge the speed of their own car (Casey & Lund, 1987) and underestimate the risks involved in speeding (Näätänen & Summala, 1976), road safety authorities reached a decision to restrict driving speeds on the roads. A consensus has been reached about the relations between high speeds and the frequency and severity of traffic accidents (Fildes & Lee, 1993). Speed limits place limits on speed as well as on speed variation (Salusjärvi, 1981). Solomon (1964) showed that accident rate was higher for drivers who drove above or below the mean speed. Garber and Gadiraju

(1989) found an increment in the accident rate that was due to an increase in speed variance and not higher average speeds. However, the effect of speed variance on traffic safety has been debated (Evans, 1991). Highest safety should be achieved if all vehicles travelled at the same speed because then there would be no need for drivers to overtake each other. Speed variation seems to be of minor importance in single-vehicle or side impact crashes occurring in intersections.

Speed limits may be seen as a trade-off between accessibility and safety. In addition to safety, a speed limit should meet the requirements of enforceability and acceptance by the community (Transportation Research Board [TRB], 1998). When speed limits have been adopted, road fatalities have diminished (Summala, 1985). Several factors are used as criteria when establishing speed limits. Speed limits are commonly effected according to (a) the 85th percentile of the speed level on the road, (b) road standard (roads with many intersections and poor geometry usually have lower speed limits than high standard roads), and (c) benefits to society are optimised (Nilsson & Roosmark, 1976). Where speed limits have been raised (e.g., from 55 to 65 mph in the USA), a concomitant increase in average speeds and the number of accidents have occurred (Rock, 1995). The effects of speed limits have been summarised by Elvik, Vaa and Østvik (1989) as follows:

- Lowering speed limits usually leads to lower average speed and fewer people injured.
- The speed limit should be set lower than the 85th percentile to ensure lower average speed and fewer accidents.
- The lower the legal speed limit, the greater the effect on average speed.
- The number and severity of accidents is reduced with a concomitant reduction in speed.
- An increase in speed limit normally results in higher average speed and an increase in the number of traffic accidents.
- Lowering the speed limit typically leads to a higher proportion of speeders.
- Lowering the speed limit seems to have its greatest impact on speed and accidents when weather and road conditions are good.

Perception of road signs

The legal aspect of speed choice is that the driver must not exceed the posted speed limit. This implies that the driver must alert in watching out for speed signs. When asked to register road signs, the driver is able to accomplish this task with great accuracy (Johansson & Rumar, 1966). When sitting as passengers, subjects were asked to report all road signs along a 170 km long route. On average, over 90% of all signs were registered. When driving, however, observation of signs is largely contingent on the message conveyed by the sign. In a follow-up study (Johansson & Rumar, 1966), five road signs of different importance to drivers were used consecutively on a straight road section. Drivers were stopped and asked about the last sign they had seen. Correct answers ranged from 17 to 78% for the different signs. The best remembered sign was a warning for reduced speed limit ahead; the lowest correct response was for a sign warning for a pedestrian crossing ahead. Differences in recollection of a sign may be related to how motivated the driver is in allocating attention to a sign (Näätänen & Summala, 1976). A general warning is too unspecific to be of much value, whereas a sign warning for a speed limit ahead contains essential information. Remembering a sign after seeing it, however, does not explain whether the driver will comply with the sign. To examine this issue Summala and Hietamäki (1984) studied speed changes of drivers after using three road signs (danger, children and speed limit 30 km/h). The signs appeared after a curve and were alternated with and without a warning flasher. The greatest decrease in speed was found for the road sign with 30 km/h with a flashing light. The authors concluded that the results supported their reasoning (Näätänen & Summala, 1976) that drivers have varying motivation to comply with different road signs and that "drivers generally have perceptual skills sufficient for detecting signs but they feel they are not in need of such symbolic information because they rely more on their own eyes and experience" (Summala & Hietamäki, 1984, p. 215).

A number of explanations for drivers' low motivation to attend to road signs have been offered (Näätänen & Summala, 1976). Some of these reasons are that drivers feel no risk when on the road, there is a low level of police enforcement of rule compliance, the driver learns that a situation is

not followed by what is implied by the sign, there is a high energy cost of being alert for signs leading to fatigue and the driver feels that a need for extra information is not required.

Attitudes

Violations on the road in relation to attitudes have been studied extensively (e.g. Åberg et al,. 1989; Åberg, Larsen, Glad & Beilinsson, 1997; Fitzgerald, Harrison, Pronk & Fildes, 1998; Parker & Manstead, 1996; Webster & Wells, 2000). A widely used theory during the past decades has been the Theory of Planned Behavior (TPB) (Ajzen, 1991). This theory is an extension of an earlier version, the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975). A diagram of the theory appears in Figure 2. A central factor in the Theory of Planned Behavior is the individual's intention to engage in a given behaviour. In general, the stronger the intention to engage in a behaviour, the more likely the person will perform the behaviour. In order that the behaviour is performed, it is necessary that the behaviour be under the volitional control of the individual. Intention is determined by three concepts: attitude, subjective norm and perceived behavioural control. Attitude toward the behaviour is the degree to which a person has a favourable or unfavourable evaluation of the behaviour. Subjective norm refers to the perceived social pressure to perform or not to perform the behaviour. A third, new concept, is perceived behavioural control. This idea refers to people's perception of how easy or difficult it is to perform the behaviour. Perceived behavioural control varies across situations and actions (Ajzen, 1991).

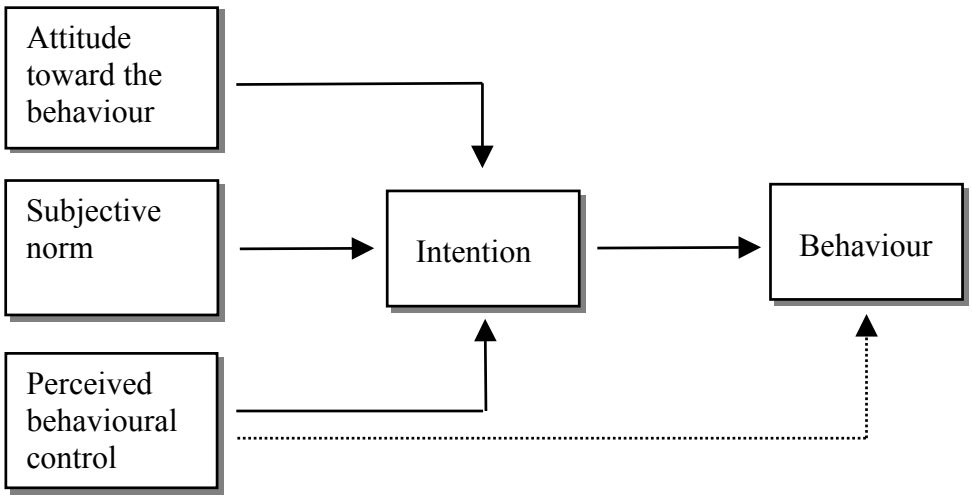

Figure 2. Theory of Planned Behavior (after Ajzen, 1991).

One feature of TPB is that it deals with attitudes and behaviour in a specific context rather than on a general level. Åberg et al. (1997) reported a higher relation between attitudes toward speeding on a specified road than attitude toward speed in general. In their study, attitude had an indirect link to observed speed through normal and reported speed. The two latter variables represented intention to speed and explained 15% of the variance in observed speed. The results were interpreted to mean that drivers who were least negative to speeding drove faster than other drivers and those drivers who perceived others to drive fast or wanted to keep up with the flow of traffic also maintained higher speeds.

Norms

Normative influences may reflect the everyday behaviour of others (Groeger & Chapman, 1997). From this viewpoint, there are several explanations to account for speed limit violations. Drivers may view speeding as acceptable (because others do it), they are unaware that they are speeding and the positive outcomes of speeding outweigh the negative ones. Each driver is a member of the driving community and thus is influenced by other road users (Zaidel, 1992). Drivers may infer from the driving behaviour of others about speed norms on a road. In a series of experiments, Van Houten and Nau (1981, 1983) showed that public posting

of the percentage of drivers who had not broken the speed limit during a specified time had a positive effect on the number of speeders. When the display showed an increasing number of legal drivers the number of speeders decreased. Theses findings suggest that drivers are motivated to comply with the norms.

Normally, drivers are not informed about what proportions of the driving population are committing or not committing traffic violations. Thus, drivers may be biased in their perceptions. Attitudes, opinions and behavioural tendencies are seen as relatively more common by people who have those attitudes and opinions or engage in those behaviours (Parker & Manstead, 1996). This phenomenon, known as false consensus bias, was first studied by Ross, Greene and House (1977). Manstead, Parker, Stradling, Reason and Baxter (1992) found that drivers who violate a specific traffic rule on a regular basis overestimate the proportions of other drivers violating the same rule.

Social comparison was studied by Connolly and Åberg (1993). They proposed that drivers have a tendency to follow the speed behaviour of other drivers that are nearby. Vehicles close to each other travelled at similar speeds, regardless of whether the lead vehicle was travelling slowly or at high speeds.

The way drivers influence each other may be the result of either correct or incorrect perceptions of drivers. Even if no other vehicles are seen, a driver may have a sound notion about what the speed norms are on the road.

The speeding driver

Because of the strong association between high speed and risk of serious traffic accidents, a fair amount of research has been aimed at identifying the characteristics of the high-speed driver. The rationale underlying this endeavour is that more precise methods (e.g., enforcement and advertising) can be administered to target groups (Fildes & Lee, 1993). Solomon (1964) found higher mean speeds for young drivers, out-of-state vehicles, vehicles of the armed forces, buses and newer, high-powered vehicles. Fildes, Rumbold and Leening (1991) found several variables to be related to

higher speeds, including the driver's age, number of passengers, the journey's purpose, mileage travelled per week and accident record. Although such factors are related to speed, they do not provide any information about the way a driver selects speed.

The speed a person chooses to drive reflects the person's degree of willingness to take risks (Wasielewski, 1984). Other behaviours regarded as risky include close following, driving without a seat belt, lane changing and behaviours that may be a manifestation of sensation seeking (Rimmö, 1999). The sensation seeking scale (Zuckerman, 1994) and variants of that scale have been used extensively (for a review, see Jonah, 1997). Persons scoring high on the scale differ on a number of characteristics from low scorers. For instance, speed choice, overtaking, racing, and shorter distance have been reported to be associated with high scores of sensation seeking. Many of these behaviours are dependent on the high speed the driver chooses to travel and those who score high perceive less danger in risky driving behaviours (Jonah, 1997).

Webster and Wells (2000) summarised characteristics of the speeding driver. They found that many drivers break the speed limit on some occasions. More speeders were found among young male drivers in non-manual occupations. Company car drivers, drivers in large cars and high mileage drivers are more likely to drive fast. Drivers tend to justify their speeding by contending that speed limits are unrealistic.

How to measure speed

Speed is one of the more easily measured driver behaviours. For instance, the police may use radar or laser guns to measure the speed of individual drivers, or detectors may be placed on the roadway to measure the general speed level on the road. The latter method is often used over specified periods with no connection to individual drivers. Speed may also be measured by timing vehicles over a specified distance. In addition to these objective speed measures, self-reports of drivers may be used. In psychological studies, questionnaires are commonly used in which respondents are asked to give self-reports about speed choice. When assessing the association between behaviour and attitudes, most research

relies on subjective data such as self-reports (e.g., Forward, 1994). In a study designed to assess the accuracy of self-reports, Manfredo and Shelby (1988) observed that the consistency between self-reported behaviour and attitudes was greater than that between actual behaviour and attitudes. The responses generated by the respondent may thus be an expression of the individual's strategy to keep coherence in his or her answers. When drivers have been asked to report their driving speed, moderately high correlations with observed speed have been obtained (Corbett, 2001). Correlation coefficients between .12 and .52 in rural and urban settings (Fildes et al., 1991) and .36 on roads in built-up areas (Åberg et al., 1997) have been reported.

Aim of the present thesis

Why drivers choose a particular speed has been the subject of intensive research. Some factors affecting speed choice have been discussed here as well. The reason for the general interest in driving speeds is the well-documented relation between high speed and accident risk. It has been estimated that speeding was a contributing factor in about one third of all fatal crashes in the USA (NHTSA, 1999).

Most people have probably encountered a traffic situation on a high standard road with very few other cars around and under such circumstances found the speed limit to be questionable. Under identical circumstances, some drivers would undoubtedly choose a speed according to the posted limit while others would choose a speed slightly above the limit or a speed well above the limit. What is the probability of being detected by the police when exceeding the speed limit? What is the speed level on the road? Is there any risk of having an accident? These are a few considerations a driver might consider when determining speed in a normal traffic situation. By investigating drivers' speed choice on the road through observations, interviews and questionnaires, and by studying drivers' judgements under laboratory conditions, this thesis hopes to contribute to the knowledge about how drivers act on the road. The primary aims are to establish how consistent drivers are in their choice of speed and to study motorists' speed choice in relation to enforcement, other motorists and the road environment.

In Study I, the consistency in drivers' speed choice is established.

In Study II, the effects of enforcement are investigated on roads with temporary reduced speed limits.

In Study III, speed choice is investigated in relation to the road and roadside environment. In addition, the study examines how accurate drivers' estimates of speed limits are and compares judgements of drivers who are versus drivers who are not informed about speed limits.

In Study IV, comparisons are made between observed speed and drivers' self-reports about their speed and how drivers on the road influence the behaviour of one another.

EMPIRICAL STUDIES

Study I
Stability in drivers' speed choice

The aim of this study was to investigate if drivers are consistent in their choice of speed. Normally, in speed-related investigations conclusions about fast and slow drivers are drawn from single speed measures (Quimby, Maycock, Palmer & Buttress, 1999). A driver's speed may vary because he or she is influenced by other drivers on the road, as would be the case in dense traffic. Speed may also fluctuate over journeys because the driver's motives vary over occasions. In addition, during the same journey the driver may vary the speed of the vehicle. Thus, the driver slows down when attention is given to the view rather than the road, or speeds up because of inattention to the speedometer.

In models of driver behaviour self-reports of driving speeds are often used. In those cases, researchers have to rely on the driver's accuracy. Correlations between .27 and .65 between subjective measures and actual behaviour have been reported (Corbett, 2001). However, the validity of self-reports concerns vehicle speeds obtained at one point on the road. This single measure of a driver's speed may not easily be generalised to other places or to other occasions. Therefore, in modelling speed choice and to understand drivers' choice of speed more fully, it is important to know to what extent drivers' speed varies across diverse situations.

The few studies that have explored the consistency issue have had methodological shortcomings (Nilsson & Obrenovic, 2000; Ogawa, Fisher & Oppenlander, 1962), or they have found relatively poor correlations between repeated speed measures (Wasielewski, 1984). The present study challenges earlier findings and investigates consistency in speed choice using different road settings.

To obtain repeated measures on the speed of individual drivers vehicles were observed at two locations along a road, or at one location for several days. Vehicle speeds were measured by unobtrusive video recordings of the traffic. Two video cameras were used simultaneously, except when

repeated observations were conducted at the same site. At each site, a camera was placed inside a car between 100 and 200 m from the road. Speeds were later calculated by the vehicles' passing time between two white poles arranged beside the road and clearly visible on the video recordings. The distance between the poles was about 200 m and measured on the roadway to the nearest 0.1 m. Speeds were measured on two roads where the speed limits were 70 and 90 km/h. In one case, speeds were measured at two sites with the same speed limit, i.e. 90 km/h. In the second case, speeds were measured at two sites with different speed limits, i.e. 90 and 70 km/h. In the third case, speeds were measured at two sites where the speed limit was 70 km/h; between these two measurement sites was a 50-km/h road segment. Distances between measurement sites ranged from about 3.5 km to 7 km. In the fourth case, speed measures were obtained at one location (speed limit was 70 km/h) for several days. Observers, sitting in cars close to the road, recorded driver characteristics (e.g., age and gender). However, because the drivers were not stopped on the road and interviewed, the observers had to estimate the age of the drivers.

The number of vehicles observed more than once and included in the analyses was 809 of which 580 were free flowing (at least a 6-sec time gap to another vehicle). Of these, 543 drivers were observed at two locations and 37 drivers were observed at the same site on two days.

The results indicate that mean speeds for free-flowing vehicles were above the speed limit on all sites. Where speed limits changed from 70 to 90 km/h, mean speed increased from 87.4 to 93.1 km/h. Where speed limits changed from 90 to 70 km/h, mean speed decreased from 98.5 to 91.7 km/h. Thus, the changes in mean speeds did not correspond to the changes in speed limit.

Correlations for free-flowing vehicles are shown in Table 1. Correlation coefficients range from .49 to .81. The highest correlations were found between sites with the same speed (90 km/h) limit. One can anticipate lower relations if speeds are measured at sites with different speed limits or where another speed limit is located between the measurement sites.

Table 1. Correlation coefficients for repeated measures for free-flowing vehicles at two sites along a road (Comparisons A - C) and for two occasions at the same site (Comparison D).

Comparison	Direction	*r*	*N*
A	East	.81	75
	West	.78	97
B	East	.75	92
	West	.67	83
C	East	.70	89
	West	.49	107
D	East+West	.70	37

Consistency in speed choice in relation to speed limit was found to vary among roads. On the road where the drivers encountered two speed limits, 4 to 5% of the drivers preserved the posted speed limit at both sites. The fact that few held the speed limit at the 70-km/h section may explain the low percentage of consistently legal drivers. The highest proportion of consistently legal drivers was found on the two 90 km/h sites, with the values 41 and 25% for east- and westbound traffic, respectively. Drivers systematically speeding at two sites during the same journey varied between 43 and 70%, while all drivers observed at the same location on two days exceeded the speed limit on both occasions.

The results show a high constancy in speed choice on rural roads. The correlations found are of the same magnitude as those reported in rural settings (Nilsson & Obrenovic, 2000; Ogawa et al., 1962). It is not clear, however, if the vehicles in those studies were free-flowing or driving in platoons. In the present study, the correlations for the repeated measures were found to vary according to road conditions. In addition, the order in which drivers encounter different speed limits was found to affect the degree of law-abidingness.

The selection of observation sites for the present study was largely based on practical considerations. For instance, to record information on a large

proportion of free-flowing vehicles intermediate traffic volume is preferred and observations should be allowed to be made unobtrusively. Thus, rural highways were selected in that such roads meet these criteria. Although the correlations found were reasonably high, they can be considered as an upper limit for relations between self-reports and observed speed.

Study II

Effects of enforcement on roads with reduced speed limits during school hours

One goal of Study II was to investigate drivers' speed choice and subjective risk of detection on roads, with and without enforcement in urban areas. The roads selected for the study have two speed limits in force at different times. The speed limit on these road sections is lowered from 50 to 30 km/h during school hours. This is a common system to regulate traffic with both speed limits appearing on the same road section. Because the roads are located in residential areas (50 km/h applies), only the 30 km/h speed limit is sign posted on these particular road sections. By studying roads with different levels of enforcement (i.e. enforcement vs. no enforcement) and varying speed limits (i.e. 30 and 50 km/h), the effects of these variables can be distinguished.

Drivers were studied on two roads with speed enforcement and on two roads without enforcement. The roads differ in that the traffic is denser on the two enforced roads Speeds were measured in the same way as described in Study I: vehicles were recorded on video and speed was calculated by the vehicles' passing time over a specified distance. Speed data were collected on four occasions on each road. Speeds were measured on three occasions in the morning during school activities when the speed limit was 30 km/h and on one occasion during school holidays when the speed limit was 50 km/h. On one of the enforced roads, police records showed three radar speed checks during the same year as the present study. The three speed checks occurred during lunch hours and lasted about one hour each. No speed check had occurred closer than three weeks before initiation of the present study. On the second enforced road, 10 radar speed checks had occurred during the year, four of which had taken place during

morning hours. One speed check had taken place two weeks before initiation of the present study.

In a follow-up study, drivers' subjective risk of detection was assessed with self-report questionnaires. Drivers who had been observed on one of the enforced roads and drivers observed on one of the non-enforced roads were selected for this part of the study. Vehicles were first observed during several days to record repeat drivers. Vehicle license plates were recorded and the car owners' names were obtained from the department of motor vehicles. Drivers with addresses that revealed they would be familiar with the road (they had been observed for several days) were selected for the questionnaire study. Drivers were contacted either by mail or were interviewed in their homes. The number of responses was 243 and 82 for the enforced and non-enforced road, respectively. Questionnaire items assessed the number of speed checks the drivers had observed on the road and the likelihood that they would be caught for speeding.

Totally, 3,608 speed observations were made. In general, mean speeds were lower on all roads when the lower speed limit was in force. On the two speed enforced roads, mean speeds for all vehicles decreased from 53.4 to 33.8 km/h and from 51.7 to 34.2 km/h. On the two non-enforced roads, mean speeds decreased from 47.7 to 40.4 km/h and from 52.7 to 41.1 km/h. All differences in mean speed were significant ($p<.001$).

Traffic density may affect drivers' speed choice. At high volume, the smallest disturbances can trigger a jam of slow-moving traffic, whereas at low volume, vehicles move independently and can achieve their preferred speed. Therefore, a separate analysis on free-flowing vehicles (N=1498) was performed. A two-way analysis of variance, with enforcement level and speed limit as factors, revealed significant main effects of speed limit ($F[1, 1494]=613.5$, $p<.001$) and enforcement level ($F=[1, 1494]=8.6$, $p<.01$), as well as an interaction between speed limit and enforcement level ($F[1, 1494]=76.7$, $p<.001$). The results are summarised in Figure 3.

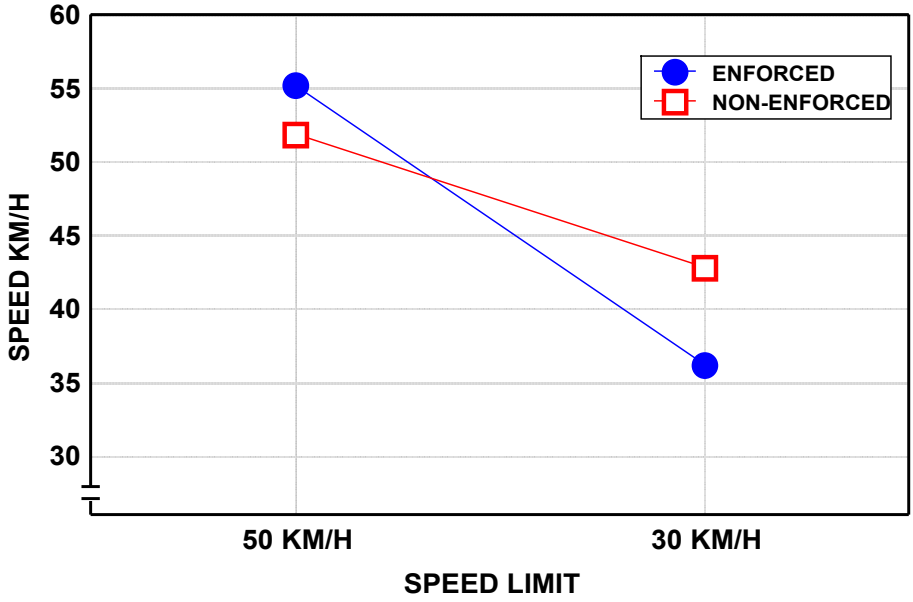

Figure 3. Mean speeds for free-flowing vehicles as a function of speed limit and enforcement level.

The questionnaire study revealed that 71.7% of the drivers on the enforced road and 7.5% of the drivers on the non-enforced road reported that they had seen speed checks on the road on which they had been observed (χ^2=96.9, p<.001). Drivers' estimated risk of being detected for speeding differed between the two driver samples. For the drivers on the enforced road, 70.6% thought they would be detected at least once per year; for the drivers on the non-enforced road, 46.3% believed they would be detected at least once per year (χ^2=15.3, p<.001). There was no difference between the two driver samples regarding intention to observe the 30 km/h speed limit. Almost all of the respondents (97.5% on either road) reported that they would observe the speed limit.

The results indicate that even moderate levels of enforcement have an effect on driving speeds. When 50 km/h was in force, mean speeds were slightly above the limit on three roads. Normally, when lower speed limits are introduced, a decrease in mean speeds will follow, but these reduced speeds do not correspond fully to the change in speed limit. These results demonstrate that, on the roads without enforcement, mean speeds decreased about 7 and 12 km/h when a 20 km/h lower speed limit is in force. With

enforcement, the decrease in mean speeds was almost as large as the speed limit change, about 20 and 18 km/h. Drivers' subjective risk of detection differed in relation to road type: more drivers on the enforced road had observed speed checks and more drivers expected to be detected, if they exceeded the speed limit. These results are consistent with research on enforcement effects.

Study III

Traffic risks and speed choice

The aim of Study III was to investigate drivers' estimates on several variables that are assumed to be related to speed choice. The specific variables studied were drivers' judgements on risk of detection, accident risk and likelihood to abide by the speed limit and how these judgements are related to speed choice. Considering the importance of speed level and speed variance for the probability of accidents (Salusjärvi, 1981; Solomon, 1964), the road layout should give unambiguous signals as to what speed limit is in force and thus what speed is appropriate for that segment of road. If a driver does not know the speed limit, what speed does he or she choose? Are estimates different when drivers know the speed limit from their estimates when they do not know the speed limit?

The importance of road layout for speed choice is well documented (Cairney, 1986; de Waard, Jessurun, Steyvers, Raggatt & Brookhuis, 1995). Higher speeds were reported on roads with open surroundings and lower speeds were associated with wooded roadside environment. Perceptual aspects as well as drivers' perceived risk of a traffic accident might be plausible explanations for differences in speed between the two roadside types. Assuming a driver is consistent in his or her estimates of accident risk on different roads (not considering other vehicles or traffic situations), speed choice should be related to such estimates of accident risk.

In Study II, the results indicated that mean speeds were lower on enforced roads. This finding concurs with previous research (Fildes & Lee, 1993; Shinar & McKnight, 1985). However, effects of enforcement are normally studied on the road on which enforcement has taken place and drivers'

estimated risk of detection may be assessed on one road. This raises several questions. For instance, do enforced roads have a common feature that all drivers can readily detect? Further, do drivers use information learned about risk of detection on a familiar road and apply this information to other, less known roads? Thus, the intention of Study III was to determine whether drivers choose lower speeds on enforced than on non-enforced roads.

In Study III, drivers watched 18 videotaped road sections with six roads for each of three speed limits: 30 , 50 and 70 km/h. For half of the roads, three for each speed limit, speed enforcement had occurred. The road segments were recorded from a moving vehicle in traffic, which would enable participants to obtain a good view of the road and its environment. For each road section, the participants (N=60) estimated risk of detection for speeding, accident risk, likelihood to observe the speed limit (all ratings were done on scales from 1 to 20) and speed choice (in km/h). Half of the participants were informed about what speed limit was in force for each road segment; the remaining subjects were also asked to make estimates about speed limit. The subjects were not informed about which roads had been enforced.

Estimated speed limits for drivers not informed about the limits for enforced and non-enforced road segments s are presented in Table 2.

Table 2. Mean speed limit estimates (km/h) on enforced and non-enforced roads.

Speed limit	Enforced	Non-enforced
30	56.0	56.4
50	62.2	51.6
70	80.2	68.4

Mean estimates on the 30 km/h limit roads were well above the actual speed limits on all roads. On the enforced 50 and 70 km/h roads, drivers' speed limits were estimated to be higher than the actual speed limits though

less than the estimated speed limits on the 30 km/h roads. Estimates below the actual speed limit were observed only on the 70 km/h non-enforced roads.

A repeated measures analysis of variance was carried out for each of the following dependent variables: risk of detection, accident risk, likelihood of keeping the speed limit and speed choice. In general, the risk of being detected for speeding was found to be higher on the enforced roads [$F(1, 58)=8.6$, $p<01$]. A post hoc analysis (Tukey's HSD test, $p<.001$) revealed that this effect was attributed to the 70 km/h roads.

Estimates on accident risk were found to be significant for speed limit [$F(2, 116)=35.7$, $p<.001$] (higher risk on 30 km/h roads) and enforcement [$F(1, 58)=62.4$, $p<.001$] (higher risk on non-enforced roads). There was no evident difference in accident risk across speed limits on non-enforced roads. Lowest risk was estimated on enforced 50 and 70 km/h roads ($p<.001$, Tukey's HSD test).

The participants estimated that it would be less likely to observe the speed limit on enforced 50 and 70-km/h roads. Significant effects of speed limit [$F(2, 116)=7.3$, $p< 01$] and enforcement [$F(1, 58)=66.4$, $p<.001$] were found. Drivers considered it more likely to keep the speed limit on 30 km/h roads and on non-enforced roads. One exception to this general effect is that drivers not informed about speed limits estimated a higher accident risk on enforced 30 km/h roads. The estimates of the uninformed drivers were made in relation to what they thought was the speed limit.

At what speed would the participants choose to drive on these roads? Significant effects of information about speed limit [$F(1, 58)=50.7$, $p<001$] (higher speed for uninformed drivers), enforcement [$F(1, 58)=202.6$, $p<001$] (higher speed for enforced roads) and speed limit [$F(2, 116)=860.0$, $p<001$] were found. The two-way Group x Speed limit interaction was significant, $F(2, 116)=80.2$, $p<.001$. Information about speed limits does not yield significant differences in estimates about speed choice on non-enforced 50 and 70 km/h roads. Both groups estimated the chosen speed to be higher on enforced 50 and 70 km/h roads. Concerning speed choice, no difference was noted within the groups between enforced and non-enforced

roads on the lowest (i.e. 30 km/h) speed limit. Uninformed drivers chose speeds that were, on average, between 0.4 and 6.6 km/h above their estimates of the speed limit, whereas the informed drivers chose speeds that were, on average, between 1.0 and 11.2 km/h above the actual speed limit. Taken together, the analyses show that 50 and 70 km/h roads with enforcement were estimated as lower in accident risk. In addition, the results indicate that drivers thought it was less likely to abide by the speed limit on those roads, which was confirmed by drivers choosing higher speeds.

Correlation coefficients computed on mean values of the estimates for each road revealed a non-significant relation between speed choice and risk of detection. Negative correlations were found between speed choice and accident risk, suggesting that lower speeds were chosen on roads that were perceived as more risky. A strong relation was found (.92 and .93 for uninformed and informed drivers, respectively) between the likelihood to keep the speed limit and accident risk.

Thus, no significant differences in estimates were found between informed and uninformed drivers, except on the estimates regarding speed choice. Estimates on speed limit yielded higher values than the actual speed limits (especially on the 30 km/h roads), and the uninformed drivers chose speeds that were comparable to what they thought was the legal speed limit. These results are in agreement with those of Study IV, where a common response among drivers on the road was that their driving speed corresponded with the posted speed limit.

The results of Study III demonstrate that the road environment does not automatically convey information on speed limit. Estimates on risk of detection, accident risk and likelihood to keep the speed limit do not depend on whether the driver knows the speed limit. However, lack of information about the legal speed limit generally leads to higher driving speeds. The relation between accident risk and likelihood to keep the speed limit suggests that accident risk is a strong motivating factor for drivers to comply with posted speed limits. It would seem less likely that drivers produce higher estimates of accident risk because they follow sanctioned speed limits.

Study IV

Speed choice in relation to speed limit and influences from other drivers

The aims of Study IV were to investigate the relations between observed and reported behaviour and to relate these measures to attitudes, subjective norms and external influences, i.e. how other drivers affect a person's choice of speed. The roads in this investigation were highways with a posted speed limit of 90 km/h.

Speed, interview and questionnaire data were obtained for drivers on seven 90-km/h roads. Vehicle speeds were measured by unobtrusive video recordings of the traffic as described in Study I. In Study IV, a second video camera, positioned close to the site where speed measurements would be registered, recorded the license numbers of the passing vehicles. About one to two kilometres further ahead vehicles were stopped by a police officer. Drivers were directed onto a roadside parking area and interviewed by staff from the Department of Psychology at Uppsala University. Each interview took about two to three minutes and each interview session lasted about three hours. (Because of technical failure, the sessions were of a shorter duration on two roads.) At this time, the speed of the vehicles was not known to the police or interviewers.

The interview was concerned with circumstances on the specific road on which the drivers were travelling at the time they were stopped by the police. The number of passengers and gender of the driver were noted on the interview form as well as the vehicle's license number. After the interview, a questionnaire was given to the drivers, which they were asked to complete at home and return it using the pre-paid envelope included with the questionnaire. The reason for noting license numbers was to obtain names and adresses from the motor vehicle register if reminders had to be sent out.

Questions during the interview and in the questionnaire assessed (1) the respondent's view on the proportion of drivers who exceed the speed limit with more than 10 km/h; (2) how fast the respondent drives on the road compared with other drivers (much faster – much slower); (3) the respondent's attitude toward speeding ("to exceed the speed limit on the

section with more than 10 km/h is: right-wrong, responsible-irresponsible, acceptable-unacceptable"); and (4) the respondent's intention to comply with the speed limit on the road section in question.

In all, 1,029 drivers were stopped and interviewed. Speed was measured for 845 (82%) of the vehicles and 856 (83%) of the drivers returned the questionnaire. The number of drivers for which speed, interview and questionnaire data were obtained was 689 (67%). Because of the possibility of omitted-variable bias, list-wise deletion was applied. This method reduced the number of valid cases to 533 (52% of the stopped drivers).

The means of the four speed measures (a) observed speed, (b) respondents' reported speed on the road, (c) normal speed as given in the interview and (d) normal speed reported in the questionnaire were all above the speed limit. In addition, 60% of the drivers travelled faster than the posted speed limit. Those drivers who reported that they had been stopped by the police for speeding drove significantly faster than drivers who had not been stopped for speeding. The correlation between drivers' reported speed at the site and observed speed was .58. Higher correlations were found between drivers' reported speed at the site and their normal driving speed (.69 and .60 for interview and questionnaire responses, respectively). These results suggest that, at least to some extent, most drivers are cognisant of their driving speed in traffic. However, a common response on reported speed (i.e. "how fast did you drive just before you were stopped?") was 90 km/h, i.e. the speed limit on the road, both among slow and fast drivers.

A summed attitude scale from the three items of the questionnaire (Cronbach alpha = .87) was used in the analyses. This summed attitude score significantly correlated (.39, $p<.001$) with observed speed. Thus, faster drivers revealed a more positive attitude toward exceeding the speed limit than slower drivers. Faster drivers also preferred raising the speed limit on the road (the correlation between observed speed and preferred speed limit was .29, $p<.001$). The sample was split into three groups according to observed speed (below 90, up to 100 and above 100 km/h). Drivers assigned to the highest speed group reported a higher driving speed, usually drove faster, believed that a higher percentage of other drivers were also speeding, and were weakly motivated when it came to

obeying the speed limit. In relation to other drivers on the road, the fastest drivers indicated a false consensus as to the proportion of other drivers speeding. A path analysis based on the Theory of Planned Behavior revealed that percentage speeding, reported speed, comparison with others, and attitude accounted for 41% of the variance of observed speed (R=.64).

Study IV demonstrated that legal speed limits were generally exceeded and that drivers are somewhat aware of how fast they drive. Fast drivers distinguished from slower drivers on all variables in this study. The phenomenon of false consensus bias was found among high-speed drivers.

GENERAL DISCUSSION

Speeding is recognised as one of the most common traffic violations (Fildes & Lee, 1993). Åberg and Rimmö (1998) found that speeding-related behaviours were by far the most common acts of driver error and violation reported by drivers themselves. The established relations between speed and accident rate and the consequences of an accident call for elaborated methods to decrease high speeds. The present thesis aimed at furthering our knowledge as to how and why drivers choose a specific speed.

In Study I, the consistency in drivers' speed choice was examined. Earlier findings have not provided conclusive evidence of the strength of the relations between repeated speed measures (Nilsson & Obrenovic, 2000; Ogawa et al. 1962; Wasielewski, 1984;). In Study I, it was shown that correlations between two sites varied as a function of road settings. The correlation was generally high (.70) and the non-perfect match between two observation points might suggest that drivers do not pay constant attention to the vehicle's speedometer. A similar interpretation could be given to account for the results of Study IV, where drivers were asked about their speed just before being stopped on the road. A driver may choose a personal speed range for a road rather than an exact speed and speed may vary within this preferred range. Because there is some variation in drivers' speed that drivers themselves may be unaware of, or some drivers may not even consider keeping a constant speed important, one cannot expect to find a perfect relation between self-reports and observed behaviour on the road.

A prerequisite for measures designed to control driver behaviour through publicity campaigns or by changing drivers' attitudes is that drivers show some consistency in speed choice and that they know their speed level. For example, it is important that fast drivers recognise that a message about the negative consequences of high speed is directed to them.

Effects of enforcement were investigated in Study II. The results confirm earlier findings (Armour, 1984; Østvik, 1989) that drivers tend to drive slower on enforced roads. Effects of enforcement have primarily been

studied on highways (Rooijers & De Bruin, 1991). In contrast to those studies, the present study examined enforcement effects on roads in built-up areas. Rural and urban roads differ on several parameters, including roadside development. Evidence indicates that drivers exhibit differential attitudes toward violating the speed limits on the two road types (Vaa & Østvik, 1989). Hence, the results observed for roads with higher speed limits may not automatically extend to roads with lower speed limits, i.e. roads in built-up areas. It has been suggested (Østvik, 1989) that high levels of enforcement (about three times the normal level) are needed to obtain effects on drivers' perceived risk of detection. On the roads investigated in Study II, moderate levels of enforcement had been used during morning hours when traffic is denser. Enforcement had also occurred at other times during the day. However, no study was done before the enforcement started and no information was obtained on when it started. Nevertheless, drivers who had been observed on the enforced road showed a higher perceived risk of detection than drivers on the non-enforced road. The differences of Study II in speed level during the 30-km/h speed limit (i.e. the speed limit during school hours) could be attributed to other differences between the roads in addition to level of enforcement. One such difference could be road size. It would seem reasonable that the police enforce speed on roads with high traffic volume and where it is possible to drive at faster speeds. It is also likely that speeds will be enforced in high accident risk areas. If enforced roads are bigger and perceived as safer than non-enforced roads drivers may feel comfortable with higher speeds, unless they suspect that the roads are enforced. However, with the 50-km/h speed limit, drivers' speed level was similar on both road types, suggesting that the physical road environment does not provoke drivers to drive faster on the enforced roads or restrict speed on the non-enforced roads. One explanation could be that a higher traffic volume on the enforced roads had a reducing effect on speeds. On average, four cars per minute passed on the enforced roads, which can be compared with the figure of about two cars per minute that passed on the non-enforced roads. As speeds were measured on free-flowing vehicles, traffic volume may therefore only be part of the effect for the differences in speed when 30 km/h was in force.

Considering the low amount of speed enforcement that was used, how can we account for the effects of Study II? Normally, there is a temporal limitation regarding the effects of enforcement. Potential factors to account for this temporal limitation phenomenon have not been studied in detail. In several reviews (e. g., Armour, 1984; Østvik, 1989; Zaal, 1994) a general effect has been discussed, but no distinction was made between different speed limits, different road settings, and so on. Most studies have been carried out on highways on which a lower percentage of drivers travel frequently on the road (e. g., weekly). Percentages of about 30% have been reported for highways (Åberg, 1983; Nilsson & Engdahl, 1983). On the roads investigated in Study II almost all (about 90%) of the drivers reported that they had travelled on the road at least once a week. If the police have a speed check for one hour during peak hours in the morning, it will still be only a small fraction of the drivers that are exposed to enforcement and most drivers will not notice the enforcement. However, on the residential road drivers not exposed to the enforcement will have more opportunities to encounter other drivers who had detected the enforcement. The slow drivers (i. e. those exposed to enforcement) will thus affect more drivers because they drive there more often and because of the higher percentage of other repeat drivers. If, in addition, traffic is dense, there is a higher probability that vehicles drive in platoons and that drivers influence each other more directly. As Connolly and Åberg (1993) showed, vehicles close in proximity tend to drive at similar speeds. On the highway, a greater proportion of non-repeat drivers are mixed with the few drivers that were exposed to enforcement. Effects of enforcement will therfore fade off more rapidly on highways than on urban roads.

In Study III, drivers watched recorded road scenes and made judgements that could be relevant to speed choice. How is speed choice related to estimates of accident risk? What speed does the driver choose if the legal speed limit is unknown? These questions were examined in Study III. The role of enforcement was investigated in Study II and drivers were observed on one road, or answered questions about risk of being detected for speeding on a familiar road. However, this does not tell us how drivers estimate the risk of detection on other roads. It has been shown (e. g., Hauer et al., 1982; Vaa, 1997) that mean speeds decrease near an enforcement site, but that the effect already starts to diminish at a short

distance from the site. This suggests that drivers do not expect enforcement to occur at another site near the first one. If enforcement has a general effect on drivers' speed choice, this effect should materialise on other roads as well. Observing effects of enforcement on one road, however, cannot resolve this issue. Several questions arise. For instance, do drivers generalise risk of detection? Is it possible to recognise roads on which enforcement occurs, i.e. do drivers express a higher estimate of risk of detection on enforced roads? If so, when drivers encounter several roads, the chosen speed should be generally lower on enforced roads. These issues were investigated in Study III.

The results of Study III are conflicting in relation to those in Study II and earlier studies. Higher speeds were chosen on roads in which risk of detection was perceived as higher. How can this finding be explained? First, even if drivers suspect that enforcement may occur, they estimate the risk of being detected for speeding as very low. The estimation of risk for traffic accidents on the enforced roads was lower than on the non-enforced roads. It seems that accident risk may be a stronger determinant for speed choice than the risk of being caught for speeding. Second, as in Study IV, in normal traffic a driver considers other drivers in addition to the road layout when choosing speed. However, in Study III, cues from surrounding traffic were held to a minimum. Thus, when the driver is not concerned about keeping up with other traffic, speed is chosen according to the road and roadside environment. Yet, even if the driver does not observe other vehicles, it is possible for drivers to estimate the average speed on the road (Cairney, 1986). Such estimates may be part of the judgement for speed choice, even in a laboratory setting.

From the driver's perspective, exceeding the speed limit is not necessarily a deliberate violation of traffic rules. In the study by Åberg and Rimmö (1998) speed-related items were categorised as either violations or inattention errors. Items in the violation factor included such phrases as "deliberately exceed the speed limit". Items in the inattention factor included such phrases as "fail to notice speed limit sign" and "forget the speed limit". Thus, in line with Åberg and Rimmö's (1998) distinction it is suggested that exceeding a speed limit may not always be a deliberate choice: it can happen that the driver overlooks a speed limit signpost or that

the road environment does not give information about a desirable speed. Although the participants who were uninformed about the speed limit in Study III generally chose higher speeds than the informed drivers, there was no difference between the groups on how likely they thought it would be to observe the speed limit. If a homogenous speed level among drivers is important, the road environment should not function to mislead drivers as to what speed limit is in force. Rather, the road itself should work as an important information cue to help the driver in choosing an appropriate speed. Large variation in speeds among vehicles may make it difficult for drivers to judge the speed of other vehicles (Brehmer, 1990).

In Study IV, respondents' knowledge of their own speed, their attitudes toward speed and how other drivers influence the respondents were investigated. When asked to report their speed on the road, drivers generally referred to the speed limit as their driving speed. However, a positive relation between reported speed and observed speed was established as well as a positive relation between attitudes and speed. That drivers tend to influence one another is nicely reflected in the finding that fast drivers, as compared with slow drivers, thought a higher number of other drivers were speeding. If high-speed drivers believe others are also speeding, they may look upon their own high speed as normal. As Rothengatter (1991) noted, normative behaviour becomes attractive if road users perceive that most others engage in the behaviour. Informing drivers that most other drivers do not travel as fast as they claim might therefore have a reducing effect on the general speed level (Walton & McKeown, 2001). Van Houten and Nau (1981, 1983) have reported positive results with this type of information.

In this thesis, it has been suggested that drivers' speed choice can be explained by a multitude of interrelated factors. Opinions about other drivers' speed, road environment, speed enforcement and attitudes have been considered in this series of studies. In the field of controlling driver's choice of speed, it would be fruitless to single out one variable. The present studies have helped in providing information on how drivers take into account variables in the driving milieu and drivers attitudes toward speed have been cosidered. Although attitudes may explain some aspects of human behaviour, it has been argued (Ajzen & Fishbein, 1980) that

attitudes is only one of a number of factors influencing behaviour. Attitudes may explain behaviour, however changing people's attitudes about speeds may take yet some time. In 1927, in discussions of abolishing speed limits, the following argument was expressed: "Even a greater responsibility and consideration has emerged [among drivers], but much still remains before all may be considered satisfactory" (SOU, 1954, p. 61; translated by the present author). Perhaps other measures than attitude change may prove worthwhile in a shorter time frame. Thus, telling people what to do might be more effective in reducing speeds than telling them how dangerous high speeds are. Consistent with this notion, is Rothengatter's (1996) finding that behavioural messages produced larger effects on speed reduction as compared with attitudinal messages.

Controlling speed by the options a driver has in performing a certain act, such as manipulating the driver's speed through road design, is one plausible alternative to increased safety. The concept of "self-explaining" (Rothengatter, 1996) road design has been introduced, claiming that road environment should be made optimal with respect to road user recognition and understanding. Thus, to contribute to smooth and efficient traffic flow, the driver needs to feel a high degree of certainty about what speed limit is in force. However, as noted in Study III, even if drivers are fully cognisant of the legal speed limit, they may still choose a higher speed based on their personal judgement. Therefore, modification of vehicles is yet another alternative for reducing speed on the roads. Thus, there are divergent methods aimed at confining speed behaviour, such as restrictions in the road or preventing drivers from exceeding the speed limit using high-tech approaches.

The discrepancy between what the individual driver perceives as risky and what the traffic safety authorities consider risky should be a central topic for traffic safety workers. The fact that speed limits are exceeded suggests that drivers fail to fully comprehend the potential danger of high speed. If speeding is to be minimised, drivers must perceive legal allowable speed as realistic in the sense that it communicates a basic element of safe driving to the motorist (Fildes & Lee, 1993; TRB, 1998; Zaal, 1994).

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