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Factors Influencing Drivers' Speeding Behaviour

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Abstract

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Every year many people all over the world are killed and severely injured in road traffic accidents. Even though driving too fast is a behaviour well known to contribute to both the number and the outcome of these accidents, drivers are still speeding. The general aim of this thesis, and its five empirical studies, is therefore to further the knowledge about drivers speeding behaviour by using the theory of planned behaviour and the model underpinning the driver behaviour questionnaire as frames of reference. The behavioural data used is obtained from field trials with intelligent speed adaptation and the speed reducing potential of this system is also examined. The results show that attitude towards exceeding the speed limits, subjective norm, perceived behavioural control and moral norm from the theory of planned behaviour, but also violations and inattention errors from the model underpinning the driver behaviour questionnaire, can be used to predict drivers' everyday speeding behaviour. These two models can also be combined in order to gain further knowledge about the causes of speeding. Identification of drivers' beliefs about exceeding the speed limits gives further insight into the underlying cognitive foundation of their attitude, subjective norm and perceived behavioural control. This provides valuable information for future design of speed reducing measures. Regarding intelligent speed adaptation, the results show that the ISA speed-warning device greatly reduces the amount of time drivers spend above the speed limits, and to some extent also reduces their mean speeds, but that this effect decreases with time. Although the drivers are not totally satisfied with the experience of the ISA speed-warning device, they like the idea and can see its usefulness. As the device tested is a first generation ISA speed-warning device, further research has the potential to greatly improve the system.

Keywords: theory of planned behaviour, driver behaviour questionnaire, intelligent speed adaptation, observed speeding, beliefs, attitudes

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To my beloved Mother and Grandmother
In Memoriam

List of Papers

This thesis is based on the following papers, which will be referred to in the text by their roman numerals.

- I Wallén Warner, H., & Åberg, L. (2006). Drivers' decision to speed: A study inspired by the theory of planned behavior. *Transportation Research Part F*, 9, 427-433.
- II Wallén Warner, H., & Åberg, L. (2006). Drivers' beliefs about exceeding the speed limits. Manuscript submitted for publication.
- III Åberg, L., & Wallén Warner, H. (accepted). Speeding - deliberate violation or involuntary mistake? *European Review of Applied Psychology*.
- IV Wallén Warner, H., & Åberg, L. (2006). *Drivers' speeding behaviour - and the long-term use of an ISA speed-warning device*. Manuscript submitted for publication.
- V Wallén Warner, H. (2005, October). *How does the use of ISA affect drivers' attitude towards the system?* Paper presented at the International Cooperation on Theories and Concepts in Traffic safety - workshop. Available online at www.ictct.org

In 2004, the respondent changed surname from Persson to Wallén Warner.
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Introduction

The first fatal car accident happened on August 17th in 1896 when 44-year-old Bridget Driscoll was killed by a motor car (Williams, 2004). She and her daughter were visiting London to watch a dancing display when she was hit by a car offering demonstration rides to the public. As she was declared dead the coroner said: “this must never happen again”. But happened again it has. In 2004, approximately 1.2 million people were killed in road traffic accidents and as many as 50 million were injured (Peden et al. 2004). This means that in less than 8 years a whole population, equalling the size of Sweden’s, is killed on the world’s roads. Vulnerable road users (e.g. pedestrians, bicyclists, motorcyclists, rickshaw- and cart-drivers) in low- and middle-income countries shoulder a large proportion of the global burden of road traffic deaths and serious injury. The elderly, children and disabled are especially vulnerable.

According to the Swedish Road Administration (n.d. a) 480 people were killed on Swedish roads in 2004. Among these people were 33 children younger than 18 years old. Within the European Union and the United States 33 081 and 42 636 people, respectively, were killed in road traffic accidents. In the western world the number of deaths in road traffic accidents is, however, smaller today than in the past, even though the number of vehicles is still increasing. In Sweden for example, the number of people killed in road traffic accidents has, since 1970, decreased with approximately 3% each year while kilometres driven have increased with approximately 2% (Brüde, 2005). According to Summala (1985) the western world’s decrease in number of deaths in road traffic accidents is due to the introduction of speed limits together with other safety measures such as seat belt laws, daylight running lights, improved road networks and better cars. According to Peden et al. (2004) road traffic deaths in high-income countries are projected to continue decreasing by 27% between 2000 and 2020.

On a global scale the trend is somewhat different (Peden et al. 2004). If nothing changes, predictions show that by 2020, road traffic injuries will step up, from being the ninth, to being the third leading contributor to the global burden of disease and injury. In comparison coronary heart disease and clinical depression will be the two major contributors with war and HIV/AIDS on eighth and tenth place, respectively. The reason for this is that, between 2000 and 2020, the annual number of road traffic deaths is

projected to increase by 83% in low- and middle-income countries (that already shoulder 90% of the global road traffic death toll).

As globalisation increases more and more people spend time abroad, both professionally and privately. According to the World Health Organization (2005) road traffic accidents are the most common cause of death among travellers. The projected increase in road traffic deaths in low- and middle-income countries will therefore also directly affect people from high-income countries. It has, for example, been estimated that more than 100 Swedes are killed each year in road traffic accidents in the Mediterranean area, the Middle East and South East Asia, compared with 400 to 500 who are killed on Swedish roads (H. Rosling, Karolinska Institutet, Sweden, personal communication, August 18th, 2006).

As human behaviour is assumed to be a major factor behind these accidents (Rumar, 1985) it is not surprising that researchers in psychology showed an early interest in traffic and traffic safety.

The History of Traffic Psychology

In traffic psychology one of the main goals has always been to develop theories that can describe the behavioural factors causing, or contributing to, accidents. As people's behaviour in traffic reflects their behaviour in other situations, the research in traffic psychology has been greatly influenced by the general trends in psychological research (Englund, Gregersen, Hydén, Lövsund & Åberg, 1998, for a Swedish review). These general trends are largely overlapping, but it is still possible to distinguish a few that have been dominant during different time periods. After World War II research about personality and individual differences gained a lot of attention and the dominating view in traffic psychology was that some drivers cause more accidents than others due to their personality. In the 1960s research in perception received a lot of interest and the dominating view in traffic psychology was that drivers are victims not able to cope with the complexity of the traffic environment. In the 1970s and 1980s research in cognition became popular and the dominating view in traffic psychology was that drivers adapt their behaviour to the traffic situation and thereby chose the level of risk they are subjected to. Around the 1990s a lot of research in automated behaviours was also conducted and the dominating view in traffic psychology was that experienced drivers are able to automate many driving tasks. Finally, today there is a move towards social psychology and in traffic psychology much research is based on the assumption that drivers behave within a social context where they are influenced by the behaviour of other road users.

The first approach, that some drivers cause more accidents than others due to their personality, produced a lot of research. In the end it did, however, turn out to be hard to identify any personality traits that correlated with involvement in traffic accidents (Englund et al. 1998). Also, even if it had been possible to identify certain traits it would never have been possible to identify all accident-prone drivers without affecting many of the non accident-prone drivers as well.

The second approach, that drivers are victims not able to cope with the complexity of the traffic environment, resulted in theories of perceptual and cognitive filters (Rumar, 1985). According to Rumar (1985), perceptual and cognitive filtering limits human information acquisition and processing which result in traffic accidents.

The third approach, that drivers adapt their behaviour to the traffic situation and thereby chose the level of risk they are subjected to, resulted in dif-

ferent risk theories (Fuller, 1984; Näätänen & Summala, 1976; Wilde, 1988). According to the risk homeostasis theory (Wilde, 1988), drivers act in a way that creates a balance between their perceived level of subjective risk of accident and the level of risk they are willing to accept. From the theory it follows that safety measures that decrease the perceived risk (e.g. seat-belts) might result in more risky behaviours (e.g. increased speeds) and therefore not necessarily result in safer traffic. According to the zero-risk model of driver behaviour (Näätänen & Summala, 1976), drivers act in a way so they do not experience any risk of accident (or arrest) for most of the time. Opposing pressures, such as speeding in order to reach their destination faster, are only counteracted when the drivers reach their subjective threshold for risk. When a driver's subjective threshold is too high (the experienced risk is zero even though there is a real risk) accidents occur. From the model it also follows that safety measures that raise the subjective threshold (e.g. seat-belts) might result in more risky behaviours (e.g. increased speeds) and therefore not necessarily result in safer traffic. According to the threat-avoidance model of driver behaviour (Fuller, 1984), drivers sometimes experience dangerous situations that have to be avoided. How the drivers act in these situations depends on the outcome of the different alternatives. When drivers become experienced they learn to identify risky situations in traffic and can then also avoid them. This theory does, in other words, describe the mechanisms behind how drivers learn to identify risky situations.

The fourth approach, that experienced drivers are able to automate many driving tasks, resulted in several hierarchical control models, which categorised behaviours depending on level of performance (Rasmussen, 1980) and underlying cognitive control (Michon, 1985). Rasmussen (1980) differentiates between skill-based, rule-based and knowledge-based levels of performance, while Michon (1985) differentiates between strategic, tactical (manoeuvring) and operational (vehicle control) levels of control. In traffic many tasks are automated and it is first when something goes wrong drivers become aware of what is happening. Much research has, therefore, focused on the mistakes drivers do. Reason, Manstead, Stradling, Baxter and Campbell (1990) developed a driver behaviour questionnaire including 50 items dealing with drivers' aberrant behaviours. These items were designed to vary with respect to how "bad" the behaviour was and how dangerous it was for other road users. The results showed that the items could be categorised into three different factors: *violations* (dangerous deliberate violations), *errors* (dangerous mistakes and slips) and *lapses* (harmless slips and lapses). The development and applications of this questionnaire are described in more detail under *The Driver Behaviour Questionnaire*.

Finally, the last approach, that drivers behave within a social context where they are influenced by other road users, has recently received a lot of attention. Zaidel (1992), for example, described four factors influencing drivers' behaviour. These factors are: others as a source of information,

communication with others, others as a reference group and imitation of others. Another theory that also takes other peoples' opinions and behaviours into account is Ajzen's (1991) theory of planned behaviour. According to this theory people's attitude towards the behaviour (positive or negative evaluation of the behaviour), their subjective norm (perceived social pressure) and their perceived behavioural control (the perceived ease or difficulty of performing the behaviour) determine their behaviour (a defined action) indirectly via their intentions (a willingness to try to perform the behaviour). The development and applications of this theory are described in more detail under *The Theory of Planned Behaviour*.

Speed

Whichever theory one uses to describe the factors causing, or contributing to, accidents there is a strong agreement within the research community that driving too fast is a behaviour that contributes to both the number and the outcome of accidents.

Nilsson (2000) suggested that the ratio of change in accident rate is proportional to the ratio of change in mean speed raised to a power, which depends on the consequence of the accident (injured, severely injured or killed). As a result of this a decrease in mean speed results in a decrease in accidents for all types of consequences. The decrease in fatal accidents is, however, larger than the decrease in accidents resulting in severe injuries, which in turn is larger than the decrease in accidents resulting in less severe injuries.

With regards to speed distribution, Solomon (1964) showed that most accidents on main rural highways involve drivers who are either driving much faster or much slower than the mean traffic speed. This means that the relationship between accident involvement rate and the deviation from the mean traffic speed is U-shaped. Several studies have since then confirmed this U-shaped curve (Finch, Kompfner, Lockwood & Maycock, 1994, for a review). Haur (1971) showed that the relationship between the rate at which overtakings take place (either overtaking someone or being overtaken yourself) and the deviation from mean traffic speed also is U-shaped and that the two curves correspond strongly. The U-shape of the accident involvement curve can therefore, at least partly, be explained by the rate at which overtakings occur.

When it comes to travelling in high speeds, humans do not experience a natural fear such as that caused by heights. The reason for this is that we have, from the beginning of mankind, been exposed to heights, which has given us enough time to develop a natural fear for being too high up. When it comes to high speeds it is only recently that we have been able to travel in the speeds we do today and therefore there has not been enough time for a natural fear to evolve. Most of us would, for example, feel uncomfortable with leaning too far out of a window on the third floor. If we would fall out of the window we would, however, hit the ground at approximately 50 km/h, which is a speed that feels quite slow when driving (Swedish National Road Administration, 1999). Another problem, with regards to how we experience driving in high speeds, is the comfort of cars, which makes it hard for us to

even perceive the speeds in which we are travelling (Rumar, 1985). To prevent us from driving too fast, speed limits have been introduced in most countries.

Speed Limits

The opinions of what is “too fast” have changed over time and are also varying between different countries. In 1907 the first speed limits were introduced in Sweden. In urban areas the speed limit was set to 15 km/h during day time and 10 km/h during night time. In 1925 the speed limit in urban areas was changed to 35 km/h and in rural areas it was set to 45 km/h. In 1930 the speed limit in urban areas was removed and in 1936 the speed limit in rural areas was also removed. In 1955 the speed limit in urban areas was reintroduced. This time it was set to 50 km/h. In rural areas trials with speed limits during weekends and holidays were conducted during the 1960s. In 1967 Sweden changed from left to right hand driving and in 1968 the first trials with differentiated speed limits on rural roads were conducted. In 1971 differentiated speed limits, with 70 km/h as the standard limit on rural roads, were introduced. The other speed limits used were 30, 50, 90 and 110 km/h. The first guidelines for 30 km/h in residential areas came in 1973. (Englund et al. 1998)

There is a general agreement that the introduction of speed limits, with few exceptions, reduces the average speeds (Elvik, Vaa, & Østvik, 1989). It has also been shown that the average speeds are affected by increases and decreases of the speed limits. According to Evans (1991), a 55 mph (88 km/h) nation-wide speed limit was introduced in the United States in 1974. This resulted in a decrease in average speeds from 63.4 mph to 57.6 mph on rural interstate roads, which previously had had a 70 mph (112 km/h) speed limit. In 1987 the nation-wide speed limit was then increased from 55 mph (88 km/h) to 65 mph (104 km/h), which resulted in an increase in average speeds from 60.8 mph to 62.2 mph.

The effect of introductions of speed limits on accidents is also well documented. In Sweden, the number of accidents resulting in serious injuries was reduced with 11% in urban areas when the speed limit (together with some other safety measures) was reintroduced in 1955 (Finch et al. 1994). In rural areas, the number of accidents per kilometre decreased with 16% when the 90 km/h speed limit was introduced and with 4% when the 110 km/h speed limit was introduced (Nilsson, 1976).

The Theory of Planned Behaviour

Even after the introduction of speed limits drivers are choosing different speeds and many are breaking the law by exceeding the speed limits. So why do drivers choose to exceed the speed limits? A well-known theory within social psychology, that can be used to predict and explain drivers' speeding behaviour, is Ajzen's (1991) theory of planned behaviour. This theory is an extension of the theory of reasoned action. The theory of reasoned action was created to explain human action with attitude towards the behaviour and subjective norm as important predictors (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). To provide a theory that could also explain behaviours over which one has not full control, Ajzen extended the theory of reasoned action with a third predictor, dealing with control. This resulted in the theory of planned behaviour. The history or research on the attitude-behaviour relationship is, however, much older.

The first systematic study on the attitude-behaviour relationship came in 1934 when LaPiere studied peoples' attitude and behaviour towards members of an ethnic minority. LaPiere travelled across the United States with a young Chinese couple and stopped at 251 restaurants and hotels. In all but one of these establishments the couple was nicely treated. After returning home LaPiere wrote to the establishments they had visited and asked if they would welcome Chinese guests. Of 128 replies 92% answered that Chinese guests were not welcome. This suggests an inconsistency between attitude and behaviour. A major limitation of the study is, however, that the persons who accepted the Chinese couple as guests might not have been the same persons as those answering the letter. This study was followed by numerous other studies on the attitude-behaviour relationship but examples of strong attitude-behaviour relationships were hard to find. In 1969 Wicker published a review of 46 studies showing that the correlation between attitude and overt behaviour rarely exceeds .30 and are often close to zero. As a result of this, Fishbein and Ajzen joined forces to try and predict behaviours. They assumed that people consider the outcomes of their behaviours in quite a rational and systematic way, before deciding what to do. Fishbein and Ajzen therefore developed the theory of reasoned action (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975), which uses intention, rather than attitude, to predict behaviour. As already mentioned, this theory was later followed by the theory of planned behaviour (Ajzen, 1991).

According to Ajzen's (2006) theory of planned behaviour people's *attitude towards the behaviour*, their *subjective norm* and their *perceived behavioural control* determine their *behaviour* (a defined action) indirectly via their *intention* (a willingness to try to perform the behaviour). Attitude towards the behaviour is determined by *behavioural beliefs*, which are beliefs about the likely consequences of the behaviour (behavioural belief strength), weighted by the evaluation of how good or bad these outcomes would be (outcome evaluation). Subjective norm is determined by *normative beliefs*, which are beliefs about what important others think of the behaviour (normative belief strength), weighted by the motivation to comply with these important others (motivation to comply). Perceived behavioural control is determined by *control beliefs*, which are beliefs about factors that may facilitate or impede performance of the behaviour (control belief strength), weighted by the perceived power of these factors (control belief power). The way these beliefs interact is in line with the expectancy-value theory. According to Eagly and Chaiken (1998) the expectancy-value theory was first proposed by researchers at the University of Michigan in the United States and later developed further by Fishbein. According to the expectancy-value theory, people's attitude towards an object, action or event is based on the sum of the expected attributes of this object, action or event, weighted by the values ascribed to those expected attributes.

According to Ajzen (2006) a positive attitude and subjective norm together with a large perceived behavioural control results in a strong intention to perform the behaviour. Given enough actual control over the behaviour, people are expected to carry out their intention as soon as an opportunity is given. For behaviours over which people have incomplete volitional control it is also useful to consider perceived behavioural control as a co-determinant (together with intention) of the behaviour. The relationship between perceived behavioural control and behaviour is however dependent on the accuracy of people's perception of their control over the behaviour. Figure 1 shows a schematic representation of the theory.

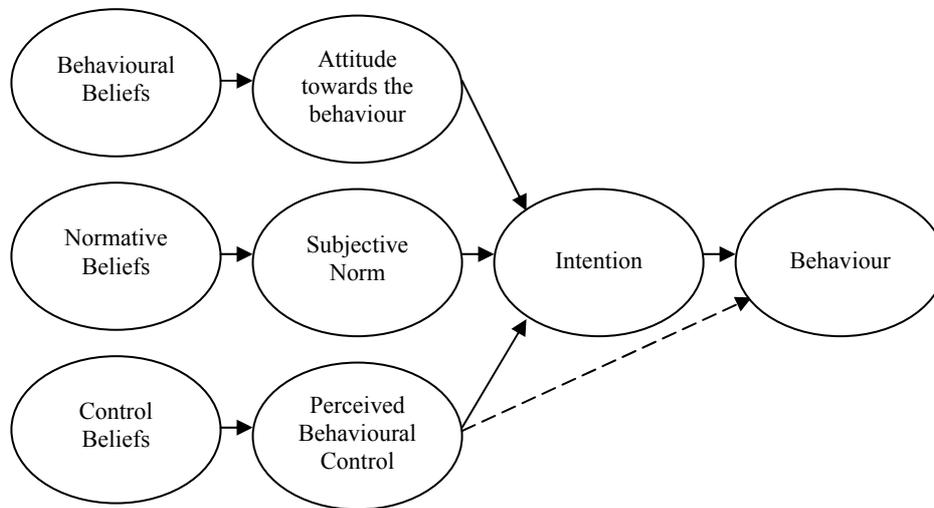


Figure 1. A schematic representation of the theory of planned behaviour. (after Ajzen, 2006)

Measures

One of the reasons the theory of planned behaviour has become so popular is probably the clear description of how to measure the different constructs, which have made the theory easy to apply. According to Ajzen (2006) the latent constructs underlying attitude towards the behaviour, subjective norm and perceived behavioural control can be measured using either direct measure or belief based measures. Intention can be measured by direct measures whilst behaviour is preferably measured through direct observations even though it can also be measured using self-reports.

Two factors that are of great importance when constructing questions based on the theory of planned behaviour are the principles of *compatibility* and of *aggregation*. The principle of compatibility requires all constructs to be defined exactly the same way in terms of time, action, target, and context. The principle of aggregations implies that aggregations of specific behaviours across different occasions, situations and actions represent a more valid measure of the underlying behavioural disposition than any single behaviour.

Direct Measures

For direct measures a small set of 7-point scales, with high internal consistency, are created. An index of each construct can be calculated by summing the results on the different scales.

Examples of direct measures are:

For me to exceed the speed limits in urban environments over the next 3 months would be: *harmful/beneficial* (attitude towards the behaviour)

People who are important to me want me to exceed the speed limits in urban environments over the next 3 months. *agree/disagree* (subjective norm)

For me to exceed the speed limits in urban environments over the next 3 months would be: *very difficult/very easy* (perceived behavioural control)

Do you intend to exceed the speed limits in urban environments over the next 3 months? *definitely do not/definitely do* (intention)

Belief Based Measures

Belief based measures can, theoretically, provide insight into why people hold a certain attitude towards a behaviour, a certain subjective norm and a certain perceived behavioural control. The belief based measures are also rated on 7-point scales but a difference between belief based measures and direct measures is that the belief based measures do not necessarily need to have high internal consistency. The logic behind this is that people's salient beliefs about a specific behaviour can be ambivalent. People might for example think that a behaviour can produce both positive and negative outcomes. The reliability of the belief based measures can instead be estimated by examining the measures' temporal stability (test-retest reliability). An index of each construct can also be calculated using belief based measures. This is done by summing the belief composites.

Behavioural belief composites are created by multiplying behavioural belief strength with outcome evaluation. Examples of questions are: "If I exceed the speed limits in urban environments over the next 3 months the risk of me losing my driving licence will increase" *not at all likely/very likely* (behavioural belief strength) and "To increase the risk of me losing my driving licence is:" *good/bad* (outcome evaluations).

Normative belief composites are created by multiplying normative belief strength with motivation to comply. Examples of questions are: "My family think I *should not/should* exceed the speed limits in urban environments over the next 3 months" (normative belief strength) and "When it comes to you exceeding the speed limits in urban environments, how much do you want to comply with that which your family think?" *not at all/very much* (motivation to comply).

Control belief composites are created by multiplying belief strength with control belief power. Examples of questions are: "When you drive in urban environments over the next 3 months, how often do you think you'll be in a hurry?" *never/very often* (control belief strength) and "If I'm in a hurry it is *much harder/much easier* for me to exceed the speed limits in urban environments over the next 3 months" (control belief power).

Scaling

According to Ajzen (2006), it is possible to use either unipolar (from 1 to 7) or bipolar scaling (from -3 to 3). Even though the shift between these two alternatives only involves a linear transformation it results in a nonlinear transformation for the belief composites of the belief based measures. As there is no theory-based method to decide on the most optimal scoring it has to be done empirically. This can either be done using a mathematical solution described in Ajzen (1991) or by using the scores that produce the strongest correlation between the belief composites and their corresponding index created by direct measures. Both the use of bipolar scaling and the use of expectancy-value models in general have however been questioned (see Trafimow and Finlay, 2002).

Extending the Theory of Planned Behaviour

There have also been several attempts to extend the theory of planned behaviour with additional variables (Åberg, 2001; Conner & Armitage, 1998; for reviews). Conner and Armitage (1998) conducted a review of the empirical and theoretical evidence to support the addition of six new variables to the theory. These variables were belief salience, past behaviour/habit, perceived behavioural control vs. self-efficacy, moral norm, self-identity, and affective belief. They found empirical evidence to support the inclusion of all these variables but concluded that it is unlikely that a researcher would like to go ahead with this. Instead different combinations of variables could be used depending on the behaviour of interest and the purpose of the study.

Applications

The theory of planned behaviour has previously been successfully used to predict such diverse behaviours as choosing a career, smoking or deciding to use condoms, among many others (Ajzen, 2001; Armitage & Conner, 2001; Sutton, 1998; for reviews). The theory has also been used as a frame of reference in traffic safety research to predict behaviours such as drinking and driving (Åberg, 1993; Beck, 1981; Parker, Manstead, Stradling & Reason 1992; Parker, Manstead, Stradling, Reason & Baxter, 1992), dangerous overtaking (Forward, 1997; Parker, Manstead, Stradling & Reason 1992; Parker, Manstead, Stradling, Reason & Baxter, 1992), close following (Parker, Manstead, Stradling & Reason 1992; Parker, Manstead, Stradling, Reason & Baxter, 1992), and lane discipline (Parker, Manstead & Stradling, 1995). Many studies concerning drivers' speeding behaviour have also used the theory of planned behaviour, or the theory of reasoned action, as a frame of

reference (Åberg, Larsen, Glad & Beilinson, 1997; Elliott, Armitage & Baughan, 2003, 2005; Forward, 1997, 2006; Letirand & Delhomme, 2005; Newnam, Watson & Murray, 2004; Parker, 1997; Parker, Manstead, Stradling & Reason 1992; Parker, Manstead, Stradling, Reason & Baxter 1992; Rothengatter & Manstead, 1997; Vogel, 1984). These studies have all shown that the theories (in their original forms or modified) are able to explain and/or predict drivers' speeding behaviour. Based on the theory of planned behaviour attempts have also been made to design for example video-based (Parker, 2002; Parker, Stradling & Manstead, 1996) and mass media (Stead, Tagg, MacKintosh & Eadie, 2005) interventions to reduce speeding.

Vogel (1984) measured drivers' actual speeds on four locations on Dutch motorways. Recorded driving speeds were used as a stratification criterion in order to include as many cars with extreme speeds as possible in the sample. A questionnaire was then sent out to this sample. In total just over 600 Dutch drivers answered the questionnaire, which included direct measures of behaviour, intention and attitude towards speeding, as well as, belief based measures of behavioural and normative beliefs. The results showed a strong correlation between the belief based measures and the direct measures of attitude towards speeding. They also showed that attitude towards speeding together with normative beliefs and "preferred level of the speed limit" could explain 56% of the variance in intention to speed. Finally, there were strong correlations between intention to speed and self-reported speeding as well as between self-reported speeding and actual speeding. Furthermore, two studies by Rothengatter, Riedel and De Bruin and Vogel, De Bruin and Rothengatter (as cited by Rothengatter & Manstead, 1997) showed that attitude towards speeding and subjective norm can successfully explain the variance in intention to speed for both private car drivers and truck drivers.

Parker, Manstead, Stradling and Reason (1992) first conducted a pilot study with 240 British drivers. In this pilot study, six behavioural beliefs and six people important to the drivers, with respect to speeding on a residential street, were identified. The result from the pilot study was then used to construct measures of behavioural and normative beliefs, in addition to direct measures of intention, with respect to speeding on a residential street. A total of 881 British drivers were then interviewed and demographic subgroups, within the sample, were differentiated on the basis of their beliefs. Parker, Manstead, Stradling, Reason and Baxter (1992; also described in Stradling & Parker, 1997) showed that behavioural beliefs (the sum of the products of the six behavioural belief strengths weighted by their corresponding outcome evaluations was used as an index), normative beliefs (the sum of the products of the six normative belief strengths weighted by their corresponding motivation to comply was used as an index) and perceived behavioural control (the sum of two direct measures) could explain approximately 47% of the variance in intention to speed.

Åberg et al. (1997; some of the results also presented in Åberg, 1997) presented a study with 241 Danish and 242 Swedish drivers. The study was carried out on six road sections in Denmark and five in Sweden - all of them being roads in built up areas with a 50 km/h speed limit. The speeds on the vehicles passing on these roads were recorded, where after the drivers were stopped. The drivers were first interviewed shortly and then handed a questionnaire including direct measures of attitude towards speeding, intention to speed and self-reported speed. The results showed that attitude towards speeding was related to the drivers' normal speed on the road section they were stopped, to their self-reported speed and to their observed speed in a descending order. The results also suggested that subjective norm could be replaced by perceived behaviour of other drivers in explaining drivers' speed choice.

Forward's (1997) first study was based on in-depth semi-structured interviews with 50 Swedish driving licence holders, while the second was based on a postal questionnaire answered by 453 Swedish driving licence holders. The interview included direct measures of subjective norm and intention while the questionnaire included measures of normative belief strength and motivation to comply as well as direct measures of intention. All questions concerned speeding in an urban area and on a major road, respectively. The results showed that normative belief strength was significantly correlated with intention to speed, while motivation to comply, on the other hand, was negatively correlated with intention to speed.

Parker (1997) measured drivers' actual speeds on four different roads using video cameras. The drivers were then contacted and asked to complete a questionnaire including direct measures of the variables in the theory of planned behaviour as well as of affect. The results from 318 British drivers showed that attitude towards speeding, subjective norm and perceived behavioural control could explain 47% of the variance in intention to speed on a suburban road (40 mph in a 30 mph zone), 48% of the variance in intention to speed on a single carriageway (50 mph in a 40 mph zone) and 56% of the variance in intention to speed on a rural road (70 mph in a 60 mph zone). Intention to speed could successfully be used to predict the drivers' actual speeding behaviour. The results also showed that the inclusion of affect improved the prediction of intention to speed. (also described in Stradling & Parker, 1997)

Elliott et al. (2003) conducted a questionnaire study with 581 British driving licence holders. The first questionnaire included direct measures of the variables in the theory of planned behaviour with respect to complying with the speed limits in built-up areas over the next three months. This first questionnaire was followed up three months later with a second questionnaire asking about the drivers' actual compliance with the speed limits in built-up areas over the past three months. The results showed that attitude towards complying with the speed limits, subjective norm and perceived behavioural

control accounted for a substantial proportion of the variance in intention. Intention together with perceived behavioural control did then account for a substantial proportion of the variance in self-reported compliance with speed limits.

Newnam et al. (2004) conducted a questionnaire study with 204 Australian commercial drivers. The questionnaire included direct measures of the variables in the theory of planned behaviour as well as of anticipated regret. The results showed that the theory of planned behaviour could successfully be used to predict driver's intention to speed in both work-related and personal vehicles. The results also showed that the inclusion of anticipated regret improved the prediction of intention to speed for both work-related and personal vehicles.

Letirand and Delhomme (2005) conducted a questionnaire study with 238 young French male drivers. The questionnaire included direct measures of the variables in the theory of planned behaviour with respect to both exceeding the speed limit 90 km/h (by at least 20 km/h) and complying with it. The results showed that an additional 12% of the variance in self-reported behaviour could be explained when both exceeding and complying with the speed limit were taken into account. In total, 47% of the variance in self-reported behaviour could be explained by intention and perceived behavioural control.

Elliott et al. (2005) first conducted pilot interviews with 16 British drivers. Based on the results from these interviews they constructed a questionnaire including belief based measures, as well as direct measures, of the variables in the theory of planned behaviour with respect to complying with the speed limits in built-up areas over the next three months. The results from the 598 British drivers that answered the questionnaire provided support for the expectancy-value theory thought to underpin the behavioural, normative and control beliefs. The study also identified those beliefs that could be used as targets for road safety countermeasures.

Finally, Forward (2006) used the theory of planned behaviour as a framework to identify beliefs associated with speeding and dangerous overtaking using a qualitative approach.

Further Research

Even though many studies have used the theory of planned behaviour to predict and explain drivers' speeding behaviour they share some limitations, which require further research. The first limitation is that all these studies concerning drivers' speeding behaviour have been based on the drivers' self-reported behaviour (Elliott et al. 2003; Letirand & Delhomme, 2005) or measurements of speed under restricted conditions (Åberg et al. 1997; Parker, 1997; Vogel, 1984). Further research is therefore required to exam-

ine drivers' everyday speeding behaviour within large areas, including both urban and rural environments, under an extended period of time.

A second limitation is that most studies concerning drivers' speeding behaviour have only used direct measures and only a few have included belief based measures. Among the studies using belief based measures the majority have only used these measures to show the link between indices of belief based items and intention, without presenting which items these indices are composed of (Forward, 1997; Parker, Manstead, Stradling, Reason & Baxter, 1992). Only a few studies have thoroughly analysed and presented the beliefs underpinning drivers' speeding behaviour. In one of these studies only behavioural beliefs concerning speeding were identified (Vogel, 1984), while behavioural and normative beliefs, concerning speeding, were identified in another (Parker, Manstead, Stradling & Reason, 1992). In a third study behavioural, normative and control beliefs concerning compliance with the speed limits were identified (Elliott et al. 2005). Complying with and exceeding the speed limit are, however, conceptually different behaviours (Letirand & Delhomme, 2005), and no study has yet, as far as I am aware, examined all three types of beliefs with respect to exceeding the speed limits in both urban and rural areas. Even if someone has, differences between countries are also to be expected as countries differ with respect to traffic density, climate, amount of wildlife on the roads etc.

As there is empirical and theoretical evidence to support the addition of new variables to the theory of planned behaviour (Conner & Armitage, 1998 [review]; Åberg et al. 1997; Newnam et al. 2004; Parker, 1997; Vogel, 1984) further research in this area is also required.

The Driver Behaviour Questionnaire

While the theory of planned behaviour is a general model, which has proven to be useful even in the area of traffic research, the driver behaviour questionnaire (Reason et al. 1990) is a tool especially designed for traffic research to make a distinction between different aberrant driving behaviours.

According to Norman (1981) action slips can be divided into *slips and lapses* (in both cases the plan of action is adequate, but the plan is then poorly executed due to an unintentional deviation in action [slips] or memory failure [lapses]) and *mistakes* (the plan of action fails to achieve its desired outcome). According to Rasmussen (1980) mistakes can be subdivided into rule-based mistakes (an established, but inappropriate, rule is used) and knowledge-based mistakes (mistakes occur because reasoning has to be done on-line due to novel circumstances), while slips and lapses have skill-based origin. By combining Norman's (1981) categorisation of action slips and Rasmussen's (1980) distinction between *skill-based*, *rule-based* and *knowledge-based* levels of performance the Generic Error-Modelling System (Reason, 1987) identified three basic error types: *skill-based slips (and lapses)*, *rule-based mistakes* and *knowledge-based mistakes*. This error classification is however restricted to unintentional deviations from the right path of action. Other types of human actions that can be potentially dangerous and cause accidents, are violations of rules or unofficial norms for what is believed to be safe conduct. According to Reason et al. (1990) violations can be subdivided into *unintended violations* and *deliberate violations*.

In an attempt to make a distinction between different types of driving behaviours the Manchester Driver Behaviour Research Group in UK designed a driver behaviour questionnaire (Reason et al. 1990) including 50 items. These items were designed to vary in two respects: how "bad" the behaviour was (slips, lapses, mistakes, unintended violations and deliberate violations) and how dangerous it was for other road users. The results showed that the items could be categorised into three different factors: *violations* (dangerous deliberate violations), *errors* (dangerous mistakes and slips) and *lapses* (harmless slips and lapses), with a clear distinction between errors (*errors* and *lapses*) and violations (*violations*).

A Swedish version (DBQ-SWE) of the original questionnaire was later suggested by Åberg and Rimmö (1998). Their results showed that the items could be categorised into four factors: *violations* (corresponding to the original violations), *mistakes* (corresponding to the original errors), *inattention*

errors (harmless slips and lapses due to inattention) and *inexperience errors* (harmless slips and lapses due to lack of experience after the initial driver training).

Measures

The driver behaviour questionnaire consists of a number of questions about various errors and violations that drivers might do. The drivers then have to rate the frequencies of these behaviours.

Examples of questions are:

How often do you:

- deliberately disregard speed limits?

(UK: violations; Sweden: violations)

- misjudge the speed of an oncoming vehicle when overtaking?

(UK: errors; Sweden: mistakes)

- miss your exit on the motorway?

(UK: lapses; Sweden: inattention errors)

- forget which gear you are currently in and have to check with your hand?

(UK: lapses; Sweden: inexperience errors)

Applications

Reason et al. (1990) designed the original version of the driver behaviour questionnaire and conducted a study with 520 British drivers. The results showed that the 50 items included in the questionnaire represented a three-factor solution accounting for 33% of the total variance. Of these factors, *violations* accounted for 22.6% of the variance, *errors* accounted for 6.5% of the variance and *lapses* accounted for 3.9% of the variance. Younger drivers committed more *violations* than older drivers, while there was no difference in number of *errors* depending on age. Women reported more *lapses* than men, while men reported more *violations* than women. Using a shorter version, with 24 items (including the eight items with the highest loading for each of the three factors), Parker, Reason, Manstead and Stradling (1995) confirmed the three-factor solution. They also examined the test-retest reliability of the questionnaire by letting 80 participants complete the questionnaire twice within seven months. The results showed strong correlations for all three factors (*violations*: $r = .81$; *errors*: $r = .69$; *lapses*: $r = .75$). Both the original version and the shorter one have since been replicated many times.

In Sweden a replication of the original study was made with over 1400 drivers (Åberg & Rimmö, 1998). In a first step, data based on the original items was analysed confirming the results of Reason et al. (1990) with a

three-factor solution explaining just over one third of the total variance and with a very similar factor structure. A Swedish version of the questionnaire (DBQ-SWE) was then developed by adding new items to the original questionnaire. This resulted in a four-factor solution accounting for 44.0% of the total variance. Two of the four factors corresponded to the British violations and errors, respectively. *Violations* accounted for 23.6% of the variance while *mistakes* (corresponding to the original errors) accounted for 10.6% of the variance. The remaining two factors resulted from a subdivision of the original lapses. These factors were named *inattention errors* accounting for 5.3% of the variance, and *inexperience errors* accounting for 4.5% of the variance. Younger drivers reported more *violations* and somewhat more *mistakes* than older drivers, while older drivers reported more *inattention errors* than younger drivers. For *inexperience errors* there were no differences due to age. Women reported more *inexperience errors* than men, while men reported more *violations* and *mistakes* than women. For *inattention errors* there were no differences due to gender. The DBQ-SWE was later replicated in both Sweden and Greece largely confirming the four-factor solution. (Kontogiannis, Kossiavelou & Marmaras, 2002; Rimmö & Åberg, 1999). Rimmö and Åberg (1999) also showed that sensation seeking explained a large part of the variation in *violations*.

As was done in DBQ-SWE new items have sometimes been added to the original questionnaire to, for example, reflect differences in driving conditions (e.g. due to climate, traffic density, etc.) or driving populations (e.g. private or professional). New items have also been added to further examine different types of violations. This was first done by Lawton, Parker, Mansstead and Stradling (1997), who found a three-factor solution: *errors*, *interpersonally aggressive violations* and *highway-code violations*. In a second study the error factor was omitted and the violations' items modified. The results from this study showed that the *highway-code violations* could be subdivided into *fast-driving violations* and *maintaining-progress violations*. Even if the factor solutions sometimes differ, the distinction between errors and violations, first shown by Reason et al. (1990), seem to be robust for private and professional drivers alike, both within and across different countries and cultures (in UK by Chapman, Roberts & Underwood, 2000 [professional drivers]; Dimmer & Parker, 1999 [professional drivers]; Parker, Lajunen & Stradling, 1998; Lajunen, Parker & Summala, 2004; Lawton et al. 1997; Özkan, Lajunen, Chliaoutakis, Parker & Summala, 2006 and Parker, Reason et al. 1995; in Sweden by Åberg & Rimmö, 1998 and Rimmö & Åberg, 1999; in Australia by Blockey & Hartley, 1995 and Davey, Wishart, Freeman & Watson, in press, [professional drivers]; in Brazil by Bianchi & Summala, 2002; in China by Xie & Parker, 2002 [private and professional drivers]; in France by Obriot-Claudel & Gabaude, 2004; in Finland by Lajunen, Parker & Summala, 1999, 2004; Mesken, Lajunen, & Summala, 2002 and Özkan, Lajunen, Chliaoutakis et al. 2006; in Greece by Kontogiannis et

al. 2002 and Özkan, Lajunen, Chliaoutakis et al. 2006; in Iran by Özkan, Lajunen, Chliaoutakis et al. 2006; in the Netherlands by Lajunen et al. 1999, 2004 and Özkan, Lajunen, Chliaoutakis et al. 2006; in New Zealand by Sullman, Meadows & Pajo, 2002 [professional drivers]; in Spain by Gras et al. 2006; in Turkey by Özkan, Lajunen, Chliaoutakis et al. 2006). The distinction between errors and violations is also supported by the two second-order factors (*unintentional errors* and *deliberate violations*) found in UK, Finland and the Netherlands (Lajunen et al. 2004), and the fact that a two-factor solution (*errors* and *violations*) was the most stable one (among possible solutions with two to six factors) over a three-year follow-up study in Finland (Özkan, Lajunen & Summala, 2006).

Recently a new addition, the positive driver behaviours scale, has been made to the original version of the driver behaviour questionnaire. The positive driver behaviours scale includes positive driving behaviours such as “avoiding close following not to disturb the car driver in front”. When those items were added to the questionnaire it resulted in a three-factor solution (*violations*, *positive driver behaviour* and *errors*; Özkan & Lajunen, 2005).

It has also been shown that private car drivers’ accident involvement can be predicted by self-reported tendency to commit *violations* (Gras et al. 2006; Özkan & Lajunen, 2005; Parker, Reason et al. 1995; Parker, West, Stradling & Manstead, 1995; Rimmö & Åberg, 1999), *aggressive violations* (Özkan, Lajunen, Chliaoutakis et al. 2006, concerning Finland and Iran) or *highway-code violations* (Kontogiannis et al. 2002). In addition, Mesken et al. (2002) found that drivers’ involvement in passive accidents (where they are hit) is correlated with the drivers’ self-reported tendency to commit *interpersonal violations*. According to Shinar (1998) driver aggression is caused by frustration because of traffic congestion and delays. To test this Lajunen et al. (1999) conducted a study in Finland, the Netherlands and UK. The results showed that *aggressive violations* did not correlate more strongly with driving in rush hour than with driving on country roads. Also, *aggressive violations* did not correlate more strongly with driving in countries with high traffic density (the Netherlands, UK) than with driving in a country with low traffic density (Finland). Therefore, the statement that driver aggression is caused by frustration because of traffic congestion and delays could not be confirmed.

When it comes to the association between accident involvement and self-reported tendency to make *errors* the results are quite antagonistic. Rimmö and Åberg, (1999) and Özkan, Lajunen, Chliaoutakis et al. (2006, concerning Turkey) found a significant association between accidents in general and self-reported tendency to make *mistakes* (corresponding to the original *errors*), while Parker, West et al. (1995) and Lajunen et al. (1999) only found a significant association between active accidents (where the driver hit something) and self-reported tendency to make *errors*. Several studies have, however, not found any significant association between accident involvement

and self-reported tendency to make *errors* or to have *lapses* (Parker, Reason et al. 1995; Kontogiannis et al. 2002; Özkan, Lajunen, Chliaoutakis et al. 2006, concerning other countries than Turkey).

As different versions of the driver behaviour questionnaire have been developed, and different populations (e.g. private and professional drivers) have been targeted, using the questionnaire for cross-cultural comparisons is difficult. Therefore, Lajunen et al. (2004) conducted a study aiming to investigate the equivalence of the factor solutions in UK, Finland and the Netherlands using the version developed by Lawton et al. (1997). The results showed that the four-factor solutions found in Finland and the Netherlands were fairly congruent with the one found in UK. Even though the three countries are all industrialised West European countries, with relatively safe traffic, the factor agreement was not perfect. According to Lajunen et al. (2004) this emphasises the importance of taking cultural factors into account when using the driver behaviour questionnaire in different settings. To enable both international comparisons and a deep understanding of the local driving behaviour they suggest that an international, as well as a national, version of the questionnaire should be developed for each country. The shorter international version should consist of a number of core items excluding all culturally sensitive items to make international comparisons possible. The national versions should then be extensions of the international version including all relevant cultural items in order to gain a deep understanding of the local driving behaviour. This suggestion is also supported by the results of Özkan, Lajunen, Chliaoutakis et al. (2006), which showed that a three-factor solution (*aggressive violations*, *ordinary violations* and *errors*) was applicable, but not firmly stable, in six different countries (Finland, Greece, Iran, the Netherlands, Turkey and UK).

Despite the problems connected with cross-cultural comparisons it seems to be a growing research area. In a study conducted in Greece, Turkey, Finland and Sweden (Özkan, Lajunen, Wallén Warner & Tzamalouka, 2006) a four-factor solution (*aggressive violations*, *ordinary violations*, *mistakes* and *slips and lapses*) was found. The results from this study showed that Greek drivers conduct more *aggressive violations* than do Turkish drivers, while Turkish drivers conduct more *aggressive violations* than do Finnish and Swedish drivers. Finnish drivers, on the other hand, conduct more *slips and lapses* than do Greek, Turkish and Swedish drivers. Concerning *ordinary violations* and *mistakes* there were no significant differences between the countries. As different types of self-reported violations have already been shown to correlate with accident involvement these results might be one explanation as to why the road traffic death toll is higher in Greece and Turkey than in Finland and Sweden.

Further Research

Even though drivers' speeding behaviour might be seen as a violation, it may also be the result of unintended driver errors. Speed control includes two distinct activities - to set a target speed for the current situation and to adjust the speed of the vehicle according to the target speed. Setting the target speed is an intentional act based on motivational factors depending on beliefs about the speed choice (Ajzen, 1991; Rothengatter, 1991) and the way the current situation is perceived (Haglund, 2001). Speed adjustment involves monitoring of the vehicle's speed and making correctional actions if the perceived speed deviates from the target speed. This means that exceeding the speed limit is the result of an intention to speed (*violation*), a misjudgement of the current traffic situation (*mistake*) and/or failures in the speed control of the vehicle (*slips and lapses*). As the driver behaviour questionnaire includes all these three types of aberrant driver behaviours it is reasonable to believe that the model could be used to predict drivers' speeding behaviour - but as far as I am aware this is yet to be tested.

In addition to this, the theory of planned behaviour includes latent variables that could be used to determine drivers' intention to speed and it is therefore reasonable to believe that a combination of the two models would improve the prediction of drivers' speeding behaviour even further. This is also supported by Parker et al. (1998), who found that the variables in the theory of planned behaviour, extended with affect and age, were significant predictors of *aggressive violations*, derived from the drivers' scores on the driver behaviour questionnaire.

Intelligent Speed Adaptation

As already mentioned, there is a strong agreement within the research community that driving too fast is a behaviour that contributes to both the number and the outcome of accidents. But despite this, many drivers are still speeding. In Sweden, depending on the speed limit, 33 to 80% of drivers exceed the limit and 11 to 46% of them exceed the limit with 10 km/h or more. (Swedish Road Administration, n.d. b). Traditional measures to change drivers' speeding behaviour are education such as driving licence education and campaigns; enforcement such as police surveillance and speed cameras; and physical measures such as speed humps, narrowing of roads, roundabouts, etc. The effects of such interventions are, however, often limited in time and space (Comte, Várhelyi & Santos, 1997).

An in-vehicle solution that recently received a lot of attention is intelligent speed adaptation (ISA), which is a series of different systems aiming to help the drivers to adapt their speeds to a static or dynamic speed limit. To enable this, different techniques have been used ranging from advisory to intervening. Advisory systems convey information about the current speed limit to the drivers and warn them by audible, visible, or haptic means if this limit is exceeded. It is, however, still up to the drivers whether to use or ignore this information. Therefore, advisory systems mainly affect drivers exceeding the speed limits due to unintended errors. Intervening systems affect the vehicles and may go as far as making it impossible for the drivers to exceed the speed limit. Therefore these systems affect drivers exceeding the speed limits due to unintended errors as well as due to deliberate violations.

The first study with an in-vehicle intelligent speed adaptation system was carried out in the beginning of the 1980s in France, and since then extensive research, including several simulations and field trials, have been conducted (Carsten 2002; Hjalmdahl, 2004; Jamson, Carsten, Chorlton & Fowkes, 2006; for reviews). The results from these studies are promising. The Swedish large-scale field trials showed a decrease in speed violations at all speed limits and it was estimated that the number of people injured in traffic could be reduced with as much as 20 to 30%, if everyone had an ISA-system installed in their vehicles (Swedish National Road Administration, 2002). In the Australian TAC SafeCar project it was estimated that serious injury accidents could be reduced with 7% and fatal accidents with 9% if a system, combining visual and audible warnings with a counterforce in the accelera-

tion pedal making it harder than normal to exceed the speed limits, was implemented on a large-scale (Regan et al. 2005). Finally, in the British External Vehicle Speed Control (EVSC) project it was predicted that injury accidents could be reduced with 20% and fatal accidents with 37% if all vehicles were fitted with a system that limited the vehicles' speed to the posted speed limits. It was also shown that injury accidents could be reduced with 36% and fatal accidents with 59% if the system also lowered the speed further in case of, for example, slippery roads or major traffic incidents (Carsten & Tate, 2005). With this as a background it is not surprising that large scale ISA-implementation is now being discussed as an effective way to decrease speeds on our roads in order to increase road safety. But how did it all start?

Field Trials

The first field trial with speed adaptation was, as already mention, carried out in France in the beginning of the 1980s (Saad & Malaterre, 1982). In this study drivers tested a system similar to a cruise control, which did not automatically set the correct speeds. Instead the drivers themselves had to set the maximum speeds of the vehicle. The results showed that, in general, the test drivers set the maximum speeds significantly over the speed limits.

After the first field trial in France it was not until 1992 that the next field trial with intelligent speed adaptation was conducted - this time in Lund in Sweden (Persson, Towliat, Almqvist, Risser & Magdeburg, 1993). In this study 75 test drivers drove an 18 km long test route with 50 km/h as well as 70 km/h speed limits. The system tested made it impossible for the drivers to exceed the speed limits. The observers turned the system on and off as well as set the speed limits, which meant that the system was automatic as far as the test drivers were concerned. The results showed that the test drivers mean speed on links between intersections was lower with, than without, the system. It did however also show some compensatory effects such as higher mean speeds before and within intersections. A small increase was also seen in incorrect behaviour towards other roads users.

After the field trials in Lund a series of Swedish field trials with intelligent speed adaptation followed. In Gothenburg 9 test drivers drove a 26 km long test route with 30, 50, 70 and 90 km/h speed limits (Nilsson & Berlin, 1992). The system tested showed the current speed limit (among other things) on the dashboard below the speedometer. The results showed no significant changes in mean speed but the test drivers looked significantly more at the dashboard when driving with, compared to without the system. According to the authors this might, however, be due to the novelty of using the system.

The next study was conducted close to Gothenburg (Almqvist & Towliat, 1993). In this study 16 test drivers drove a 35 km long test route with 30, 50,

70, 90 and 110 km/h speed limits. Two systems were tested. One informed the test drivers about the current speed limit and the recommended speed for certain road conditions (among other things) and the other adapted the vehicle's speed to the recommended speed. While driving with the intervening system the test drivers could easily disengage the system by putting their foot on the accelerator or brake pedal or using a control stick. The results showed that the advisory system had very little effect on the test drivers' speed choice. The intervening system, on the other hand, resulted in speeds better adjusted to the current speed limit. When used in urban areas, or much curved road conditions, the test drivers did however feel that the speed chosen by the system was often too high.

The first field trial including everyday driving with intelligent speed adaptation was conducted in Eslöv, near Lund, in 1996 (Almqvist & Nygård, 1997). In this study 25 test drivers had a system, which made it impossible to exceed the speed limits, installed in their vehicles for two months. Eslöv has a 50 km/h speed limit in the whole urban area and the system was automatically engaged within this area and disengaged outside the area - even though the test drivers could manually engage the system also outside the urban area. With the system activated the test drivers could not exceed the speed limits. In addition to this, observations of driver behaviour indicated improved interactions with other road users.

Another field trial, including everyday driving with intelligent speed adaptation, was conducted in Umeå in 1996 (Marell & Westin, 1999). In this study 92 test drivers, including both private and professional drivers, had a system installed in their vehicles for nine months. On two different road segments, with a 30 km/h speed limit, the system warned the test drivers, with a flashing red light and sound signals, if the speed limit was exceeded. The results showed that the test drivers thought they were more aware of traffic regulations and behaved more in accordance with safety regulations when driving with the system. No speed data was however collected.

A field trial with intelligent speed adaptation aiming to assure the quality of municipal transport services was conducted in Borlänge (Myhrberg, Thunquist, Holting & Rusk, 2000). In this study approximately 65 professional drivers drove 14 vehicles that had a system installed for approximately half a year. The system informed the test drivers of the current speed limit and warned them, with a flashing red light and sound signals, if this limit was exceeded whenever they drove within the city of Borlänge or on any of the surrounding roads. The speed limits included were 30, 50, 70, 90 and 110 km/h. The test drivers' speeds were also recorded to assure the quality of the transport they provided. The results showed that the test drivers' attitude towards the system in general was quite positive but their attitude towards the recording of their speeds was more negative. As no speeds were recorded for driving without the system the effect of the system could not be evaluated.

In 1999 this series of trials culminated in large-scale field trials with approximately 4500 vehicles (Swedish National Road Administration, 1999, 2002). These trials were conducted in four different cities and were funded by the Swedish Road Administration. Three of these cities were Borlänge, Umeå and Lund in which trials with intelligent speed adaptation had previously been conducted. The fourth city was Lidköping. These cities differed with respect to the number of test vehicles (Borlänge: 400; Umeå: 4000, Lund: 290; Lidköping: 280) as well as systems used (Borlänge, Umeå, Lidköping: advisory; Lidköping, Lund: intervening).

In Umeå (Sundberg & Sjöström, 2002), approximately 4000 vehicles, equalling approximately 10% of the total number of vehicles in the county, had a system installed in their vehicles for approximately 12 months. The system warned the test drivers, with a flashing red light and sound signals, if the speed limit was exceeded. The speed limits included were 30, 50 and 70 km/h. The results showed that the mean speed within the test area was lowered when the trials were conducted. This suggests that it is enough with a 10% penetration rate to get an effect even on drivers driving without the system.

In Lund (Elmkvist, 2002), 290 vehicles had a system installed for 6 to 12 months. The system exerted a counterforce in the acceleration pedal at speeds over the speed limit. This meant that the drivers had to press the acceleration pedal three to five times harder than normal in order to exceed the limits. The speed limits included were 30, 50 and 70 km/h. The results showed that the test drivers mean speed was lower with, than without, the system.

In Lidköping (Dahlstedt, 2002), 280 vehicles had a system installed for approximately 12 months. Of these, 150 systems informed the test drivers of the current speed limit and warned them, with a flashing red light and sound signals, if this limit was exceeded and 130 systems exerted a counterforce in the acceleration pedal at speeds over the speed limit. The results showed that the test drivers preferred the two systems to traditional speed reducing measures such as speed humps, narrowing of roads, roundabouts etc.

The trials conducted in Borlänge are described in more detail under *Borlänge Field Trials*.

Parallel with the Swedish field trials with intelligent speed adaptation, several trials were also conducted in other parts of Europe. In the Netherlands the first system tested in the 1990s, warned the test drivers if they exceeded the speed limits (among other things), but did not give them any information about the current speed limit (De Waard & Brookhuis, 1997). The study was carried out in an instrumented vehicle on a test route and the results showed that the numbers of speed limit violations were significantly reduced when driving with the system.

In another study in the Netherlands an advisory system was tested (Brookhuis & De Waard, 1999). This system used different colours to show

the test drivers how they were driving. A green light indicated that they complied with the speed limit, an amber light that they exceeded the speed limit with less than 10% and a red light that they exceeded the speed limit with more than 10%. In addition a vocal message was given when amber changed to red. In this study 24 test drivers (12 were controls) drove a test route with 50, 70, 80, 100 and 120 km/h speed limits. The results showed that the test drivers' mean speed decreased with 4 km/h when driving with the system. In addition the speed variation also decreased.

In 1999 the Dutch trials culminated in the second major project funded by a national ministry (Duynstee, Katteler & Martens, 2001). This study was divided into six different periods of two months each. During each period 20 vehicles with a system installed were available to 20 test drivers in the area of Campenhoef in the city of Tilburg. In addition, professional drivers also tested a bus equipped with the system. After the first two weeks of each period, the system was activated making it impossible for the test drivers to exceed the speed limits (if the emergency button was not pushed) whenever they drove within the area of Campenhoef or on any of the surrounding roads. The speed limits included were 30, 50 and 80 km/h. The speed limits could only be exceeded with the system activated by using the emergency button, and this button was only used twice. The results showed that the average speed, as well as the speed variation, decreased as a result of this.

Both Sweden and the Netherlands were also involved in a cross-cultural study with intelligent speed adaptation, which was conducted in 1997 in Sweden, the Netherlands and Spain (Várhelyi & Mäkinen, 2001). In each country 20 to 24 test drivers drove the same instrumented vehicles along 20 to 30 km long test routes. In Sweden the speed limits included were 30, 50, 70, 90 and 110 km/h, in the Netherlands: 30, 50, 80, and 120 km/h, and in Spain: 30, 40, 50, 60, 90, and 120 km/h. The system tested made it more or less impossible for the test drivers to exceed the speed limits. The results showed that the mean speed decreased on roads with speed limits ranging from 30 km/h to 70 km/h when driving with the system. On roads with speed limits ranging from 80 km/h to 120 km/h there were, however, no significant changes. This might be due to heavy traffic, or general speed levels under the speed limits, on these roads and motorways. On urban roads, the highest proportion of interference of the system was found in the Netherlands followed by Sweden and Spain. This might explain the increased level of frustration that the test drivers felt which was largest in the Netherlands followed by Sweden and Spain, respectively.

A second cross-cultural study with intelligent speed adaptation was conducted in Hungary and Spain in 2003 and 2004 (Várhelyi, Adell & Hjälm-dahl, 2005). In this study 20 Hungarian and 19 Spanish test drivers had two different systems installed in their vehicles for two months each (one month with the system activated and one month as a control period). Both systems informed the test drivers of the current speed limit but while the advisory

system used a flashing red light and sound signals to warn the test drivers if this limit was exceeded, the intervening system used a counterforce in the acceleration pedal making it harder than normal to exceed the limit in the first place. In Hungary the systems worked whenever the test drivers drove within the city of Debrecen or on any of the surrounding roads, including 20, 30, 40, 50, 60, 70 and 90 km/h speed limits. In Spain the systems worked whenever the test drivers drove within the city of Mataró or on any of the surrounding roads, including 20, 30, 40, 50, 60, 80 and 120 km/h speed limits. The results showed that both mean speed and speed variation were reduced when driving with any of the two systems. The results also showed that the intervening system tended to be more effective than the advisory, at the same time as it was less accepted by the test drivers.

In UK the national research on intelligent speed adaptation started in 1997, using both field trials and driving simulator studies during the following three years. In the field trials test drivers tested two different intervening systems (Carsten & Fowkes, 2000). One of the systems could be switched on and off at will, while the other was on at all times. A total of 24 test drivers participated. The test drivers were divided into three groups with 8 test drivers in each group. One group tested the system that could be switched off and one the system that could not. The third group was a control group. The systems were tested on a 67 km long test route including 30, 40, 60 and 70 mph speed limits. The results showed that the test drivers who were able to switch off the system tended to do so when the traffic conditions gave them an opportunity to speed.

A new project, ISA-UK, started in 2001 and a series of four field trials, in different parts of UK, began in 2003 (O. M. J. Carsten, University of Leeds, UK, personal communication, February 15th, 2006). In these trials 80 private and professional test drivers drove 20 vehicles that had a system installed for six months (during the first and last month the system was not activated). The system made it impossible for the test drivers to exceed the speed limits without using kick-down or pressing an emergency button. At the present time the results from these field trials have not yet been released.

In Denmark field trials with intelligent speed adaptation started in 2000 (Lahrmann, Madsen & Boroch, 2001). In this study 20 test drivers drove with a system installed in their vehicles for six weeks (during the two first weeks the system was not yet activated). The system informed the test drivers of the current speed limit and warned them, with a flashing display, a red light and a digital voice message, if this limit was exceeded whenever they drove within the city of Aalborg or on any of the surrounding roads. The results showed that, on average, the test drivers decreased their speeds when the system was activated.

In Finland field trials with intelligent speed adaptation started in 2001 (Päätaalo, Peltola & Kallio, 2001). In this study 24 test drivers drove a 17.6 km long test route including 40, 60, 70 and 80 km/h speed limits. All test

drivers drove the test route four times: once with only a route guidance system, once with the route guidance in combination with an advisory system, once with the route guidance in combination with an intervening system and once with the route guidance in combination with a recording system. The advisory system informed the test drivers of the current speed limit and warned them, with a text and a voice message, if this limit was exceeded. The intervening system informed the test drivers of the current speed limit and made it impossible for them to exceed this limit. Finally, the recording system informed the test drivers of the current speed limit as well as monitored their actual speeding behaviour and showed a speed limit offence diagram on the display. The results showed that the intervening system tended to be the most effective system in making the test drivers comply with the speed limits at the same time as it was the least accepted one.

In France a series of field trials with intelligent speed adaptation started in 2001 and this time two large car manufacturers, Renault and PSA, were participating in the project (Ehrilch et al. 2003). A pre-assessment phase was first carried out using two prototype vehicles. The study was then extended to 100 test drivers who drove an instrumented vehicle for eight weeks. After the first two weeks, when no system was activated, each test driver tested three different systems for two weeks each. The first system tested informed the test drivers of the current speed limit and warned them if this limit was exceeded. The second system made it impossible for the test drivers to exceed the speed limit without using kick-down. The third system also made it impossible for the test drivers to exceed the speed limit but this system did not have any kick-down function. All three systems were activated whenever the test drivers drove within the communes of Saint Quentin en Yvelines, Versailles, Vélizy, Villacoublay, Le Chesnay or on any of the surrounding roads. At the present time the data from these field trials is being analysed and the results will probably be released during the autumn of 2006 (F. Saad, INRETS, France, personal communication, May 16th, 2006).

In Belgium field trials with intelligent speed adaptation started in 2002. In this study 20 private vehicles and 17 commercial vehicles (including three buses) had a system installed for approximately one year. The system informed the test drivers of the current speed limit and used a counterforce in the acceleration pedal making it harder than normal to exceed the limit whenever the test drivers drove within the city of Ghent or on any of the surrounding roads. The speed limits included were 15, 30, 50, 70, 90 and 120 km/h. The first results based on questionnaires showed that the number of test drivers answering that they never speed increased during the project with 49% on highways, 26% outside urban areas, 16% in urban areas and 7% in 30-areas (<http://www.isaweb.be>).

In a second Belgian trial, 100 vehicles had a dynamic system installed for more than six months. The system informed the test drivers of the current or recommended (depending on weather conditions, incidents etc.) speed limit

and warned them if this limit was exceeded. One of the main focuses in this project was to demonstrate the possibility to deliver a dynamic speed adaptation system as part of a wide range of in-vehicle telematics services (Kenis, 2003).

In Austria field trials with intelligent speed adaptation started in 2004. The system tested informed the test drivers of the current speed limit and warned them if this limit was exceeded. The system also informed the test drivers of, for example, schools, nurseries and accident black spots (<http://www.roncalli-telematics.com>; Maurer, 2003).

Finally, in Norway a demonstration project is presently being planned in the city of Karmøy. The aim of the project is to have 50 test drivers between 18 and 23 years old driving with an intelligent speed adaptation system. The system will inform the test drivers of the current speed limit and warn them, with a flashing speed limit sign, if this limit is exceeded. (A. B. B. Hansen, Norwegian Public Roads Administration, Norway, personal communication, May 30th, 2006)

Outside Europe, research on intelligent speed adaptation has been conducted in, for example, Australia, where 23 test drivers drove with an intelligent speed adaptation system for 16 500 km (Regan et al. 2005). The system combined visual and audible warning signals with a counterforce in the acceleration pedal making it harder than normal to exceed the speed limit. Preliminary results show that both time spent above the speed limit and the standard deviation of speed was reduced when driving with the system. According to Sundberg and Myhrberg (2006), research on and/or plans for, implementation of intelligent speed adaptation have also been conducted in, for example, Canada, Japan and the United Arab Emirates (IBM, 2004).

Summary of Field Trials

Since the first trials in France more than 25 field trials with intelligent speed adaptation have been conducted in more than 10 European countries. The driving situations have ranged from streets with 15 km/h speed limits in urban environments to roads with 120 km/h speed limits in rural environments. Both private and professional drivers have participated in the trials. The systems tested have ranged from purely informative (giving information about the speed limit but not any warnings if this limit is exceeded) to intervening ones (making it impossible to exceed the speed limit). The field trials have shown that most systems of intelligent speed adaptation (the exception being some of the purely informative ones) have the potential to decrease drivers' average speed as well as the speed distribution. Systems making it impossible for drivers to exceed the speed limit have proven to be the most effective in keeping the speeds down, but the acceptance of these systems amongst the public is lower than for other types of systems. The field trials have also shown that ISA-systems with a recording function can be used to

assure the quality of professional transports by recording the vehicles' speed. Finally, it has been shown that it is possible to deliver dynamic speed limits as well as combining the ISA-function with a wide range of other in-vehicle telematics services.

Further Research

Even though many field trials with intelligent speed adaptation have been conducted the large majority of these studies have been limited in time. As the effect of newly implemented systems might change over time further research is required to examine drivers' speeding behaviour after long-term use of the systems. If it is found that the effect changes over time it is also of interest to examine what causes these changes.

Even if the purpose of new technologies, like intelligent speed adaptation, is not to facilitate research, this is sometimes one of the side effects. A recurring limitation in many studies within traffic psychology is that they are based on drivers' self-reported behaviour or behaviour measured under restricted conditions. In studies based on the theory of planned behaviour, for example, drivers speeding behaviour has either been based on self-reports (Elliott et al. 2003; Letirand & Delhomme, 2005) or measurements of speed under conditions restricted in time and place (Åberg, 1997; Åberg et al. 1997; Parker, 1997; Vogel, 1984). As many of the systems for intelligent speed adaptation include a function to record data (which can be used even if the warning system is not activated) it is now possible to examine drivers' everyday speeding behaviour within large areas under extended periods of time.

Borlänge Field Trials

Among the field trials mentioned above the Swedish trials are by far the largest, with approximately 4500 participating vehicles. In the city of Borlänge, an ISA speed-warning device was installed in approximately 250 private and 150 commercial vehicles (only data from private vehicles has been used in the current thesis). The device was, in principle, a navigation system based on a digital map covering approximately 700 km of roads within the city of Borlänge and four main roads leaving the city. Using GPS techniques the device continuously monitored where the vehicle was and with which speed it was travelling. Using map matching this information was then compared with the digital map that included speed limits, and the test drivers were informed of the current speed limit at their present position. If this speed limit was exceeded the test drivers were warned with a flashing red light and sound signals. In addition to this, the device continuously logged the test drivers' behaviour at least once every 10 seconds as soon as the vehicles were driven within the area covered by the digital map. Using GSM technique the logged data was collected from the vehicles and stored in a central Microsoft SQL-server database (version 7.0) where analyses could be performed. For further technical description see Myhrberg, Holting and Brus (2002).

Test Drivers

In 1999 private test drivers were recruited among 1000 randomly selected car owners (with cars no older than from 1984) in the city of Borlänge. Approximately one year later a new recruitment was made among an additional 2000 randomly selected car owners in the area.

In total, 1144 car owners answered the recruitment questionnaire (response rate of 38.1%). Out of these, 759 stated that they did not want to participate in the field trials while 385 were interested in participating. Among the 385 interested in participating approximately 200 did eventually participate. Independent-samples T-test between those who did participate, and those who did not, showed no significant differences in how often they reported exceeding the speed limits with 10 km/h or more in urban or rural environments. Not surprisingly, there was, however, a significant difference

in their views on having different kinds of ISA-systems installed in their vehicles.

In addition to the test drivers recruited as described above some test drivers were also recruited in other ways and a total of approximately 250 private car owners and their co-drivers (other family members that regularly used the vehicle) finally participated in the Borlänge field trials. For further description of the recruitment process see Boëthius, Andelius, Sehlin and Åberg (2002).

The majority of all test drivers were men and the test drivers' average age was above 50 years. The skewed distribution can to some extent be explained by the fact that 68% of the total number of car owners in the Borlänge municipal area are men and the car owners' average age is 50 years (H. Granlund, Swedish Road Administration, Sweden, personal communication, December 11th, 2003).

The national field trials continued to 2002, but some test drivers in Borlänge chose to end their participation prior to this. The main reasons for ending their participation were change of car or repeated problems with the function of the ISA speed-warning device.

At the end of the national trials in 2002, a number of test drivers in Borlänge chose to continue driving with the devices installed in their vehicles. This created a unique opportunity to study the effects of long-term use of an ISA speed-warning device.

Data Collection

Logged Behavioural Data

After recruitment, an ISA speed-warning device was installed in the test drivers' vehicles. During the first two to four weeks the device logged the test drivers' behaviour but the warning system was not yet activated. This means that the test drivers did not get any information about the current speed limit or any warning signals if this limit was exceeded, but they were, however, aware of the fact that their driving behaviour was being logged. The warning system was then activated. During the whole field trials the test drivers' behaviour (speed, position, etc.) was then logged at least once every 10 seconds as soon as the vehicles were driven within the area covered by the digital map used by the ISA speed-warning device. This area included streets and roads with 30, 50, 70, 90 and 110 km/h speed limits. On streets with a 30 km/h speed limit as well as on roads with a 110 km/h speed limit there were however some problems. One problem was that these speed limits were often restricted in time (e.g. 30 km/h during school hours or 110 km/h during summer), which caused some technical problems. Another was that

the total distance with 30 km/h or 110 km/h speed limits was fairly small and the amount of logged data from these speed limits was therefore also small. Because of this, all data logged on streets with a 30 km/h speed limit or roads with a 110 km/h speed limit are excluded from the current thesis (except for Study III which includes data from roads with a 110 km/h speed limit).

The target behaviour of speeding was taken as the total time exceeding the speed limits by at least 2 km/h, divided by the total time driven. The speeds measured by the device were all based on the vehicles actual speeds measured by GPS. These speeds did not necessarily correspond to the speeds shown on the vehicles speedometers. This is due to the fact that most car manufacturers use a margin so that the speed shown on the speedometers is somewhat higher than the vehicle's actual speed. The size of this margin differs between brands but on average the speedometers in most of the test drivers' vehicles showed a speeding rate of approximately 7 km/h when the ISA-device measured a 2 km/h excess in speed.

Questionnaires

In addition to the recruitment questionnaire (which was sent out to approximately 3000 car owners in the city of Borlänge), three more questionnaires were distributed to the test drivers who chose to participate in the field trials. The first of these three questionnaires was posted to the test drivers as soon as they had had the device installed in their vehicles, several weeks before the warning system was activated. The second one was posted to the test drivers when they had driven with the ISA speed-warning device activated for approximately one month, and the final one was posted to the test drivers at the end of the field trials, approximately one year later. In the end of the national field trials in 2002, all test drivers in Borlänge were offered to keep driving with the ISA speed-warning device installed in their vehicles. Some of the test drivers chose to accept this offer and in the spring of 2004 one last questionnaire was sent out to these test drivers. Two questionnaires were also sent out to the public in Borlänge but only data from private test drivers has been used in the current thesis.

All questionnaires included questions concerning different aspects of speed and road safety, attitude towards the ISA speed-warning device as well as background questions. Several questionnaires also included questions based on theoretical constructs such as the theory of planned behaviour (Ajzen, 1991), as well as items from the Swedish version of the driver behaviour questionnaire (DBQ-SWE; Åberg & Rimmö, 1998).

The questions based on the theory of planned behaviour were all asked for 50 km/h in urban environments, 70 km/h in urban environments, 70 km/h in rural environments and 90 km/h in rural environments. The questions were also asked for 30 km/h in urban environments and for 110 km/h for rural

environments. The logged data from these speed limits was however excluded from the current thesis (except for 110 km/h in Study III) and the corresponding questions were therefore also excluded. Only direct measures were used. Attitude towards exceeding the speed limits, subjective norm, perceived behavioural control and moral norm were measured on 5-point scales while self-reported speeding was measured on 6-point scales.

Attitude towards exceeding the speed limits was measured by asking: "How acceptable is it for you personally to exceed different speed limits? X km/h in urban/rural environments?" 1 = not acceptable; 3 = neither; 5 = totally acceptable.

Subjective norm was measured by asking: "What do you believe people important to you (family, close friends etc) think if you exceed different speed limits? X km/h in urban/rural environments? 1 = not acceptable; 3 = neither; 5 = totally acceptable.

Perceived behavioural control was measured by asking: "How hard is it to comply with different speed limits? X km/h in urban/rural environments? 1 = very hard; 3 = neither; 5 = very easy.

Moral norm was measured by asking: "From your own moral point of view. How important is it to comply with different speed limits? X km/h in urban/rural environments? 1 = not at all important; 3 = neither; 5 = very important.

As the test drivers received the questionnaire just before the device in their vehicles was activated, and it was assumed that this might affect their answers about future intention, this question was removed from the questionnaire. This means that the theory of planned behaviour could not be tested in its original form. Instead the theory was used as a conceptual frame of reference and a similar model was tested by replacing the question about intention with a question about self-reported speeding. The reason for including self-reported speeding is that this measure gives information about to which extent the test drivers are aware of their own speeding behaviour. Several studies (Conner & Armitage, 1998 for a review) have also shown that past behaviour (in Study I and III: self-reported speeding at the time the test drivers got the ISA speed-warning device installed in their vehicles) add significantly to the prediction of future behaviour (in Study I: logged speeding during two to four weeks after the ISA speed-warning device had been installed; in Study III logged speeding during 3 months approximately one year after the ISA speed-warning device had been installed).

Self-reported speeding was measured by asking: "If you consider your own behaviour as a driver. How often do you exceed the speed limit X km/h in urban/rural environments by 10 km/h or more?" 1 = never; 2 = very rarely; 3 = rarely; 4 = sometimes; 5 = often; 6 = very often.

The items included in the Swedish version of the driver behaviour questionnaire were all measured on 5-point scales: 1 = never; 2 = very rarely; 3 = rarely; 4 = sometimes; 5 = often; 6 = very often. Examples of questions are:

“How often do you deliberately exceed the speed limit when overtaking” (violation); “How often do you overtake but are forced to withdraw the manoeuvre” (mistake); “How often do you fail to notice speed limit signs” (inattention error); “How often do you forget which gear you are currently in and have to check with your hand” (inexperience error).

Limitations

The logged speeding behaviour was collected whenever the test drivers drove on any of the 700 km of roads covered by the digital map used by the ISA speed-warning device. This created uncontrollable variation as the data was collected during different times of year, at different times of day and on different roads, depending on when the test drivers were recruited and when and where they then chose to drive.

Also, all test drivers participated voluntarily in the field trials and only 250 car owners out of approximately 3000 chose to participate. It is therefore reasonable to believe that the variation within the group was reduced. As already mentioned, analyses of the recruitment questionnaire did, however, not show any significant differences between those who participated in the field trials, and those who did not, with regards to how often they reported exceeding the speed limits with 10 km/h or more in urban or rural environments.

During the field trials some test drivers also chose to end their participation. The main reasons for this were change of car or repeated problems with the function of the device. Unfortunately, no analyses were conducted to see if these drop-outs behaved significantly differently to those who completed the field trials.

In addition to this, there were some technical constraints that should be highlighted. Firstly, even though the digital map was thoroughly tested in the field before it was distributed to the test drivers, it still contained several errors regarding speed limits. Secondly, the ISA speed-warning device logged data as soon as the vehicle was driven within the mapped area and it was not possible to match the data collected with individual drivers. The majority of test drivers included in the current thesis had however driven their vehicle for 90% of the time or more.

Analyses

Data has been analysed using common parametric and non-parametric tests as well as structural equation modelling using LISREL 8.71 (Jöreskog & Sörbom, 1993). This program models the latent structure of data, free from errors of measurements, by using path analysis.

In the first study a polychoric correlation matrix as well as an asymptotic covariance matrix needed to be estimated as all questions were measured on ordinal scales. As each of the four latent variables (attitude towards exceeding the speed limits, subjective norm, perceived behavioural control and self-reported speeding) were measured by their respective questions under four different conditions (50 km/h in urban environments, 70 km/h in urban environments, 70 km/h in rural environments and 90 km/h in rural environments), the number of test drivers was too small to estimate these matrixes for the total model. Instead one measurement model was created for each latent variable. For these measurement models polychoric correlation matrixes and asymptotic covariance matrixes could then be estimated using maximum likelihood. The factor scores for the latent variables were thereafter used in the final model, together with the factor scores for the behaviour, which was calculated from three observed variables (for 50, 70 and 90 km/h) measured on a continuous scale. Satorra-Bentler Scaled Chi-Square was used to evaluate the fit between the measurement models and the data and Normal Theory Weighted Least Squares Chi-Square was used to evaluate the fit between the final model and the data.

In the third study principal component analyses (PCA) were used to create factor scores, and the coefficient theta (θ ; based on number of items and the largest eigenvalue) was used to indicate variable reliability (Walsh, 1990). These factor scores were then used in the final models tested by LISREL.

In both the first and the third studies, chi-square implying a non-significant difference between model and data and a RMSEA less than .05 were seen as indicators of a close fit between model and data (Browne & Cudeck, 1993).

In the second study standard multiple regressions were used to identify the belief composites that contributed to the prediction of the indices, constructed with direct measures of the latent variables in the theory of planned behaviour.

In the fourth study several measurements were not normally distributed and therefore non-parametric tests were used. Data from different time periods were compared using Wilcoxon Signed Rank Test and to examine the stability over time, for the latent variables in the theory of planned behaviour, Spearman's Rank Order Correlation was used.

Finally, in the fifth study data from different time periods were compared using Paired-Samples T-test.

Aim of the Thesis

Every year many people all over the world are killed and severely injured in road traffic accidents (Peden et al. 2004). Even though it is well known that driving too fast is a behaviour that contributes to both the number and the outcome of these accidents, drivers are still speeding (Swedish Road Administration, n.d. b). So why do drivers choose to exceed the speed limits?

The general aim of this thesis was to further the knowledge about drivers speeding behaviour by using the theory of planned behaviour and the model underpinning the driver behaviour questionnaire as frames of reference. The behavioural data used was obtained from field trials with intelligent speed adaptation and the speed reducing potential of this system was also examined. In order to achieve this aim, five empirical studies were conducted.

The aim of the first study was to examine if, and to what extent, drivers' everyday speeding behaviour could be predicted using the theory of planned behaviour as a frame of reference.

The aim of the second study was to examine drivers' view on their own speeding behaviour, in both urban and rural environments, by focusing on the belief based measures suggested by the theory of planned behaviour.

The first aim of the third study was to compare the theory of planned behaviour and the model underpinning the driver behaviour questionnaire with regards to their ability to predict drivers' speeding behaviour. The main aim was then to combine these two frames of reference in an attempt to further the knowledge about drivers speeding behaviour.

The first aim of the fourth study was to examine drivers' speeding behaviour after long-term use of an ISA speed-warning device. The second aim was to try to understand what caused possible behavioural changes by examining the variables in the theory of planned behaviour.

The aim of the fifth study was to examine how the use of an ISA speed-warning device affects the drivers' attitude towards the system.

Empirical Studies

Study I

Drivers' decision to speed:

A study inspired by the theory of planned behavior

Even though many studies have used the theory of planned behaviour to predict and explain drivers' speeding behaviour they share some limitations, which open up for further research. One of these limitations is that all studies, concerning drivers' speeding behaviour, have been based on the drivers' self-reported behaviour (Elliott et al. 2003; Letirand & Delhomme, 2005) or measurements of speed under restricted conditions (Åberg, 1997; Åberg et al. 1997; Parker, 1997; Vogel, 1984). Further research is required to examine drivers' everyday speeding behaviour within large areas, including both urban and rural environments, under an extended period of time.

The aim of this first study is therefore to examine if, and to what extent, drivers' everyday speeding behaviour can be predicted using the theory of planned behaviour as a frame of reference.

The study is based on data from 112 test drivers participating in the Borlänge field trials. All test drivers had driven their vehicle more than 45% of the time the vehicle was driven and had logged data successfully retrieved from at least 10 journeys. All behavioural data used was collected during two to four weeks before the warning system of the ISA speed-warning device was activated which means that the test drivers did not receive any information about the current speed limit or any warning signals if this limit was exceeded. The test drivers also completed a questionnaire (including direct measures of the latent variables in the theory of planned behaviour), which was distributed before the warning system was activated. The test drivers' age ranged from 25 to 88 years old, with a mean of 54 years. Sixty-five percent of the test drivers were men while 35% were women.

To start with five measurement models were created. Four of these models included attitude towards exceeding the speed limits, subjective norm, perceived behavioural control and self-reported speeding, measured by their respective questions under four different conditions (50 km/h in urban environments, 70 km/h in urban environments, 70 km/h in rural environments

and 90 km/h in rural environments). The fifth model included logged speeding measured at three different speed limits (50, 70 and 90 km/h). The results showed that there were no significant differences between the five measurement models and their data ($p > .05$). This indicates uni-dimensional factors and the factor scores of the latent variables could therefore be used in a final structural model. Of the different conditions, the 70 km/h in rural environments had the largest standardized path coefficients, up to $r = 1.00$, on the latent variable in all of the measurement models (see table 1).

Table 1. The five measurement models and their fit to the data.

Latent variables	χ^2 ¹	df	p	Standardized solution			
				50	u70	r70	90
Attitude	1.60	2	.45	0.84	0.81	1.92	0.85
Subjective Norm	1.81	3	.61	0.83	0.78	1.00 ²	0.91
Perceived Behavioural Control	3.87	2	.15	0.75	0.43	0.82	0.71
Self-Reported Speeding	4.79	2	.09	0.75	0.84	1.00	0.88
Logged Speeding	-	0	-	0.73		0.91	0.77

¹ Satorra-Bentler Scaled Chi-Square

² For subjective norm the error variance of r70 is fixed to zero

u70 = 70 km/h in urban environments

r70 = 70 km/h in rural environments

The median for attitude towards exceeding the speed limits and subjective norm varied between two and three over the four different conditions, while the median for perceived behavioural control varied between two and four over the four different conditions. On average, the test drivers exceeded the speed limits between 17% and 28% of the time at the three different speed limits.

Figure 2 shows the final structural model with standardized path coefficients and explained variance for self-reported speeding and for logged speeding. Using structural equation modelling it was found that drivers' subjective norm did not only add significantly to the prediction of the drivers' logged speeding indirectly, via self-reported speeding, but also directly to logged speeding. A direct path from subjective norm to logged speeding was therefore added to the model. On the contrary, perceived behavioural control did not add significantly to the prediction of drivers' logged speeding, apart from its indirect contribution via self-reported speeding. Therefore the direct path between perceived behavioural control and logged speeding was excluded from the model. After excluding the direct path from perceived behavioural control to logged speeding, all remaining variables added significantly, directly or indirectly, to the prediction of logged speeding. The standardized path coefficients varied from .22 to .29, with the coefficient for subjective norm being the highest. The intercorrelation between the independent variables was relatively high, ranging from .34 to .57. Thirty-nine

percent of the variance in self-reported speeding, and 28% of the variance in the logged speeding, was explained by the model. The statistics show a close fit between the data and the model (χ^2 [df = 2, N = 112] = 2,01; p = .365; RMSEA = .008).

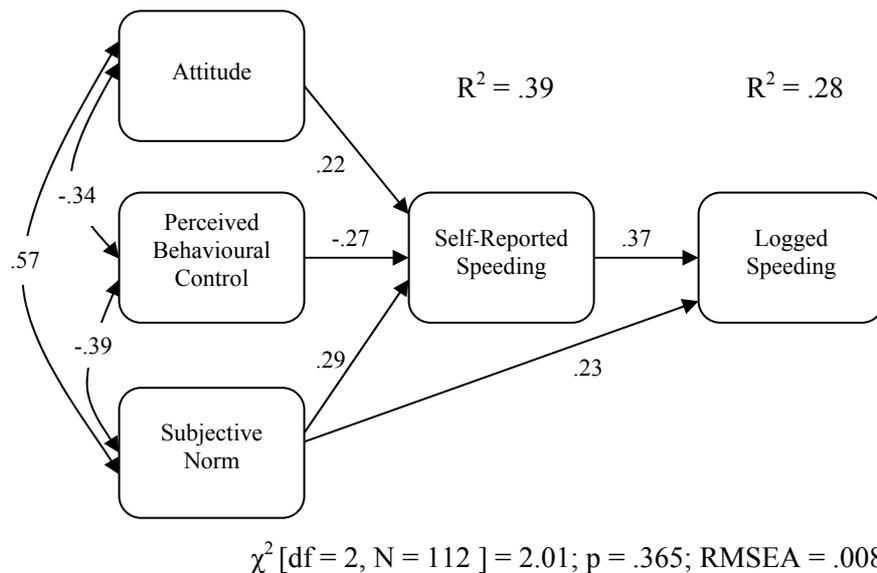


Figure 2. The complete model with standardized path coefficients and explained variance for self-reported and logged speeding.

According to Ajzen (1991) the effect of attitude towards the behaviour, subjective norm, and perceived behavioural control should be mediated by the variable intention. In this study intention was, for practical reasons, replaced by self-reported speeding, which means that the theory of planned behaviour could not be tested in its original form. Instead the theory was used as a conceptual frame of reference which is a likely explanation as to why subjective norm also add significantly to the prediction of logged speeding via a direct path.

Regarding the contribution from perceived behavioural control to the prediction of logged speeding, Ajzen (1991) argues that it can be useful to consider perceived behavioural control in addition to intention for behaviours over which people have incomplete volitional control. When people are realistic in their judgements of a behaviour's difficulty, a measure of perceived behavioural control can contribute to the prediction of the behaviour by serving as a proxy for actual control. In the current study perceived behavioural control did not add significantly to the prediction of drivers' logged speeding, apart from its indirect contribution via self-reported speeding. This may be due to the possibility that drivers with several years of experience already

take into account the actual control they have over the target behaviour when reporting their speeding behaviour.

This study demonstrates that the theory of planned behaviour can be used as a frame of reference to predict drivers' self-reported speeding as well as their logged speeding, even when the behaviour is measured during several weeks, for different times of the day and on different types of roads. If we not only want to predict drivers' speeding behaviour, but also want to gain a further understanding of it, we do, however, need to examine the beliefs underpinning the behaviour. Therefore the second study will focus on these beliefs.

Study II

Drivers' beliefs about exceeding the speed limits

Even though many studies have used the theory of planned behaviour to predict and explain drivers' speeding behaviour only a few have thoroughly analysed and presented the beliefs underpinning drivers' speeding behaviour. In one of these studies only behavioural beliefs concerning speeding were identified (Vogel, 1984), while behavioural and normative beliefs, concerning speeding, were identified in another (Parker, Manstead, Stradling & Reason, 1992). In a third study behavioural, normative and control beliefs concerning compliance with the speed limits, were identified (Elliott et al. 2005). Complying with and exceeding the speed limit are, however, conceptually different behaviours (Letirand & Delhomme, 2005) and no study has yet, as far as I am aware, examined all three types of beliefs with respect to exceeding the speed limits in both urban and rural environments. Even if someone has, differences between countries are also to be expected as countries differ with respect to traffic density, climate, amount of wildlife on the roads, etc.

The aim of this second study is therefore to examine drivers' view on their own speeding behaviour, in both urban and rural environments, by focusing on the belief based measures suggested by the theory of planned behaviour. This will be done by examining the relationship between the belief based measures, and indices constructed with the direct measures, of attitude towards exceeding the speed limits, subjective norm, perceived behavioural control and intention, respectively. The beliefs contributing to the prediction of each index will be identified and based on the results some suggestions for appropriate interventions to reduce speeding on our streets and roads will be made.

A qualitative pilot study was first conducted in order to identify the beliefs associated with drivers' speeding behaviour. A total of 15 people (8 private car owners, 3 colleagues and 4 family members/friends to the researchers) answered a questionnaire with 12 open-ended questions as suggested by Ajzen (2006). Based on the answers, the questionnaire in the main study was then constructed.

The questionnaire in the main study included both direct and belief based measures of attitude, subjective norm and perceived behavioural control, as well as direct measures of intention, with regards to exceeding the speed limits in urban/rural environments during the next 3 months. The questionnaire also included some demographic questions (gender, age, mileage, years holding a driving licence and everyday speeding behaviour). After two postal reminders, 162 randomly selected private car owners (with cars no older than 10 years) in the county of Dalarna, Sweden, had completed the questionnaire. The participants' age ranged from 23 to 86 years, with a mean

age of 53 years. Sixty-one percent of the participants were men while 39% were women. On average the participants had had their driving licence for 34 years and had driven approximately 20 000 km in the previous year. One quarter of the participants reported never speeding in urban environments whilst only 5% reported never speeding in rural environments. At the same time 63% completely agreed that the number of accidents would decrease in urban environments if all drivers complied with the speed limits, and 53% completely agreed, with regards to rural environments.

Table 2 shows that the indices constructed with the direct measures of attitude, subjective norm and perceived behavioural control explained 70% and 73% of the variance in intention to exceed the speed limits in urban and rural environments, respectively. As expected, indices constructed with the belief based measures made a much smaller contribution, explaining 31% and 44% of the variance in intention to exceed the speed limits in urban and rural environments.

Table 2. Standard multiple regressions on intention to exceed the speed limits in urban and rural environments, on the indices, constructed with the direct (above) and belief based (below) measures.

Index	Intention (urban)				Intention (rural)			
	β	r	α	items	β	r	α	items
<i>Direct measures</i>								
N=162								
Attitude	.23***	.68***	.92	4	.68***	.68***	.93	4
Subjective Norm	.26***	.68***	.59	3	.68***	.68***	.66	3
Perceived Behavioural Control	.48***	.77***	.59	2	.77***	.77***	.70	2
<i>Belief based measures</i>								
N=156								
Behavioural Beliefs	.21**	.37***		10	.03	.29***		14
Normative Beliefs	.32***	.47***		4	.34***	.54***		4
Control Beliefs	.20**	.39***		9	.42***	.59***		19

** p < .01 *** p < .001
 α = Cronbach's alpha

Among the direct measures attitude, subjective norm and perceived behavioural control all made significant contributions to the prediction of intention to exceed the speed limits in both urban and rural environments. Perceived behavioural control made the largest contribution in both environments.

Among the belief based measures behavioural, normative and control beliefs made significant contributions to the prediction of intention in urban environments, while only normative beliefs and control beliefs made significant contributions in rural environments. Normative beliefs made the largest contribution in urban environments while control beliefs made the largest contribution in rural environments.

One reason for the indices constructed with the direct measures explaining a larger portion of the variance, than those constructed with the belief based measures, is that the direct measures are quite general and therefore only a few items are needed in order to cover a large portion of the variance in intention. The belief based measures, on the other hand, are much more specific and it is therefore much harder to include enough items to cover a similar portion of the variance. From this follows that studies only aiming to predict a sample's speeding behaviour should use the direct measures as they make a larger contribution to the prediction of intention at the same time as they are much cheaper and more time efficient to use as no pilot study is needed and fewer items are required. If, on the other hand, the aim is to identify beliefs about the behaviour it is necessary to use the belief based measures. As the aim of this second study is to examine drivers' view on their own speeding behaviour, in both urban and rural environments, the focus is on the belief based measures.

Tables 3-8 show how the participants rated the different beliefs with regards to exceeding the speed limits in urban and rural environments. The tables also show the correlation between the different belief composites and their respective index, constructed with the direct measures, plus the index of intention.

Table 3 shows that in urban environments the test drivers rated "Increases the risk of me getting fined" as the most likely outcome ($M = 5.67$, $SD = 1.75$) and "Makes driving more fun" as the least likely outcome ($M = 1.35$, $SD = 1.04$) of exceeding the speed limits. They rated "Makes me follow the traffic rhythm better" as the best outcome ($M = 1.57$, $SD = 1.47$) and "Increases the risk of me colliding with another vehicle" as the worst outcome ($M = -2.44$, $SD = 1.28$). Taken together "Makes me follow the traffic rhythm better" got the highest rating ($M = 5.69$, $SD = 6.85$) while "Increases the risk of me colliding with another vehicle" got the lowest ($M = -12.83$, $SD = 7.92$).

Including all belief composites the model could explain 41% of the variance in attitude towards exceeding the speed limits and 34% of the variance in intention. Only some of these composites did, however, have significant β -weights. "Makes me arrive quicker" made a significant contribution to the prediction of attitude towards exceeding the speed limits in urban environments ($\beta = .42$, $N = 159$, $p < .001$) while "Makes me arrive quicker" and "Increases the risk of me losing my driving licence" made significant contributions to the prediction of intention ($\beta = .40$, $N = 159$, $p < .001$ and $\beta = .19$, $N = 160$, $p < .05$, respectively) to exceed the speed limits in urban environments.

Table 3. The mean and standard deviation (in brackets) of behavioural belief strength (BS: 1 = not likely; 7 = very likely), outcome evaluation (OE: -3 = very bad; 3 = very good) and the belief composite (BC: -21 – 21) of these two variables. The two last columns show the correlation between the belief composite and attitude towards exceeding the speed limits (A) and intention (I), respectively.

Exceeding the speed limits in urban environments over the next three months:	N	BS 1 - 7	OE -3 - 3	BC -21 - 21	A r	I r
Makes me follow the traffic rhythm better	157	3.79 (1.94)	1.57 (1.47)	5.69 (6.85)	.18*	.14*
Makes me arrive quicker	159	3.67 (2.24)	0.53 (1.82)	3.00 (7.80)	.52***	.49***
Makes driving more fun	155	1.35 (1.04)	1.34 (1.70)	1.94 (3.13)	.22**	.28***
Increases the risk of me losing my driving licence	160	4.90 (2.24)	-1.48 (1.96)	-7.93 (11.04)	.25**	.22**
Increases the risk of me getting fined	156	5.67 (1.75)	-1.60 (1.90)	-9.97 (11.19)	.26**	.15*
Increases my fuel costs	156	5.28 (1.98)	-2.11 (1.50)	-11.74 (9.17)	.25**	.15*
Increases the pollution	155	5.14 (2.03)	-2.21 (1.44)	-12.07 (8.75)	.31***	.17*
Increases the risk of me hitting a vulnerable road user	158	5.03 (2.07)	-2.42 (1.54)	-12.68 (9.32)	.33***	.26***
Makes me contribute to a more stressful city environment	157	5.20 (2.05)	-2.36 (1.27)	-12.76 (8.30)	.40***	.28***
Increases the risk of me colliding with another vehicle	153	5.02 (1.91)	-2.44 (1.28)	-12.83 (7.92)	.37***	.26**

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

Table 4 shows that in rural environments the test drivers rated “Makes the consequences of a possible accident more severe” as the most likely outcome (M = 6.19, SD = 1.46) and “Makes driving more fun” as the least likely outcome of exceeding the speed limits (M = 2.37, SD = 1.76). They rated “Makes me avoid feeling stressed” as the best outcome (M = 2.00, SD = 1.64) and “Makes the consequences of a possible accident more severe” and “Increases the risk of me driving off the road” as the worst outcomes (M = -2.50, SD = 1.33; M = -2.50, SD = 1.31, respectively). Taken together “Makes me follow the traffic rhythm better” got the highest rating (M = 6.70, SD = 7.85) while “Makes the consequences of a possible accident more severe” got the lowest (M = -15.52, SD = 9.60).

Table 4. The mean and standard deviation (in brackets) of behavioural belief strength (BS: 1 = not likely; 7 = very likely), outcome evaluation (OE: -3 = very bad; 3 = very good) and the belief composite (BC: -21 – 21) of these two variables. The two last columns show the correlation between the belief composite and attitude towards exceeding the speed limits (A) and intention (I), respectively.

Exceeding the speed limits in rural environments over the next three months:	N	BS 1 - 7	OE -3 - 3	BC -21 - 21	A r	I r
Makes me follow the traffic rhythm better	158	4.49 (1.98)	1.59 (1.48)	6.70 (7.85)	.24**	.12
Makes it easier for me to overtake other vehicles	157	4.48 (2.09)	1.03 (1.74)	5.72 (8.64)	.49***	.51***
Makes me avoid feeling stressed	161	3.07 (2.07)	2.00 (1.64)	5.34 (7.58)	.22**	.14*
Makes me arrive quicker	160	4.51 (2.06)	0.54 (1.82)	4.10 (9.12)	.58***	.50***
Makes driving more fun	157	2.37 (1.76)	1.34 (1.69)	3.72 (5.51)	.38***	.31***
Makes me impede the traffic situation for other road users	158	3.79 (2.03)	-2.32 (1.38)	-8.64 (7.84)	.34***	.18*
Increases the risk of me getting fined	160	5.63 (1.68)	-1.59 (1.92)	-9.22 (12.03)	.19**	.07
Makes me contribute to a more stressful traffic environment	158	4.71 (2.08)	-2.18 (1.38)	-10.78 (8.44)	.36***	.25**
Increases my fuel costs	157	5.56 (1.76)	-2.10 (1.50)	-11.85 (9.89)	.18*	.05
Increases the risk of me driving off the road	156	4.72 (1.98)	-2.50 (1.31)	-11.94 (8.49)	.27***	.13
Increases the pollution	155	5.35 (1.94)	-2.23 (1.41)	-12.42 (9.14)	.23**	.07
Increases the risk of me colliding with another vehicle	157	4.92 (1.92)	-2.44 (1.28)	-12.49 (8.11)	.33***	.16*
Increases the risk of me hitting wildlife (e.g. elks)	160	5.44 (1.60)	-2.34 (1.45)	-12.74 (9.17)	.30***	.12
Makes the consequences of a possible accident more severe	161	6.19 (1.46)	-2.50 (1.33)	-15.52 (9.60)	.16*	-.02

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

Including all belief composites the model could explain 47% of the variance in attitude towards exceeding the speed limits and 38% of the variance in intention. Only some of these composites did, however, have significant β -weights. “Makes me arrive quicker”, “Makes it easier for me to overtake other vehicles” and “Makes me contribute to a more stressful traffic environment” made significant contributions to both the prediction of attitude towards exceeding the speed limits ($\beta = .35$, $N = 160$, $p < .001$; $\beta = .19$, $N = 157$, $p < .05$ and $\beta = .19$, $N = 158$, $p < .05$, respectively) and intention ($\beta = .30$, $N = 160$, $p < .01$; $\beta = .33$, $N = 157$, $p < .001$ and $\beta = .20$, $N = 158$, $p < .05$, respectively) to exceed the speed limits in rural environments.

Looking at both urban and rural environments it seems like the behavioural belief that exceeding the speed limits makes one arrive quicker is what differs the most between those who intend to exceed the speed limits and those who do not. Even if it is logical to believe that travel time will decrease if one exceeds the speed limits this is not necessarily the case. In a field trial with intelligent speed adaptation, 290 vehicles had a device installed for 6 to 12 months (Elmkvist, 2002). The device exerted a counterforce in the acceleration pedal at speeds over the speed limit, which means that the test drivers had to press the acceleration pedal three to five times harder than normal in order to exceed the limits. The results of this study showed that the test drivers mean speeds were lower when they drove with, than without, the device for roads with 30, 50 and 70 km/h speed limits. Surprisingly, their travel times were unchanged, or even marginally improved! The authors of the study suggested that this was because the test drivers drove more calmly but more effectively (with fewer and shorter stops) when driving with the device.

Table 5 shows that in urban environments the test drivers rated “Drivers in cars behind you” as being least negative towards them exceeding the speed limits ($M = -1.04$, $SD = 1.99$) and “People along the streets” as being most negative towards them exceeding the speed limits ($M = -2.54$, $SD = 1.08$). They rated the opinion of “People along the streets” as most important to them ($M = 5.37$, $SD = 1.85$) and the opinion of “Drivers in cars behind you” as least important to them ($M = 3.71$, $SD = 2.33$). Taken together “Drivers in cars behind you” got the highest rating ($M = -5.14$, $SD = 9.58$) while “People along the streets” got the lowest ($M = -13.96$, $SD = 7.76$).

Including all belief composites the model could explain 36% of the variance in subjective norm and 37% of the variance in intention. Only one of these composites did, however, have a significant β -weight. “People along the streets” made significant contributions to the prediction of both subjective norm and intention ($\beta = .49$, $N = 147$, $p < .001$; $\beta = .56$, $N = 147$, $p < .001$, respectively).

Table 5. The mean and standard deviation (in brackets) of normative belief strength (BS: -3 = should not; 3 = should), motivation to comply (MC: 1 = not at all; 7 = very much) and the belief composite (BC: -21 – 21) of these two variables. The two last columns show the correlation between the belief composite and subjective norm (SN) and intention (I), respectively.

Who affects you when it comes to exceeding the speed limits in urban environments over the next three months:	N	BS -3 - 3	MC 1 - 7	BC -21 - 21	SN r	I r
Drivers in cars behind you	147	-1.04 (1.99)	3.71 (2.33)	-5.14 (9.58)	.33***	.27***
Relatives and Friends	146	-1.97 (1.28)	3.75 (2.22)	-8.04 (7.75)	.45***	.43***
Family	145	-2.25 (1.15)	4.66 (2.29)	-11.26 (8.10)	.44***	.41***
People along the streets	147	-2.54 (1.08)	5.37 (1.85)	-13.96 (7.76)	.58***	.60***

*** p < .001

Table 6 shows that in rural environments the test drivers rated “Drivers in cars behind you” as being least negative towards them exceeding the speed limits (M = -0.30, SD = 2.18) and “People living along the roads” as being most negative towards them exceeding the speed limits (M = -2.28, SD = 1.24). They rated the opinions of “People living along the roads” as most important to them (M = 4.78, SD = 2.10) and the opinion of “Drivers in cars behind you” as least important to them (M = 3.51, SD = 2.31). Taken together “Drivers in cars behind you” got the highest rating (M = -3.44, SD = 9.93) while “People living along the roads” got the lowest (M = -11.66, SD = 8.13).

Table 6. The mean and standard deviation (in brackets) of normative belief strength (BS: -3 = should not; 3 = should), motivation to comply (MC: 1 = not at all; 7 = very much) and the belief composite (BC: -21 – 21) of these two variables. The two last columns show the correlation between the belief composite and subjective norm (SN) and intention (I), respectively.

Who affects you when it comes to exceeding the speed limits in rural environments over the next three months:	N	BS -3 - 3	MC 1 - 7	BC -21 - 21	SN r	I r
Drivers in cars behind you	146	-0.30 (2.18)	3.51 (2.31)	-3.44 (9.93)	.39***	.31***
Relatives and Friends	145	-1.59 (1.45)	3.68 (2.22)	-6.89 (7.96)	.58***	.58***
Family	144	-1.70 (1.48)	4.48 (2.17)	-8.64 (8.78)	.63***	.53***
People living along the roads	146	-2.28 (1.24)	4.78 (2.10)	-11.66 (8.13)	.48***	.49***

*** p < .001

Including all belief composites the model could explain 42% of the variance in subjective norm and 38% of the variance in intention. Only some of these composites did, however, have significant β -weights. "Family" made a significant contribution to the prediction of subjective norm ($\beta = .49$, $N = 144$, $p < .01$) while "Relatives and Friends" and "People living along the roads" made significant contributions to the prediction of intention ($\beta = .52$, $N = 145$, $p < .01$; $\beta = .26$, $N = 146$, $p < .05$, respectively).

Looking at both urban and rural environments it seems that the normative belief about people along the streets and roads is what differs the most between those who intend to exceed the speed limits and those who do not. This means that drivers, who intend to exceed the speed limits, think that people along the streets and roads accept higher speeds than what those who do not intend to exceed the speed limits, think - and/or they are less motivated to comply with these opinions. Åberg et al. (1997) showed that the observed speeds were higher for drivers, who thought that vulnerable road users considered their speed to be too high, than for drivers, who thought that vulnerable road users considered their speed to be acceptable. There was also a tendency for drivers, who thought that vulnerable road users considered their speed to be too high, to have a low concern for vulnerable road users. This suggests that it is the motivation to comply with the opinions of people along the streets and roads that differs between those who intend to exceed the speed limits, and those who do not, rather than the amount of speeding they think people along the streets and roads find acceptable.

Table 7 shows that in urban environments the test drivers agreed most with "The price of petrol being high" ($M = 6.67$, $SD = 1.12$) and rated "You passing a speed camera" as happening least frequently ($M = 2.89$, $SD = 1.84$). They rated "You being in a hurry" as making it easiest for them to exceed the speed limits ($M = 1.21$, $SD = 1.54$) and "You driving over physical measures to reduce the speed" as making it hardest for them to exceed the speed limits ($M = -2.24$, $SD = 1.37$). Taken together "You being in a hurry" got the highest rating ($M = 4.69$, $SD = 6.20$) while "You driving over physical measures to reduce the speed" got the lowest ($M = -10.79$, $SD = 8.00$).

Including all belief composites the model could explain 27% of the variance in perceived behavioural control and 22% of the variance in intention. Only one of these composites did, however, have a significant β -weight. "You passing a speed sign" made significant contributions to the prediction of both perceived behavioural control and intention ($\beta = .35$, $N = 160$, $p < .001$; $\beta = .31$, $N = 160$, $p < .01$, respectively).

Table 7. The mean and standard deviation (in brackets) of control belief strength (BS: 1 = never; 7 = very often), control belief power (BP: -3 = much harder; 3 = much easier) and the belief composite (BC: -21 – 21) of these two variables. The two last columns show the correlation between the belief composite and perceived behavioural control (PBC) and intention (I), respectively.

How is you exceeding the speed limits in urban environments over the next three months affected by:	N	BS 1 - 7	BP -3 - 3	BC -21 - 21	PBC r	I r
You being in a hurry	158	3.34 (1.63)	1.21 (1.54)	4.69 (6.20)	.25**	.24**
The road being good (e.g. straight, wide)	156	3.72 (1.70)	1.11 (1.52)	4.29 (6.89)	.20**	.12
The street being free from vulnerable road users	160	3.23 (1.85)	0.38 (1.82)	1.10 (7.55)	.19**	.17*
The price of petrol being high	153	6.67 ¹ (1.12)	-0.44 (1.48)	-3.10 (10.31)	.25**	.31***
Other drivers keeping to the speed limits	159	3.47 (1.41)	-1.18 (2.00)	-3.98 (7.75)	.27***	.19**
You passing a speed camera	157	2.89 (1.84)	-1.90 (1.48)	-5.78 (6.37)	.21**	.16*
The roads being in a bad state (e.g. snowy, slippery)	160	3.29 (1.79)	-2.16 (1.34)	-7.25 (6.33)	.24**	.12
You passing a speed sign	160	6.19 (1.40)	-1.20 (1.40)	-7.61 (9.23)	.45***	.40***
You driving over physical measures to reduce the speed	161	4.78 (1.78)	-2.24 (1.37)	-10.79 (8.00)	.18*	.15*

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

¹ For the item regarding whether the price of petrol is too high the scale was 1 = completely disagree; 7 = completely agree.

Table 8 shows that in rural environments the test drivers agreed the most with “The price of petrol being high” (M = 6.68, SD = 1.12) and rated “You using Cruise Control” as happening least frequently (M = 3.13, SD = 2.36). They rated “You being in a hurry” as making it easiest for them to exceed the speed limits (M = 1.52, SD = 1.46) and “You using Cruise Control” as making it hardest for them to exceed the speed limits (M = -1.41, SD = 1.73). Taken together “The road being good (e.g. straight, wide)” got the highest rating (M = 7.45, SD = 7.69) while “The fines for speeding being high” got the lowest (M = -4.88, SD = 6.65).

Including all belief composites the model could explain 47% of the variance in perceived behavioural control and 41% of the variance in intention. Only some of these composites did, however, have significant β -weights. “You passing a speed sign”, “The road being good (e.g. straight, wide)”, “The roads having central median barriers” and “Large speed margins before driving licence confiscated” made significant contributions to the prediction of perceived behavioural control ($\beta = .37$, N = 156, $p < .001$; $\beta = .19$, N =

161, $p < .05$; $\beta = .17$, $N = 160$, $p < .05$; $\beta = .15$, $N = 154$, $p < .05$, respectively). “You passing a speed sign” and “You being in a hurry” made significant contributions to the prediction of intention ($\beta = .24$, $N = 156$, $p < .01$; $\beta = .21$, $N = 162$, $p < .05$, respectively).

Table 8. The mean and standard deviation (in brackets) control belief strength (BS: 1 = never; 7 = very often), control belief power (BP: -3 = much harder; 3 = much easier) and the belief composite (BC: -21 – 21) of these two variables. The two last columns show the correlation between the belief composite and perceived behavioural control (PBC) and intention (I), respectively.

How is you exceeding the speed limits in rural environments over the next three months affected by:	N	BS 1 - 7	BP -3 - 3	BC -21 - 21	PBC r	I r
The road being good (e.g. straight, wide)	161	4.70 (1.66)	1.48 (1.37)	7.45 (7.69)	.36***	.35***
You being in a hurry	162	3.76 (1.67)	1.52 (1.46)	6.50 (6.66)	.37***	.39***
Lanes going in different directions being separated	159	3.90 (1.72)	1.36 (1.60)	5.11 (7.81)	.30***	.36***
You driving a fast car	159	3.55 (2.01)	1.17 (1.64)	4.59 (7.42)	.17*	.25**
The roads having wildlife fences	158	4.47 (1.73)	0.62 (1.47)	2.99 (7.50)	.34***	.40***
Large speed margins before driving licence confiscated	154	3.27 ² (2.25)	0.25 (1.73)	1.42 (6.02)	.30***	.30***
Other drivers driving too close behind you	157	5.18 (1.58)	0.26 (1.54)	1.10 (8.62)	.22**	.14*
The roads having central median barriers ¹	160	3.98 (1.72)	0.17 (1.74)	0.92 (8.03)	.39***	.37***
Other drivers keeping to the speed limits	159	3.16 (1.54)	-0.88 (1.85)	-2.97 (6.29)	.26***	.27***
The price of petrol being high	155	6.68 ² (1.12)	-0.52 (1.31)	-3.57 (9.12)	.33***	.28***
You passing a speed sign	156	5.92 (1.40)	-0.72 (1.31)	-4.28 (7.95)	.52***	.41***
You using Cruise Control	150	3.13 (2.36)	-1.41 (1.73)	-4.29 (7.46)	.19*	.25**
The fines for speeding being high	156	3.87 ² (2.15)	-1.37 (1.36)	-4.88 (6.65)	.16*	.12

* $p < .05$ ** $p < .01$ *** $p < .001$

1. In Sweden there is a special sort of 1+2 lane highway with a central median barrier stopping drivers from entering the lane for oncoming traffic.

2. For the item regarding the size of the speed margins before the driving licence is confiscated, the price of petrol and the size of speeding fines the scales were 1 = completely disagree; 7 = completely agree.

Looking at both urban and rural environments it seems like different measures to increase road safety (the roads being straight and wide, as well as,

free from vulnerable road users, oncoming traffic and wildlife) are rated very highly by the drivers. This suggests that these types of measures might result in drivers exceeding the speed limits more often, which is in accordance with risk theories like the risk homeostasis theory (Wilde, 1988) and the zero-risk model of driver behaviour (Näätänen & Summala, 1976). According to the risk homeostasis theory (Wilde, 1988), drivers act in a way that creates a balance between their perceived level of subjective risk of accident and the level of risk they are willing to accept, and according to the zero-risk model of driver behaviour (Näätänen & Summala, 1976), drivers act in a way so that they do not experience any risk of accident (or arrest) for most of the time. These two models represent different views on what motivates drivers to drive the way they do, as well as, on drivers' perception of risk. Even so, from both of them follows that safety measures that decrease the subjective risk or raise the subjective threshold for experiencing risk (e.g. wildlife fences) might result in more risky behaviours (e.g. increased speeds) and therefore not necessarily result in safer traffic. It is therefore very important that the effects of all safety measures are carefully studied after implementation, to make sure that the benefits of these measures are greater than the detrimental effects of possible negative behavioural changes.

This study identifies several beliefs, important for drivers' intention to exceed the speed limits, by using the belief based measures suggested by the theory of planned behaviour. Drivers' speeding behaviour might, however, not always be a deliberate violation but may instead be the result of an unintended error. Therefore the third study will focus on the driver behaviour questionnaire as the model underpinning this questionnaire includes both these categories.

Study III

Speeding – deliberate violation or involuntary mistake?

Drivers' speeding behaviour can be seen as a deliberate violation or as a result of an unintended error. The model underpinning the driver behaviour questionnaire (Reason et al. 1990) includes both these categories and it is therefore reasonable to believe that this model could be used to predict drivers' speeding behaviour.

The first aim of this third study is therefore to compare the theory of planned behaviour (Ajzen, 1991) and the model underpinning the driver behaviour questionnaire (Reason et al. 1990) with regards to their ability to predict drivers' speeding behaviour. The main aim is then to combine these two frames of reference in an attempt to further the knowledge about drivers speeding behaviour.

The study is based on data from 175 test drivers participating in the Borlänge field trials. All test drivers had driven their vehicle more than 45% of the time the vehicle was driven and had logged data successfully retrieved from at least 10 journeys. All behavioural data used was collected during September to November in 2001. During this period the warning system of the ISA speed-warning device was activated which means that the test drivers received information about the current speed limit as well as warning signals if this limit was exceeded. The test drivers also completed a questionnaire, which was distributed in March 2000, before the warning system was activated. The test drivers' age ranged from 24 to 88 years old, with a mean of 55 years. Seventy-one percent of the test drivers were men while 29% were women.

Before the model testing, preparatory analyses were made to obtain model variables. Principal component analyses (PCA) revealed that each variable in the theory of planned behaviour could be represented by a uni-dimensional factor score. These single factors explained 65.5% of attitude towards exceeding the speed limits ($\theta = .926$), 70.6% of subjective norm ($\theta = .939$), 43.9% of perceived behavioural control ($\theta = .810$), 61.2% of moral norm ($\theta = .914$) and 73.3% of self-reported speeding ($\theta = .900$). Principal component analysis with varimax-rotation also revealed a four-factor structure explaining 52.2% of the total variance of the Swedish version of the driver behaviour questionnaire (DBQ-SWE). The four factors were interpreted as violations, mistakes, inattention errors and inexperience errors (θ : .835, .888, .791, and .819, respectively). Of the variance in logged speeding on different roads, 67.7% could be explained by one single factor ($\theta = .936$). The results from the principal component analyses were saved as factor scores and used in the subsequent LISREL analyses for tests of the goodness of fit of the models. In table 9 the intercorrelations between factor scores used in the current analyses are shown.

Table 9. Correlations between logged speeding in 2001 (L S) and self-reported speeding in 2000 (SR S), TPB- and DBQ-variables. (N = 175).

	SR S	TPB A	TPB SN	TPB MN	TPB PBC	DBQ Viol.	DBQ Mis.	DBQ Inatt.	DBQ Inexp.
L S	.45**	.27**	.28**	-.39**	-.28**	.43**	.06	.08	-.16*
SR S	-	.49**	.45**	-.54**	-.44**	.63**	-.08	.20**	.09
A		-	.46**	-.56**	-.29**	.32**	-.01	.15	-.01
SN			-	-.47**	-.37**	.44**	-.04	.17	.01
MN				-	.52**	-.47**	.02	-.10	.10
PBC					-	-.34**	-.07	-.14	-.09
Viol.						-	-.05	.04	-.04
Mis.							-	.03	-.02
Inatt.								-	-.02
Inexp.									-

* p < .05 ** p < .01

A = Attitude, SN = Subjective Norm, MN = Moral Norm, PBC = Perceived Behavioural Control, Viol = Violations, Mis = Mistakes, Inatt = Inattention Errors, Inexp = Inexperience Errors.

Firstly, the theory of planned behaviour, extended with moral norm, was used to predict self-reported speeding. The results, presented in figure 3, show that a model with moral norm as an intermediate variable (47% of the moral norm was explained by attitude towards exceeding the speed limits, subjective norm, and perceived behavioural control) with direct paths from attitude towards exceeding the speed limits and perceived behavioural control could explain 38% of the variance in self-reported speeding. The variance in logged speeding could be explained to 24% and there were direct paths from moral norm and self-reported speeding to logged speeding. The statistics show a close fit between the data and the model (χ^2 [df = 4, N = 175] = 5.55; p = .24; RMSEA = .048).

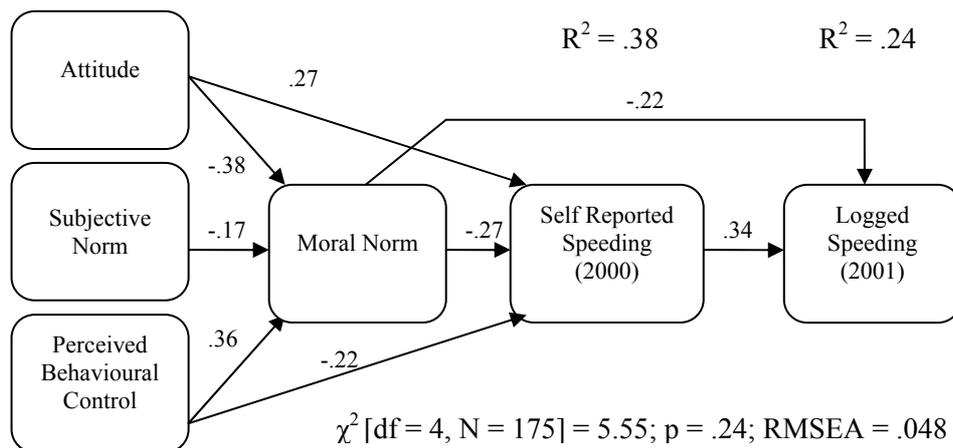


Figure 3. The model, based on the theory of planned behaviour, with standardized path coefficients and explained variance for self-reported and logged speeding.

Then, the model underpinning the driver behaviour questionnaire was used to predict self-reported speeding. The results, presented in figure 4, show that a model with the variables, violations and inattention errors could explain 42% of the variance in self-reported speeding. Self-reported speeding together with violations could then explain 24% of the variance in logged speeding. The statistics show a close fit between the data and the model (χ^2 [df = 1, N = 175] = .07; p = .79; RMSEA = .000).

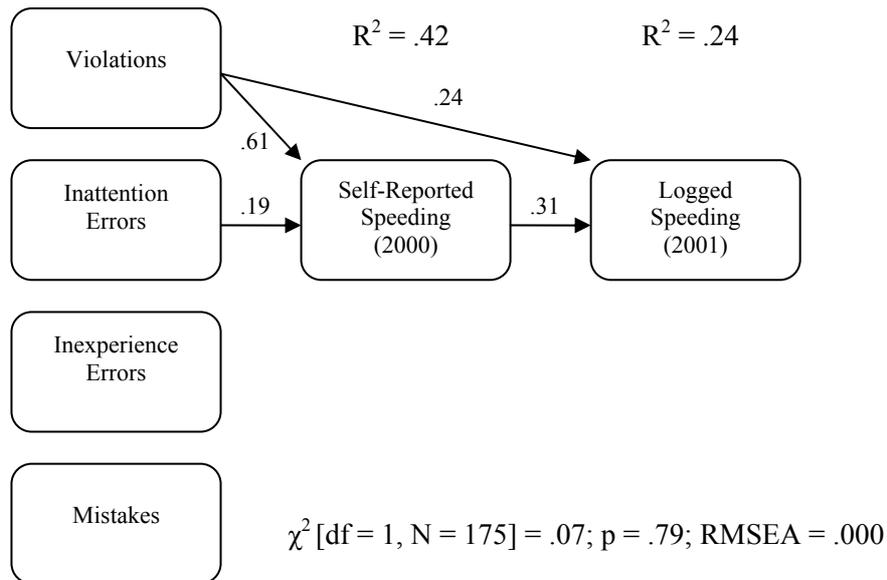


Figure 4. The model, based on the model underpinning the driver behaviour questionnaire, with standardized path coefficients and explained variance for self-reported and logged speeding.

Finally, the theory of planned behaviour (extended with moral norm) and the violations and inattention errors from the driver behaviour questionnaire, were combined in an attempt to improve the amount of variance explained in self-reported speeding and logged speeding. As the driver behaviour questionnaire concerns driver errors in general and the theory of planned behaviour is more focused on specifically explaining speeding behaviour it is reasonable to assume that violations should precede self-reported speeding in the combined model. Also, the unintentional errors tapped in the driver behaviour questionnaire should precede perceived behavioural control. In the new model violations from the driver behaviour questionnaire were therefore placed between moral norm and self-reported speeding. The remaining variables from the driver behaviour questionnaire were placed on the left side of the model. The results, presented in figure 5 show that the combined model could explain 53% of self-reported speeding and 26% of logged speeding.

The statistics show a close fit between the data and the model (χ^2 [df = 10, N = 175] = 5.72; $p = .84$; RMSEA = .000). There were direct paths from violations, inattention errors, attitude towards exceeding the speed limits and perceived behavioural control to self-reported speeding and from self-reported speeding, violations and moral norm to logged speeding. However, no path from inattention errors or inexperience errors to perceived behavioural control could improve the model.

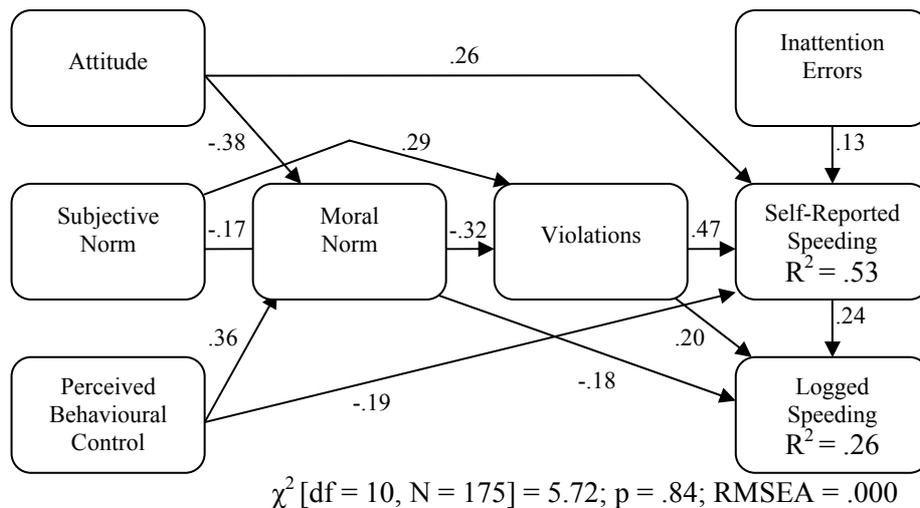


Figure 5. The combined model, based on the theory of planned behaviour combined with the model underpinning the driver behaviour questionnaire, with standardized path coefficients and explained variance for self-reported and logged speeding.

Pair-wise comparison between the fit indices (χ^2) of the different models did not reveal any significant differences.

This study demonstrates that it is possible to combine the theory of planned behaviour (extended with moral norm) with violations and inattention errors, from the model underpinning the driver behaviour questionnaire, in a way that leads to increased knowledge about the mechanisms behind drivers' speeding behaviour. Even if each of the models has good predictive power the combined model is, if only marginally, better in explaining the variance in logged speeding. The results indicate that some drivers perceive difficulties in keeping the speed limits, not primarily because they lack information about the current speed limit or their own speed, but rather because of pressure from other drivers. One way to affect drivers' actual and perceived control is by using different systems for intelligent speed adaptation. Therefore the fourth study will examine drivers' speeding behaviour after long-term use of an ISA speed-warning device.

Study IV

Drivers' speeding behaviour - and the long-term use of an ISA speed-warning device

Even though many field trials with intelligent speed adaptation have been conducted the large majority of these studies have been limited in time. As the effect of newly implemented systems might change over time further research is required to examine drivers' speeding behaviour after long-term use of the systems. If it is found that the effect changes over time it is also of interest to examine what causes these changes.

The first aim of this fourth study is therefore to examine drivers' speeding behaviour after long-term use of an ISA speed-warning device. The second aim is to try to understand what caused possible behavioural changes by examining the variables in the theory of planned behaviour.

The study is based on data from 61 test drivers participating in the extended Borlänge field trials. All test drivers had driven their vehicle more than 45% of the time the vehicle was driven and had logged data registered on roads with 50, 70 and 90 km/h speed limits from four different time periods selected for the current analyses. The first of these periods was during two to four weeks in the autumn of 2000 to the spring of 2001, depending on when the test driver had the ISA speed-warning device installed in their vehicle. During this period the warning system was not yet activated which means that the test drivers did not receive any information about the current speed limit or any warning signals if this limit was exceeded. The second period was during four weeks in the autumn of 2000 to the spring of 2001. During this period the warning system had just been activated and the test drivers received information about the current speed limit as well as warning signals if this limit was exceeded. The third period was during May to July 2001 (approximately 35% of the test drivers had their warning systems activated during April or May 2001 which means that their data from the period after activation overlaps somewhat with the data collected during the spring of 2001) and the last period was during May to July 2003. The test drivers also completed several questionnaires and out of the 61 test drivers mentioned above, 27 test drivers had completed questionnaires from March 2000 (before the warning system was activated), December 2001 and June 2004 as well as having logged data from the spring of 2004. At the start of the trials in 2000 the 61 test drivers' age ranged from 27 to 79 years old, with a mean of 56 years. Seventy-two percent of the test drivers were men while 28% were women. Mann-Whitney U Tests showed that the 27 test drivers (who had three completed questionnaires and also logged data from 2004) did not differ from the other 34 test drivers as far as age, gender, number of trips, mean speed and time spent speeding was concerned.

The results, presented in figure 6, show that the median test drivers' mean time spent driving above the speed limit greatly decreased when the warning system was activated. It also shows that this initial decrease was reduced with time.

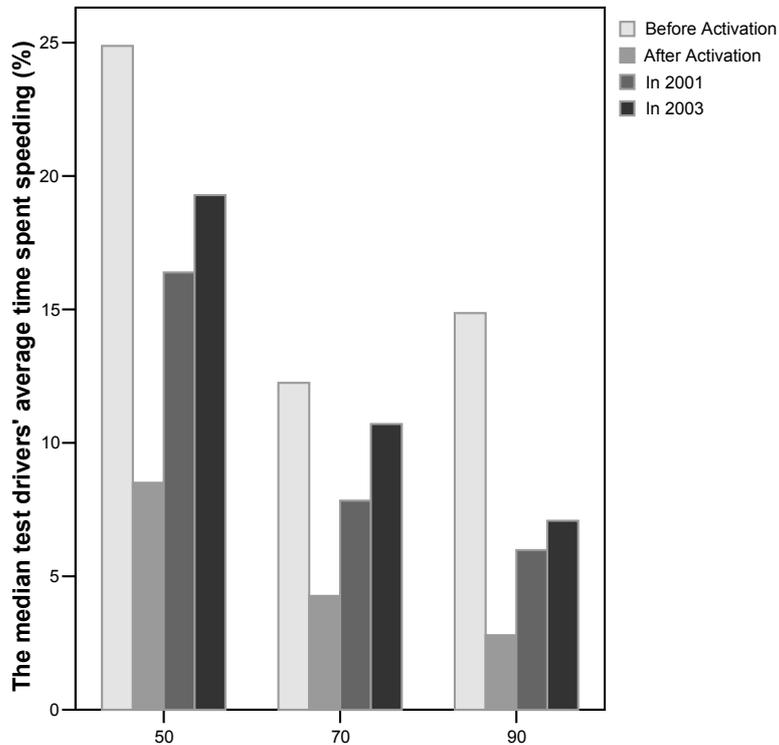


Figure 6. The median test drivers' total time exceeding the speed limits by at least 2 km/h divided with the total time driven for roads with 50, 70 and 90 km/h speed limits during the periods before activation, after activation, spring 2001 and spring 2003. (N = 61)

On streets with a 50 km/h speed limit the median test driver drove above the speed limit 24.9% of the total time driven before the warning system was activated. After activation the amount of time spent above the speed limit decreased to 8.5%. The amount of time spent above the speed limit then started to increase again and during the spring of 2003 the median test driver drove above the speed limit 19.3% of the total time driven. Even if the amount of time spent above the speed limit increased after long-term use the decrease was still significant during the spring of 2003, compared with the period before the warning system was activated [$Z(60) = -3.37$; $p < .01$].

On roads with a 70 km/h speed limit the median test driver drove above the speed limit 12.2% of the total time driven before the warning system was

activated. After activation the amount of time spent above the speed limit decreased to 4.3%. The amount of time spent above the speed limit then started to increase again and during the spring of 2003 the median test driver drove above the speed limit 10.7% of the total time driven. The decrease in the amount of time spent above the speed limit was still significant during the spring of 2001, compared with the period before the warning system was activated [$Z(60) = -4.23$; $p < .001$], but during the spring of 2003 there were no longer any significant differences.

On roads with a 90 km/h speed limit the median test driver drove above the speed limit 14.9% of the total time driven before the warning system was activated. After activation the amount of time spent above the speed limit decreased to 2.8%. The amount of time spent above the speed limit then started to increase again and during the spring of 2003 the median test driver drove above the speed limit 7.1% of the total time driven. Even if the amount of time spent above the speed limit increased after long-term use the decrease was still significant during the spring of 2003, compared with the period before the warning system was activated [$Z(60) = -2.58$; $p < .05$].

Svedung (2005) showed that the time drivers in general spent above the speed limits on governmental roads in urban and rural areas in Sweden increased significantly between 2000 and 2003. There was, however, no decrease in time spent above the speed limits corresponding to the decrease the group of test drivers showed after the warning system of the ISA speed-warning device was activated. With regards to the amount of time drivers in general spent above the speed limits on non-governmental roads in urban areas, there were no significant differences between 1997 and 2003. As the changes in the amount of time spent above the speed limits differ between the group of test drivers and drivers in general, it is reasonable to believe that the large reduction in the amount of time spent above the speed limit, found among the test drivers, is indeed due to the ISA speed-warning device. The fact that the effect of the device decreased with time is in accordance with previous research, which has shown that the initial effect of an active accelerator pedal (which exerts a counterforce at speeds over the speed limit) is greater than the effect after five to eleven months (Hjälmdahl, Almqvist & Várhelyi, 2002; Várhelyi, Hjälmdahl, Hydén & Draskóczy, 2004).

On streets with a 50 km/h speed limit the median test driver's mean speed was 37.6 km/h before the warning system was activated. After activation the median test driver's mean speed decreased to 36.7 km/h. The speed then started to increase again and during the spring of 2003 the median test driver's mean speed was 37.8 km/h. The decrease in mean speed was significant during the period just after the warning system was activated [$Z(60) = -3.76$; $p < .001$], but during the spring of 2001 there were no longer any significant differences compared with the period before the warning system was activated.

Visual inspection of figure 7-10 revealed that the speed distribution became somewhat more homogeneous, with both the low and the high extreme mean speeds disappearing, when the system was activated. Over time the speed distribution did however become more heterogeneous again.

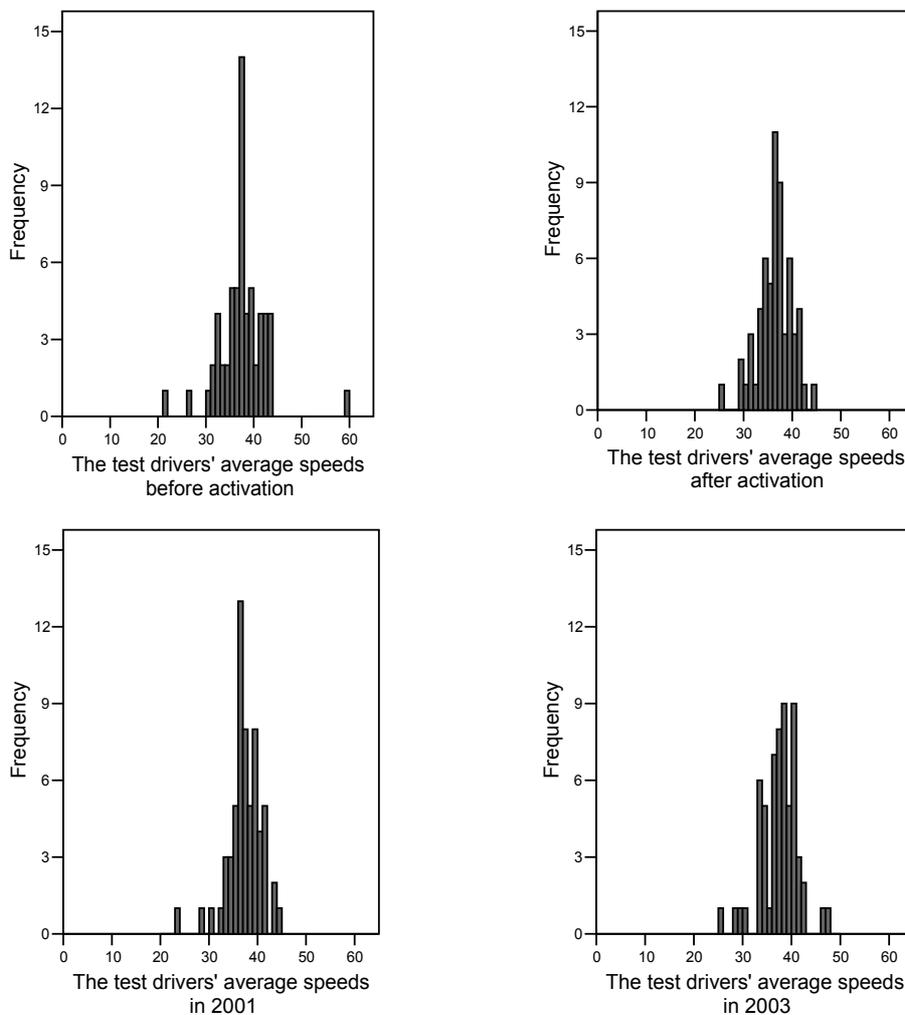


Figure 7-10. The distribution of the test drivers' mean speeds on roads with 50 km/h speed limit during different time periods. (N = 61)

On roads with a 70 km/h speed limit the median test driver's mean speed was 57.0 km/h before the warning system was activated. After activation the median test driver's mean speed decreased to 56.2 km/h. The speed then started to increase again and during the spring of 2003 the median test driver's mean speed was 57.8 km/h. The decrease in mean speed was still

significant during the spring of 2001, compared with the period before the warning system was activated [$Z(60) = -2.60$; $p < .01$], but during the spring of 2003 there were no longer any significant differences. The fastest test driver's mean speed decreased with approximately 6 km/h when the warning system was activated but, as a whole, visual inspection did not reveal any large changes in speed distribution.

On roads with a 90 km/h speed limit the median test driver's mean speed was 82.2 km/h before the warning system was activated. After activation the median test driver's mean speed decreased to 81.4 km/h. The speed then started to increase again and in 2003 the median test driver's mean speed was 81.7 km/h. The decrease in mean speed was significant during the period just after the warning system was activated [$Z(60) = -2.14$; $p < .05$] and during the spring of 2003 [$Z(60) = -2.51$; $p < .05$], but during the spring of 2001 there were no significant differences compared with the period before the warning system was activated. Visual inspection did not reveal any large changes in speed distribution.

These results differ from previous research where clearer decreases in speed variation have been found (Almqvist & Nygård, 1997; Brookhuis & De Waard, 1999; Hjalmdahl et al. 2002; Duynstee et al. 2001; Regan et al. 2005; Várhelyi et al. 2004, 2005; Várhelyi & Mäkinen, 2001). More research is therefore required. At the same time it should be remembered that the sample size in the current study is fairly small ($N = 61$).

Tables 10 and 11 show that the 27 test drivers' attitude towards exceeding the speed limits as well as their subjective norm correlate over time. The tables also show that approximately one third of the variance in the test drivers' attitude towards exceeding the speed limits and their subjective norm was shared between the period before the warning system was activated and the periods after activation in 2001 and 2004, respectively. After activation in 2001 and 2004 between half, and two thirds, of the variance was shared. For perceived behaviour control (table 12), there was no significant correlation between the test drivers' feeling of control during the period before the warning system was activated and the test drivers feeling of control after activation in 2001 and 2004, respectively. The table also shows that hardly any variance was shared between the period before the warning system was activated and the periods after activation in 2001 and 2004, respectively. After activation, there was however a significant correlation between the test drivers feeling of control in 2001 and 2004 and approximately half of the variance was shared. Finally, table 13 shows that the test drivers' self-reported speeding correlates over time. The table also shows that approximately one third of the variance in the test drivers' self-reported speeding was shared between the period before the warning system was activated and the period just after activation in 2001, while approximately half of the variance was shared between the period before the warning system was activated

and the last period after activation in 2004. After activation in 2001 and 2004 approximately 40% of the variance was shared.

Table 10. The coefficient of determination (r^2) for attitude towards exceeding the speed limits over time. (N = 27)

Variable	Attitude: Before	Attitude: 2001
Attitude: 2001	.364**	
Attitude: 2004	.375**	.623***

** correlation significant on 1 % level

*** correlation significant on .1 % level

Table 11. The coefficient of determination (r^2) for subjective norm over time. (N = 27)

Variable	Subjective Norm: Before	Subjective Norm: 2001
Subjective Norm: 2001	.336**	
Subjective Norm: 2004	.318**	.576***

** correlation significant on 1 % level

*** correlation significant on .1 % level

Table 12. The coefficient of determination (r^2) for perceived behavioural control over time. (N = 27)

Variable	PBC Before	PBC 2001
Perceived Behavioural Control: 2001	.013	
Perceived Behavioural Control: 2004	.021	.507***

*** correlation significant on .1 % level

Table 13. The coefficient of determination (r^2) for self-reported speeding over time. (N = 27)

Variable	SR S Before	SR S 2001
Self-Reported Speeding: 2001	.582***	
Self-Reported Speeding: 2004	.333**	.421***

** correlation significant on 1 % level

*** correlation significant on .1 % level

This suggests that there are some individual differences, with regards to attitude towards exceeding the speed limits and subjective norm, in the way the test drivers are affected by the activation of the warning system. After activation, long-term use affects the test drivers in a more homogenous way. Regarding perceived behavioural control there is an even greater variation in the way different test drivers are affected by the activation of the warning system. Long-term use, on the other hand, does again affect the test drivers in a more homogenous way.

Table 14 shows how the test drivers rated their attitude towards exceeding the speed limits, their subjective norm, their perceived behavioural control and their self-reported speeding during different time periods. No significant

differences were found between the period before the warning system was activated and the periods after activation in 2001 and 2004, respectively. Between the periods after activation there was, however, a significant difference in how the test drivers' rated their attitude towards exceeding the speed limits as well as their perceived behavioural control. In 2004, compared with 2001, the test drivers found it less acceptable to exceed the speed limits [2001: Median = 2.00, Range = 2.25; 2004: Median = 1.50, Range = 2.25; $Z(26) = -3.27$, $p < .01$] and easier to comply with these limits [2001: Median = 3.25, Range = 2.75; 2004: Median = 4.00, Range = 2.50; $Z(26) = -3.17$, $p < .01$].

Table 14. The median and range (in brackets) for the variables in the theory of planned behaviour during different time periods. (N = 27)

Variables	Before	2001	2004
Attitude (Speeding: 1 = not acceptable, 5 = totally acceptable)	1.75 (2.50)	2.00 (2.25)	1.50 (2.25)
Subjective Norm (Speeding: 1 = not acceptable, 5 = totally acceptable)	2.00 (3.00)	2.00 (2.75)	1.75 (2.25)
Perceived Behavioural Control (Comply with limits: 1 = very hard, 5 = very easy)	3.50 (3.50)	3.25 (2.75)	4.00 (2.50)
Self-Reported Speeding (Speeding: 1 = never; 6 = very often)	3.00 (4.00)	3.00 (4.00)	3.00 (3.50)

The fact that the test drivers found it less acceptable to exceed the speed limits, at the same time as they report no changes in their speeding behaviour is hard to explain. It is, however, important to be careful while considering these results as the sample size is very small (N = 27). A possible explanation for why the test drivers find it easier to comply with the speed limits in 2004, than in 2001, may be that it took a while for them to get used to the new device before they felt comfortable using it.

This study demonstrates that, initially, the ISA speed-warning device greatly reduces the amount of time drivers spend above the speed limit, and to some extent also reduces their mean speeds, but this effect decreases with time. It also show that the activation of the warning system affects different drivers in different ways, with regards to attitude towards exceeding the speed limits, subjective norm and, especially, perceived behavioural control. After activation, long-term use does, however, affect the drivers in a more homogenous way. When considering these results it is important to remember that the device tested is a first generation ISA speed-warning device without any consideration taken to the rapid development of, for example, the interface between driver and device that has taken place during recent years. Therefore the fifth and final study will examine how the use of an ISA speed-warning device affects the drivers' attitude towards the system.

Study V

How does the use of ISA affect drivers' attitude towards the system?

In the fourth study drivers' speeding behaviour after long-term use of an ISA speed-warning device was examined and the variables in the theory of planned behaviour were investigated in order to try and understand what caused the changes in drivers' speeding behaviour. But no matter how effective different measures are in reducing speeding during field trials, they also have to be accepted by the drivers who are expected to use them.

The aim of the final study is therefore to examine how the use of an ISA speed-warning device affects the drivers' attitude towards the system.

The study is based on data from 161 test drivers participating in the Borlänge field trials. All test drivers had driven their vehicle more than 45% of the time the vehicle was driven and had also completed three questionnaires. The first of these three questionnaires was distributed before the warning system of the ISA speed-warning device was activated. The second questionnaire was distributed after they had driven with the warning system activated for approximately one month and the last questionnaire was distributed after they had driven with the ISA speed-warning device for up to 14 months. At this point the warning system had just been inactivated again. During the period when the warning system was activated the test drivers received information about the current speed limit as well as warning signals if this limit was exceeded. The questions analysed concern how the test drivers thought their driving experience would be affected by having the ISA speed-warning device installed in their vehicles, and later on, how they actually were affected. The test drivers' age ranged from 24 to 79 years old, with a mean of 55 years. Seventy percent of the test drivers were men while 30% were women.

Table 15 shows the test drivers' expectations on the ISA speed-warning device concerning its effect on different aspects of their driving experience. The test drivers' highest expectation of having the ISA speed-warning device installed concerned their feeling of being controlled, where they thought that their feeling of being controlled would increase when the warning system was activated. During the periods just after activation and more than a year after activation, respectively, it was shown that the test drivers' feeling of being controlled was significantly lower than expected by the data collected before activation [Just after: $t(160) = 2.74$, $p < .01$; More than a year after: $t(160) = 5.13$, $p < .001$]. More than a year after the warning system had been activated the test drivers also thought that their travel time in urban environments had increased less than expected by the data collected before activation [More than a year after: $t(160) = 2.03$, $p < .05$]. On the other hand, they thought that their feeling of irritation in traffic had increased more than expected by the data collected before activation [More than a year after:

$t(160) = -2.74, p < .01$]. The test drivers' lowest expectation, before activation of the device, concerned the feeling of being stressed. The test drivers did not think that activation of the warning system would make them either less or more stressed in traffic. This was confirmed after activation where no significant differences concerning level of stress were recorded.

Table 15. The test drivers' opinion of how the ISA speed-warning device affects their driving experience. (N = 161)

Driving experience 1 = decrease a lot 5 = increase a lot	Before Activation		After Activation		2001	
	M	SD	M	SD	M	SD
Feeling controlled	3.58	0.54	3.42**	0.61	3.29***	0.59
Safety in traffic	3.41	0.59	3.37	0.68	3.42	0.64
Attention of pedestrians	3.24	0.46	3.22	0.52	3.15	0.46
Travel time in urban areas	3.22	0.50	3.18	0.44	3.12*	0.47
Irritation in traffic	3.05	0.58	3.11	0.71	3.22**	0.66
Stress in traffic	3.04	0.54	3.00	0.68	3.08	0.67

Compared to before activation: *** significant on .1% level, ** significant on 1% level

Table 16 shows the effect the ISA speed-warning device had on the test drivers' driving in general after extended use of the device. The largest effects were found for the feeling of being in the way for others and the amount of time spent looking at the speedometer which the test drivers experienced had increased after activation of the warning system. After the test drivers had driven with the device installed for more than a year there was a significant decrease, compared with the period before activation, in how much time the test drivers felt they needed to spend looking at the speedometer [$t(160) = 3.42, p < .01$]. After having driven with the device for more than a year the test drivers also experienced a significant increase in how much better they were as drivers compared to what they had felt during the period just after activation [$t(160) = -2.64, p < .01$].

Table 16. The test drivers' opinion of how the ISA speed-warning device affects their driving. (N = 161)

Affect on driving 1 = much less, 5 = much more	After Activation		2001	
	M	SD	M	SD
Feeling of being in the way	3.79	0.73	3.89	0.72
Looking at the speedometer	3.53	1.11	3.26***	1.13
Need for paying attention	3.34	0.79	3.29	0.88
Feeling of frustration	3.25	0.76	3.32	0.80
Feeling of time pressure	3.20	0.62	3.16	0.64
Need for effort	3.17	0.64	3.08	0.72
Need for accelerating/braking	3.12	0.83	2.99	0.91
Being a better driver	3.40	0.62	3.54**	0.68

1 = much worse, 5 = much better
Compared to before activation: *** significant on .1% level, ** significant on 1% level

A principal component factor analysis with varimax rotation was used to evaluate the ISA speed-warning device on an acceptance-scale. Two factors were extracted using the Kaiser criterion of eigenvalue over 1.0 and the Catell scree plot test. The first factor explained 34.2% of the variance while the second explained 32.7% of variance. In accordance with Van der Laan, Heino and De Waard (1997) the first factor was named usefulness and as table 17 shows it includes items concerning clearness, informativeness, effectiveness and importance. The second factor was named satisfying and includes items concerning agreeability, niceness, calmness and pleasantness. The item good/bad loaded more or less equal on the two factors. For clarity all factor loadings smaller than .30 have been excluded from the table. In general, the items included in the usefulness factor scored higher (were more positively received) than the items included in the satisfying factor.

Table 17. The test drivers' opinion of the ISA speed-warning device more than a year after activation.

I think the ISA speed-warning device is: 1-7	M	SD	Factor 1 Usefulness	Factor 2 Satisfying	N
Unclear - Clear	6.11	1.19	.819		158
Confusing - Informative	5.98	1.46	.800		159
Ineffective - Effective	5.84	1.40	.778	.341	159
Unimportant - Important	5.80	1.41	.771	.359	158
Bad - Good	6.03	1.20	.574	.432	160
Disagreeable - Agreeable	4.51	1.47		.864	158
Ugly - Nice	4.61	1.45		.559	159
Irritating - Calming	4.27	1.61		.857	158
Unpleasant - Pleasant	4.61	1.45		.823	157

The test drivers were also asked what they thought of the ISA speed-warning device as a measure to make drivers keep to the speed limit (1 = very bad, 3 = neither good or bad, 5 = very good). Before the device was activated the test drivers thought the device would be a good measure for both urban [M = 4.34, SD = .79, N = 161) and rural (M = 4.03, SD = .99, N = 161) environments. After activation they still thought that the device was a good measure to make drivers keep to the speed limit but after using the device for more than a year their evaluation of it had decreased for both urban and rural environments, even though this decrease was only significant for urban environments [After more than a year: *urban* M = 4.19, SD = .88, $t(160) = 2.18$, $p < .05$; *rural* M = 3.90, SD = 1.06, N = 161].

Finally the test drivers were asked when and for whom the device was desirable. The result showed that the test drivers thought that the device was more desirable in certain situations and for certain groups of drivers rather than for the whole driving population in general. The test drivers thought it was desirable to have an ISA speed-warning device installed on roads with a low speed limit (30 km/h and 50 km/h). A reason for this might be that roads

with low speed limits are also used by vulnerable road users which means that even rather limited speeding can have disastrous consequences. If a pedestrian is hit by a car driving in 30 km/h the chance of survival is 90% but if the speed is 50 km/h the chance of survival has decreased to 15-60% (Englund et al. 1998). The test drivers also thought that it was more desirable to have a device installed while driving in busy traffic which can be explained by the fact that the risk for an accident to happen at all, is higher in busy traffic than on a calm road with little traffic. Regarding for whom the test drivers thought it was desirable to have an ISA speed-warning device installed, they thought it was more desirable to have a device installed for drivers who repeatedly had been convicted for speeding and for drivers that were inexperienced. For elderly drivers and for commercial or private drivers in general the test drivers thought it was less desirable to have a device installed. This is in accordance with the risk of accident involvement where young inexperienced drivers are more likely to be involved in a traffic accident than older and more experienced drivers.

On the whole drivers seem to be able to predict the effect the ISA speed-warning device later has on their driving (after the warning system is activated) and therefore the use of the device does not largely affect their attitude towards the system. But even if drivers' attitudes in general are stable over time there are a few exceptions for which the use of the device affects the drivers' view of the system. In some cases the personal experience of the device makes drivers more positive towards the system, while in other cases the personal experience make them more negative towards the system. The results also show that drivers like the idea with the ISA speed-warning device and can see its usefulness, at the same time as they are not totally satisfied with the experience of the device. Drivers also think that the device is more desirable in certain situations and for certain groups of drivers, rather than for the whole driving population in general.

General Discussion

Every year many people all over the world are killed and severely injured in road traffic accidents (Peden et al. 2004). Even though it is well known that driving too fast is a behaviour that contributes to both the number and the outcome of these accidents, drivers are still speeding (Swedish Road Administration, n.d. b). The general aim of this thesis was therefore to further the knowledge about drivers speeding behaviour by using the theory of planned behaviour and the model underpinning the driver behaviour questionnaire as frames of reference. The behavioural data used was obtained from field trials with intelligent speed adaptation and the speed reducing potential of this system was also examined. In order to achieve this, five empirical studies were conducted.

Even though the theory of planned behaviour has previously been used to predict and explain drivers' speeding behaviour all research has been based on the drivers' self-reported behaviour (Elliott et al. 2003; Letirand & Delhomme, 2005) or measurements of speed under restricted conditions (Åberg et al. 1997; Parker, 1997; Vogel, 1984). According to Haglund and Åberg (2000) the relationship between self-reported speed and actual speed is strong ($r = .58$; $r^2 = .34$). Even if this is so, the use of self-reported speed, as well as momentary or restricted measurements of speed, still poses a threat to a study's validity because the decision making process in keeping to speed limits is an ongoing process. After the driver decides on a target behaviour (e.g. to aim at keeping the speed limit) the speed of the vehicle has to be continuously monitored and correctional actions have to be made if the speed deviates from the target speed. This means that a momentary or restricted measurement of speed is much less reliable than that of, for example, seat belt use (where the driver only decides once each trip whether or not to use the seat belt). The first study in this thesis did, however, demonstrate that the theory of planned behaviour can be used as a frame of reference to predict drivers' self-reported speeding, as well as their logged speeding, even when the behaviour is measured during several weeks, for different times of the day and on different types of roads. Attitude towards exceeding the speed limits, subjective norm, and perceived behavioural control were significant determinants of self-reported speeding. Self-reported speeding and subjective norm, but not perceived behavioural control, did then contribute to the prediction of drivers' logged speeding. The fact that the theory of planned behaviour can be successfully used to predict drivers' everyday speeding

behaviour suggests that exceeding the speed limits is a conscious decision, except in those cases where the drivers do not have full control over their speed choice.

To understand why drivers choose to exceed speed limits it is, however, not enough to be able to predict their speeding behaviour. In addition, we also need to find out which are the beliefs affecting this choice. The second study therefore used belief based measures, as suggested by the theory of planned behaviour, in order to examine these beliefs.

In a pilot study, conducted as part of the second main study in the current thesis, an extensive set of beliefs about exceeding the speed limits were identified. In the main study belief composites shown to contribute to the prediction of drivers' attitude, subjective norm and perceived behavioural control, as well as to their intention to exceed the speed limits, were identified. From the theory of planned behaviour it follows that changes in drivers behavioural, normative and control beliefs should result in corresponding changes in their intention, as well as in their actual behaviour. Interventions aiming to change drivers' speeding behaviour should, therefore, be based on these three sets of belief composites in order to be effective.

Unfortunately, interventions based on the theory of planned behaviour have in the past had mixed success. A video-based intervention included four short experimental videos, of which three were designed to address drivers' behavioural, normative and control beliefs, respectively (Parker et al. 1996). In total, between 41 and 50 drivers saw each video. The results showed that only the video addressing normative beliefs brought about changes in the desired direction while changes in the "wrong" direction were found for control beliefs. No changes were found for behavioural beliefs or intention. Another intervention, aiming to reduce speeding, was the Scottish Road Safety Campaign (Stead et al. 2005). During a three-year period three adverts, designed to address drivers' behavioural, normative and control beliefs respectively, were produced and shown on television. The results showed that only the advert addressing attitude brought about changes in the desired direction while no changes were found for subjective norm, perceived behavioural control, intention or self-reported speeding. Both these interventions did however have some limitations. The video-based intervention, for example, was conducted in an experimental setting that only allowed the participant to view the videos once, while the Scottish Road Safety Campaign, due to time constraints, was not based on belief composites produced by the target population. Another kind of intervention that has recently increased in popularity is Speed Awareness Courses. These courses are educational alternatives to traditional punishment, such as penalty points on the driving licence. The aim of these courses is to change drivers' intention to exceed the speed limits by explaining the significance of high speeds and speed choice (<http://www.perceptionandperformance.com>).

The task of changing drivers' intention and speeding behaviour will, however, not be an easy one to complete. The second study also showed that drivers' speeding behaviour is closely related to their life-style and the society as a whole. On a general level, being in a hurry, closely connected with the behavioural belief that exceeding the speed limits makes one arrive quicker, largely contribute to drivers exceeding the speed limits in both urban and rural environments, which is also in accordance with previous research (Elliott et al. 2005). This suggests that in terms of changing drivers' speeding behaviour we might also have to change their whole lifestyle, which is supported by a comment from one of the participants in the second study who wrote: *"Because I am retired I never need to be in a hurry, and therefore I follow the traffic rules"*. Unfortunately, changing drivers' life-style and the society as a whole, is a scope much larger than that which could be handled just within traffic psychology.

The results from studies like this second one can, however, also be used as guidelines when implementing new traffic safety measures. Drivers see some safety measures, such as good roads, central median barriers and wild-life fences, as measures that make it easier for them to exceed the speed limits while enforcement such as police surveillance and speed cameras as well as physical measures such as speed humps, narrowing of roads and roundabouts makes it harder for them to exceed the speed limits. On a more specific level, one of the belief composites that most clearly differs between those who intend to exceed the speed limits and those who do not is "You passing a speed sign". This means that drivers who intend to exceed the speed limits notice fewer speed signs and/or more easily disregard the ones they do notice, compared with drivers who do not intend to exceed the speed limits. This suggests that intelligent speed adaptation might be one effective way to reduce speeding. It is, however, essential that any in-vehicle measure aiming to reduce speeding has a very high penetration rate as the behavioural belief composite that scored highest, in both urban and rural environments, was that exceeding the speed limits "Makes me follow the traffic rhythm better". One kind of device for intelligent speed adaptation will be further discussed below.

As suggested above, exceeding the speed limits might not always be a deliberate violation but may instead be the result of an unintended error due to the driver, for example, failing to notice a speed limit sign as a result of inattention. Therefore the focus of the third study was to combine the theory of planned behaviour with the model underpinning the driver behaviour questionnaire.

The third study in this thesis demonstrates that the theory of planned behaviour and the model underpinning the driver behaviour questionnaire are equally effective in explaining drivers' speeding behaviour. The result is interesting because the items based on the theory of planned behaviour are constructed to specifically explain drivers' speeding behaviour whilst the

driver behaviour questionnaire measures aberrant driving behaviour in general. However, a close inspection of the violation items in the driver behaviour questionnaire reveal that these, to a large extent, concern fast driving. This suggests that drivers are aware of their speeding behaviour and also that they knowingly violate the law. The result of the study is also in agreement with the theory of planned behaviour specifications, as Ajzen (1991) stated that behaviour measures should be compatible with the variables, which means that an index of speeding that covers different roads and speed limits demands predictor variables that cover the same kind of activities in traffic. A combination of the theory of planned behaviour and the model underpinning the driver behaviour questionnaire resulted in a new model with improved predictive power and the potential to increase our understanding of drivers' speeding behaviour.

In this third study the theory of planned behaviour was extended with moral norm, which turned out to be a powerful predictor of self-reported and logged speeding but also, at least to some extent, a mediator of other variables in the theory of planned behaviour. About half of the variance in moral norm could be explained by attitude towards exceeding the speed limits, subjective norm and perceived behavioural control. The results from the third study indicate that it might be possible to affect drivers' speeding behaviour through changes in attitude towards exceeding the speed limits, subjective norm and moral norm and that some drivers perceive difficulties in keeping the speed limit, not primarily because they lack information about the current speed limit or their own speed, but rather because of pressure from other drivers. One way to affect drivers' actual and perceived control is by using different systems for intelligent speed adaptation. Therefore the focus of the fourth study was to examine drivers' speeding behaviour after long-term use of an ISA speed-warning device. As a continuation of the theoretical framework underpinning the first three studies this study also tried to explain what caused possible behavioural changes by examining the variables in the theory of planned behaviour.

The fourth study in the current thesis shows that, initially, the ISA speed-warning device greatly reduces the amount of time the drivers spend above the speed limit, and to some extent also reduces their mean speeds, but this effect decreases with time. One explanation for the decreased effect of the ISA speed-warning device with time may be found within classical conditioning where the concept of habituation has been acknowledged for many years. According to classical conditioning habituation is a decline in the tendency to respond to stimuli that have become familiar due to repeated exposure. The adaptive benefits with habituation are to allow us to ignore the familiar and to focus on things that are new and may signal danger. In this study the flashing red light and sound signals were meant as warning signals, but in reality nothing much happened (except for the flashing red light and sound signals continuing) if the drivers did not respond to the signals by

decreasing their speeds. Therefore, with time, drivers are likely to have been habituated to the signals, making it easier to ignore them and to continue driving without decreasing their speeds.

Another reason for the drivers' tendency to ignore the warning signals can be that some technical problems occurred during the study. Even though the digital map was thoroughly tested in the field, before it was distributed to the drivers, it still contained several errors regarding speed limits. As the drivers experienced some of these errors they might have actively learnt to ignore the warning signals. Besides making future ISA-systems as reliable as possible, drivers' tendency to ignore the warning signals of the ISA speed-warning device must be counteracted. This can, for example, be done by increasing the drivers' motivation to adapt their driving behaviour according to the information given by the device or by changing the design of the device.

To increase the drivers' motivation to adapt their driving behaviour, according to the information given, economic incentives can be used. Ninety-five drivers in Borlänge participated during the spring of 2002 in a project aimed to study the effect of economic incentives (Hultkrantz & Lindberg, 2003). Half of the drivers received a bonus of 200 SEK (\approx 20 EUR) while the other half received a bonus of 500 SEK (\approx 50 EUR). Their speeding behaviours were then registered and for every minute they spent speeding a certain amount, ranging from 0 to 2 SEK (\approx 0.2 EUR), were taken from their bonuses. The results showed that even these relatively small incentives resulted in reduced amount of time spent speeding. In the future it may be possible to combine the use of an ISA-system with a reduction of, for example, the car insurance premium.

When looking at the effect of the ISA speed-warning device it is important to remember that the device tested is a first generation voluntary system. Another type of system that has previously been tested is the intervening one where the vehicles' speed is limited to the current speed limit, and not overrideable by the drivers (Comte, 2000; Päätaalo et al. 2001; Persson et al. 1993; Van Loon & Duynstee, n.d.; Várhelyi & Mäkinen, 2001). These systems have proven to be very effective in keeping the speeds down, but the acceptance of the systems is lower than for other types of ISA-systems (Päätaalo et al. 2001).

The fourth study also shows that the activation of the warning system affects different drivers in different ways, with regards to attitude towards exceeding the speed limits, subjective norm and, especially, perceived behavioural control. After activation, long-term use does, however, affect the drivers in a more homogenous way. Before large-scale implementation of any ISA-system it is important that we continue to examine these personal differences to make sure that drivers' who are in greatest need of intelligent speed adaptation (e.g. the drivers' speeding the most today) are also affected by the systems. A possible solution might therefore be to combine different

types of systems depending on where the vehicle is (e.g. urban or rural areas) and who is driving (e.g. slow or fast driver).

The fifth and last study in the current thesis shows that drivers, before activation of the ISA speed-warning device, seem to be able to predict the effect the device will have on their driving after activation. The use of the device does, therefore, not largely affect their attitude towards the system. But even if the drivers' attitudes in general are stable over time there are a few exceptions for which the use of the device affects the drivers' view of the system. In some cases the personal experience of the device makes the drivers more positive towards the system, while in other cases the personal experience makes them more negative towards the system. The results also show that the drivers like the idea with the ISA speed-warning device and can see its usefulness, at the same time as they are not totally satisfied with the experience of the device. Finally, the drivers think that the ISA speed-warning device is more desirable in certain situations and for certain groups of drivers, rather than for the whole driving population in general.

The results presented in the current thesis have shown that attitude towards exceeding the speed limits, subjective norm, perceived behavioural control and moral norm from the theory of planned behaviour, but also violations and inattention errors from the model underpinning the driver behaviour questionnaire, can be used to predict drivers' everyday speeding behaviour even when the behaviour is measured during several weeks, for different times of the day and on different types of roads. The results also show that it is possible to combine these two models in order to gain further knowledge about the causes of speeding. In addition, identification of drivers' beliefs about exceeding the speed limits gives further insight into the underlying cognitive foundation of their attitude, subjective norm and perceived behavioural control. According to Ajzen (2006) this information can prove very valuable in designing effective speed reducing measures. Past interventions based on the theory of planned behaviour have, however, had mixed success with changing drivers' intention and actual behaviour but as all of them have had some limitations I still believe that further research in this area has the potential to succeed. Another way to change drivers' speeding behaviour is to use intelligent speed adaptation. The results from the current thesis show that initially, the ISA speed-warning device greatly reduces the amount of time the drivers spend above the speed limits, and to some extent also reduces their mean speeds, but this effect decreases with time. Although the drivers are not totally satisfied with the experience of the ISA speed-warning device, they like the idea and can see its usefulness. As the device tested is a first generation ISA speed-warning device further research has the potential to greatly improve the system and make the speed reducing effects more stable during long-term use.

As mentioned in the beginning of the current thesis the global trend for road safety is very depressing with the annual number of road traffic deaths

being projected to increase by 83% in low- and middle-income countries (that already shoulder 90% of the global road traffic death toll) between 2000 and 2020. If these predictions turn out to be correct, road traffic injuries will step up from being the ninth, to being the third leading contributor to the global burden of disease and injury while, in comparison, coronary heart disease and clinical depression will be the two major contributors with war and HIV/AIDS on eight and tenth place, respectively. One way to effect this trend would be by changing drivers' behaviour - a task where traffic psychologists all over the world should have a given role.

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