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Risk control is not risk adjustment: the zero-risk theory of driver behaviour and its implications

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The zero-risk theory, originally presented by Näätänen and Summala (1974, 1976 a), posits that due to human perceptual, cognitive, and motivational processes, drivers adapt to risks on the road, whilst being motivated towards faster speeds and objectively more risky behaviour. In decision-theoretic terms, both the subjective probability distribution of the outcomes of drivers' behaviour and their speed–utility function are severely distorted. Drivers are not, however, adjusting risk. With experience, driving simply becomes a habitual, largely automatized activity in which risk control is based on maintaining safety margins. Because of this adaptation to risk and the motives involved, drivers are not able to take traffic risks into account to a degree that would be rational from their own point of view and that of society. The main implication of the theory is that we have to prevent this tendency for drivers to be motivated towards higher speeds and thus to adapt to greater risk in the traffic system. The primary means of doing so are restrictive. Speed limits are therefore a necessary condition of effective traffic-safety work.

1. Introduction

A Finnish driver incurs a fatal accident, on average, once in 40 million km, which means about once in 1600 years. For one trip the average chances of being killed are less than one in a million. Using another index, however, almost certain death lurks quite close every day: for example, at a distance of about 2 to 3 m when one meets an oncoming car on a two-lane road. Which of the two indices has the greater effect on driver behaviour?

It is worth noting that the concept of subjective risk of accident still appears to be quite attractive when considering how drivers control risks on the road. Some theorists even seem to believe that, when controlling (objective) risks, drivers are continuously adjusting some (subjective) risk measure. The concept of subjective risk also has an important role in the zero-risk theory presented by Näätänen and Summala (1974, 1976 a). However, this theory posits that the main problem of traffic safety results from drivers adapting to risks on the road to the extent of experiencing no risk at all. This paper therefore first reviews some basic ideas of the zero-risk theory, with some historical background (from Summala 1985 a) and, second, presents the major implications of the theory which continue to be of primary importance for effective traffic-safety work.

2. Skill model vs. motivational model

In a historical perspective, during the first decades of motorization it was quite natural to consider driving as a perceptual-motor skill and accidents as failures of this skill. This skill model implied that the safety of a driver is mainly determined by the level of his skills in relation to the situational demands on them. Accordingly, the general strategy for traffic-safety work was to increase drivers' skills and decrease environmental demands.

The skill model was supported by early accident-proneness theories suggesting that some people are less skillful drivers and, therefore, more prone to accidents. Because certain individuals are more clumsy than others at table, or when climbing stairs, or when running, why not when driving a car? These kinds of 'scape-goat' theories are generally easily accepted and they also provide a basis for claiming freedom of individual action in traffic: as we are skillful drivers, not having been involved in accidents, we must have full freedom on the road. Accordingly, we need neither speed limits nor seat-belts. Only those less skillful and more accident-prone people should be screened out of traffic, or re-educated.

Forbes (1939) long ago questioned the adequacy of the accident-proneness model in traffic, in his paper entitled 'The normal automobile driver as a traffic problem' and, since the early 1950s, there has been much criticism and a change in emphasis from the differential to general psychological aspects of accident involvement (for a review, see Haight 1964). Although there are certainly differences between people in driving, as in other human activities, their differences in traffic behaviour are not sufficiently reliable and large to make screening among ordinary drivers a practical contribution to road safety. This does not mean that we should ignore the problem of deviant or risky driving. To some extent we are able to identify high-risk individuals by observing their driving behaviour before accident involvement has changed their driving habits (Evans and Wasielewski 1982, Wasielewski 1984, Summala *et al.* 1986). Second, the concepts of skill and accident-proneness models still have strong influences on drivers' everyday experience of safety (Svenson 1981, Sivak and Soler 1987), and they are also highly influential in both individual and societal decision making.

In another early, very important development in the field of traffic safety, Gibson and Crooks (1938) introduced the idea of driver reaction to environmental changes. Smeed (1949) reported the existence of 'a body of opinion that holds that the provision of better roads, for example, or an increase in sight lines, merely enables the motorist to drive faster and the result is the same number of accidents as previously'. He continued that 'there will nearly always be a tendency of this sort, but I see no reason why this regressive tendency should always result in exactly the same number of accidents as would have occurred in the absence of active measures for accident reduction'.

It was only in the 1960s and 1970s that the view of driving as a *self-paced task*, in which the driver himself is able to adjust its difficulty, started to gain in popularity. Taylor (1964) suggested that the demands of driving are governed by the level of emotional tension or anxiety which the driver wishes to tolerate and that he adjusts his level of risk taking so as to keep his emotional responses at a constant level. Cownie and Calderwood (1966) formulated the so called 'compensation principle', by arguing that accidents are products of a basically simple closed-loop model of the accident process: the favourable effects of a safety measure being counterbalanced when the 'warning' feedback is eliminated from the system. They suggested (p. 260) that 'what has been called the "black spot" approach to accident control may be no more than a method of spreading accidents more uniformly in the system. The object of attack should not be the material causes of accidents but the balance between the motivating and inhibitory forces of positive and negative motivating events'.

Näätänen and Summala (1974) concluded that more emphasis should be placed on 'what the driver actually does in any given traffic situation, rather than on his driving skill and/or the traffic conditions as such'. If we provide drivers with better roads and vehicles, how do they change their behaviour? Recently Evans (1985 a, b) extensively described such human behavioural adaptations to changes in the traffic system in terms of a compensatory closed-loop process. But is there a psychologically sound explanation for this type of reaction? And could we develop a general theory of driver behaviour which would provide a better basis for efficient traffic safety work?

In their motivational model, or as they later entitled it, the 'zero-risk model' Näätänen and Summala (1974, 1976 a) focussed on motivating (excitatory) and warning (inhibitory) processes in the determination of driver behaviour. The two most important starting points in the zero-risk theory are, (1) the motivational basis of driver behaviour and, (2) adaptation to perceived risks on the road.

3. Motivational tendencies: towards higher speed

The very basis of human behaviour in traffic, as anywhere else, is motivational. Therefore driver behaviour may be viewed as the satisfying of motives for using the traffic system. Mobility provided by the car is the primary motive for using the traffic system; however, easy (and safe) transport from one place to another is not the only motive. First of all, *speed* provides outlets for a multitude of different driver motives. Speed, as such, is motivating and higher speeds mean shorter travel times (although these time savings tend to be overestimated; see Svenson 1973).

Second, drivers adapt to speed and they show a clear *reluctance to reduce speed* from their actual (or desired) level. This has been demonstrated in a variety of traffic situations (Summala 1980 a, Summala *et al.* 1981, Summala and Hietamäki 1984). A common example is provided by the driver who overtakes another car just before turning off the road. Effort, or *conservation of effort*, is another basic motive in driving, which is closely connected both to this reluctance to slow down and to the *habitual nature of driving* (Näätänen and Summala 1976 b).

Speed also provides an outlet for many other '*extra motives*' (Näätänen and Summala 1976 a). If a driver becomes irritated by delay caused by another driver, he (or more seldom she) typically takes the first opportunity to overtake that driver and continue at a higher speed. If a youngster wishes to demonstrate his skill to his peers or his girl friend, high-speed driving is an easier way of making an impression than via academic or athletic prowess.

In conclusion, the different kinds of utilities associated with high speed, plus the extra motives, all tend to push drivers towards faster driving and higher (objective) risks. In terms of decision-theoretic concepts, the driver's speed–utility function (rather than his time–utility function; cf. Janssen and Tenkink 1986) is severely distorted due to these different motivational, as well as perceptual and cognitive, effects.

4. Drivers' hazard perception: adaptation to risk

Vehicles weighing 1000 kg or more are obviously dangerous when moving at speeds of 20–30 m/s, but people show surprisingly few signs of fear when passing them at quite small distances, or even when meeting them at high closing speeds on narrow roads. While driving, we do not really worry about such risks; in fact, we usually do not even think about them.

First, therefore, we need to clarify the concept of 'subjective risk' which has evoked much confusion in the traffic psychology literature. The concept of objective risk will not be dealt with here. For a recent discussion see, e.g. Haight (1986). It is, however, necessary to distinguish between the notions of subjective or estimated risk typically used in the decision research literature (even the concept 'perceived risk' is sometimes used as a synonym; e.g. Slovic *et al.* 1980) and emotional, immediate, 'ostensive'* risk, which is often simply a feeling of fear or uncertainty (Summala 1986). The concept of subjective risk should, in fact, be reserved for 'arm-chair estimates' (cf. McKenna 1982) of the risks of, say, different societal activities or of traffic scenes shown to subjects for research purposes. This is the main accepted and well-established use of the term and one component of *optimizing rational decision making models*, such as the Subjective Expected Utility model.

On the other hand, Näätänen and Summala (1974, 1976 a) introduced the concept of a Subjective Risk Monitor which 'becomes activated and generates different degrees of subjective risk or fear depending on the amount and nature of the risk experienced in the present or expected traffic situation'. And they continued: 'In most cases, we could also use the word "frightening" instead of subjective-risk experience' (p. 188). This risk or fear experience is an immediate reaction to a threatening stimulus, and it involves the basic bodily mechanism (of the sympathetic nervous system) to prepare the organism to meet emergencies; it is also observable in the activity of the autonomous nervous system (see e.g. Grings and Dawson 1978).

In traffic, this response is exemplified most commonly by fear resulting from the perception or expectation of loss of control of one's car, or of being on a collision course (Näätänen and Summala 1976 a, Taylor 1976). The critical point is that the driver normally tends both to escape and to avoid such experiences. Thus, in addition to the immediate inhibitory response (typically slowing down), these experiences also provide the primary aversive event in avoidance learning necessary for the control of risks on the road.

However, this emotional response may also be due to uncertainty, e.g. a feeling that the car and the traffic situation are not fully under control. It has effects on speed when driving in poor conditions, or when driving an unfamiliar car (see below).

This experience of risk is understood to function mainly on an all-or-none basis, although we are certainly able to rank different degrees of fear. What is important, however, is the *satisfying nature of decision making* (Simon 1955) when an emotional risk experience is considered: drivers typically tend to avoid such behavioural alternatives which elicit, or are expected to elicit, fear. Of course some slight uncertainty and fear may be tolerated when under motivational pressure and some, especially young people, may even seek risk (or 'target' it; see Summala 1986) because of the excitement it evokes. But it is inconceivable that drivers would continually operate under such emotional stress (Brown 1980).

How do drivers adapt to risk? Most novice drivers initially feel a sense of uncertainty or fear in many traffic situations, but extensive extinction occurs with increased experience (see Näätänen and Summala 1976 a, p. 76). Beginners acquire

* The term 'ostensive' was adapted from Carnap (1937) whose 'ostensive definition' implies that the object described by a term must have a certain relation (for instance, likeness or congruence) to a specific indicated object. For example, the colour 'pink' is 'ostensively' defined by pointing to a pink wall, or a physical segment is said to have the length of 1 m when it is congruent with the segment between two marks on the standard metre measure in Paris.

greater control and fluency of driving as their skills become increasingly automatized. Thus adaptation to risk is largely a function of increasing self-confidence.

Here we should briefly consider the cognitive basis of advanced skilled behaviour such as driving a car (Summala 1985 a). The basis for any success in driving must be an internal representation of the traffic system and concurrent automatization of the subtasks of driving. Representation of the system can be understood to consist of hierarchically organized programmes or internal models which interactively govern both perceptual and motor behaviour (Kelley 1968, Conant and Ashby 1970, Neisser 1976, Schneider and Schiffrin 1977). In the case of driver behaviour, it is usual to differentiate, from bottom to top, the control (handling, operational), manoeuvering (tactical, guidance), and planning (strategic, navigational) levels (e.g. see Michon 1979, Johannsen and Rouse 1979).

A beginner, when first seated behind the wheel, starts to learn the use of the controls. The complex co-ordination of hands and legs first requires his complete attention and conscious control but, gradually, programmes or internal models develop which automatically, without need for conscious control, take care of vehicle handling most of the time. In traffic, a driver further learns how to guide his vehicle along his desired path, how to adjust his speed, and how to maintain his lateral position on the road. At the same time, the driver achieves a feeling of control over his car and surrounding traffic. His perceptual and motor programmes controlling various aspects of driving gradually become more automatized and predictions get better and better. His feeling of uncertainty diminishes as his confidence in his control skills increases. But when starting to drive an unfamiliar car, even the experienced driver has to update his automatized control models. At first, he may either tolerate slight subjective uncertainty, or slow down from his normal speed. During this updating phase, conscious control is also called upon more often. Only when his internal models have sufficiently adapted to the controls and dynamics of the new car and his predictions been sufficiently confirmed by perception, does the driver feel that he has regained full control of the task and his sense of uncertainty disappears.

With increasing experience, the driver learns, just as he has learned physical laws, the behaviour of other cars and pedestrians. Just as he has learned to predict ballistic trajectories, he learns to predict the behaviour of other road users (and of the behaviour of his own vehicle, of course). With experience, he thus acquires internal representations of the traffic system and internal models or expectancies in specific situations. As pointed out by Näätänen and Summala (1976 a), these expectancies are more perception-like and more deterministic than the reality is: they have often largely lost the stochastic aspect of the traffic system.

This is proposed as one basic mechanism which results in: (a) human inability to take into account small stochastic risks within the traffic system and (b) extinguishing of the original and very basic fear responses to a variety of traffic situations. (For other factors see Näätänen and Summala 1976 a.)

In terms of decision-theoretic concepts, we can therefore conclude that the probability distribution of possible outcomes in driver decision making is severely distorted: the driver learns to discard small stochastic risks.

5. Controlling risks: safety margins

If risk is not normally experienced, how then do drivers control risks? Does risk have any important role to play if, as pointed out by McKenna (1982) and Fuller (1984), drivers seldom experience it?

Näätänen and Summala (1976 a) proposed the driver's *safety margin* as a critical measure to be controlled. Instead of regulating some risk measure as proposed by Taylor (1964) and Wilde (1982), drivers are said to be controlling and maintaining safety margins around themselves, as do humans in any potentially hazardous situation. This concept of a safety margin has a deep-rooted evolutionary and individual history. For example, anthropologists have long discussed distance regulation among animals and men in terms of 'critical space' and 'critical situation' (Hall 1966). A perceived or anticipated threat to this critical space triggers the 'fight or flight' response (the preparation for which can be observed in the autonomous nervous system).

The concept of a safety margin in traffic safety research could be simply defined in terms of the spatial or temporal distance of the agent from the hazard. (It is to be noted that this definition differs somewhat from those which regard a safety margin as work done surplus to requirements, or the existence of a carrying capacity greater than the maximum expected load; see e.g. Katz 1951). In experimental field research, we have operationalized safety margin in terms of space, time or related measures. Quite simple safety margins are exemplified by longitudinal time or space distances in car following; or by lateral separation when passing or meeting a cyclist; or by the distance between the critical and the real lateral acceleration, friction or speed when negotiating curves.

For a researcher, the distribution of lateral safety margins, say, between a cyclist and passing cars, provides a probability distribution which may even make it possible to compute the probability of a 'hit' (see Summala 1985 a). However, for the driver approaching a cyclist from behind, the question is simply whether there is a space enough to pass the cyclist or not. Such a threshold measure was also proposed by Godthelp (1986) in modelling driver steering (path-following) behaviour. He pointed out that steering should not be conceived simply as a permanent closed-loop error-correction task; it also incorporates a component which neglects path-error. Steering strategy seems to include a threshold of time-to-line-crossing for switching from error-neglecting to error-correcting behaviour.

Time-to-collision (Lee 1976) is another measure of safety margins, which obviously is based on quite simple heuristics that drivers use in controlling traffic risks. For an adequate explanation of these mechanisms, typically including a safety-margin measure with some simple heuristics or underlying controlled variable, we should analyse different subtasks in driving, such as lane keeping, car following, curve negotiation, crossing, gap acceptance, overtaking and so on. The critical point is that in any rapid dynamic decision making we necessarily have recourse to simple heuristics (Brehmer and Allard 1986).

How then do drivers learn to identify risks? Näätänen and Summala (1976 a, p. 190) listed two main types of effects of the activation of the driver's 'Subjective Risk Monitor': (1) effects on ongoing decision making and behaviour; and (2) effects on future decision making and behaviour (which latter effects might mainly involve situations similar to those in which the subjective risk was first experienced). The first category covers an immediate inhibitory (escaping) function which typically results in slowing down (except when in a hurry or under some other powerful motivational pressure). The second refers to the avoidance learning process in which the experience of risk or fear is the primary aversive stimulus: the driver learns what cues anticipate this experience which, of course, is closely related to actual objective hazards. Fuller (1984, 1986) has recently provided a well-developed formulation of this avoidance-learning and avoidance-conditioning paradigm in driving.

Automatization of the driving task and avoidance learning make it possible that most of driving eventually becomes a habitual activity based largely on automatized control of safety margins in partial tasks. No consideration is normally given to risks. However, in most situations, drivers obviously know exactly what they should not do if they want to avoid a certain, or an almost certain, accident. And, whenever necessary, they can focus their conscious attention on estimates as to whether, say, a gap is sufficiently wide to permit merging, or a following distance is sufficient, or the outer lane is free for safe overtaking. Similarly, they can switch to conscious, controlled information processing at any other level of the driving task.

6. Overview of the zero-risk theory

Figure 1 shows the main points of the zero-risk theory. In general, it describes any situation where a driver (or an agent in another hazardous activity) is maintaining a certain safety margin. A specific interpretation is provided, for example, by curve negotiation where 'environmental opportunities' for satisfying the driver's motives describe the distribution of the highest speed at which the curve can be rounded without loss of control.

The objective variance (the solid distributions) can be understood either as *intra*curvial due to friction (and visibility) or *inter*curvial due to curvature, lateral slope, friction etc. Similarly, the driver's behavioural variance (the solid distribution on the left) may be conceived either as *inter*individual or *intra*individual, either in the same curve or in different curves. (For experimental examples of the related cases, see e.g. Rumar *et al.* 1976, Summala and Merisalo, 1980).

The solid lines refer to the objective variance and the overlapping area indicates the probability of loss of control. (It should be noted that loss of control in a curve results in running off the road only stochastically: the driver may succeed in keeping the car on the road.) By contrast, the dotted lines refer to subjective distributions concerning variance in both the driver's own performance (including his car) and the environmental circumstances (including other cars). In some situations at least, subjective variance may even be conceived as zero, as indicated by the bars in the figure.

The figure thus illustrates the main points of the zero-risk theory:

(1) Drivers' subjective variance, both in their own performance and in their environmental conditions, is smaller than the objective variance. Extreme values, in particular, are apt to drop out from this subjective representation of the traffic system. There may even be no variance due to deterministic expectancies. Furthermore, subjective distributions tend to be shifted as a result of adaptational and motivational effects, producing subjective safety margins larger than the objective ones.

It should be noted that overlap of these subjective distributions is zero: i.e. drivers do not normally feel any risk. Due to the objective overlap which sometimes occurs in near misses or accidents, drivers learn via avoidance conditioning the cues and the limits within which to remain in order to avoid further aversive experiences. It is particularly important to note, from the safety point of view, that biased subjective distributions result, in decision-theoretical terms, in a distorted distribution of accident probabilities.

(2) Different kinds of motives typically push drivers towards higher speed and, if the traffic system provides (environmental) opportunities to satisfy these motives, drivers are inclined to use them. Therefore if a sharp curve is improved, allowing higher speeds, the driver behaviour takes up this opportunity and curve speeds tend to increase. (The limiting factor here is presumed to be centrifugal force, the

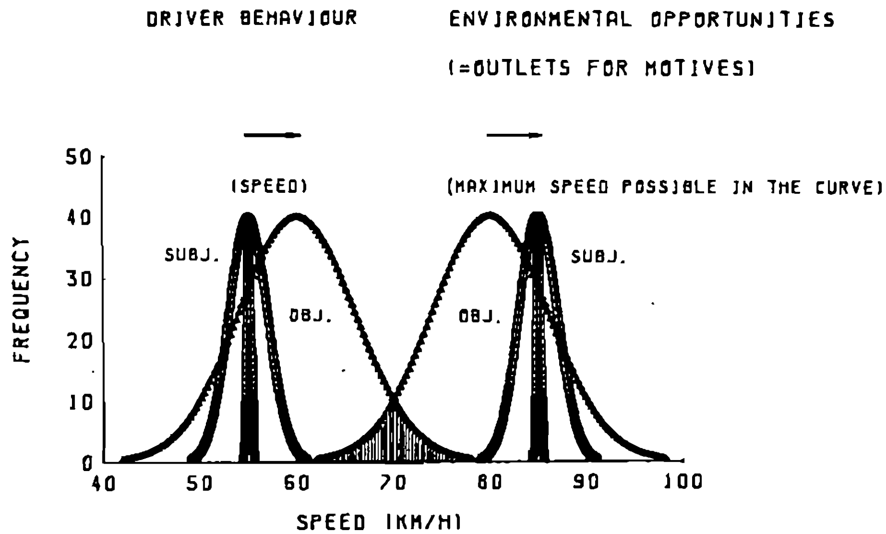

Figure 1. The zero-risk theory as illustrated in curve negotiation.

Drivers' risk control is based on maintaining safety margins, here exemplified by the difference between the highest speed possible in a curve (environmental opportunities) and the actual speed (driver behaviour). But if new environmental opportunities for motive satisfaction are provided, for example, by improving a winding road, driver behavioural manifestation follows, resulting in increased speeds. Furthermore, drivers' subjective variance in relation both to their own behaviour and their assessment of environmental opportunities is smaller than the objective variance; sometimes even zero (due to overdeterministic expectancies; see the vertical bars), and they experience no risk (no overlap in subjective distributions). In decision-theoretic terms, both the drivers' subjective probability distribution of the outcomes of their behaviour and their speed–utility function are distorted. This results in habitual driving with inadequate safety margins and, consequently, in actual accident risk (overlap in the objective distributions) which is larger than would be rational from the point of view of society and individual.

threshold for which is learned by avoidance conditioning.) Similarly, if drivers improve their skills in curve negotiation (vehicle control, curvature estimation, etc.), that is, subjective variance in performance diminishes, then the behaviour follows these new opportunities for motivational satisfaction.

This is the simple psychological mechanism for drivers' behavioural responses to environmental changes which is sometimes, erroneously, called 'risk compensation'. (It should be noted that it is *risk* compensation only from the point of view of the traffic researcher who considers probability distributions across drivers, or from a societal perspective). From the point of view of the individual driver, we need not presuppose any *risk* compensation, but merely this tendency for motivational satisfaction.

In conclusion, driving is a habitual, largely automatized activity in which drivers are not able to take into account the variance (especially small stochastic risks) in the traffic system and where they are apt to use any opportunities to satisfy their motives, which typically results in higher speeds. Additionally, drivers' speed–utility functions are distorted by perceptual, cognitive and motivational factors. This produces inadequate safety margins and, consequently, results in accidents provoked by very 'normal' behaviour. In decision-theoretic terms, we could say that drivers' subjective probability distributions and their speed–utility functions are both distorted, neither being compatible with rational individual and societal decision making.

7. Implications of the theory: restrictive measures

There are two main implications of the zero-risk theory for increasing traffic safety. First we should try to eliminate variance, especially deviating performance, from the system. This also means increasing predictability of events, which is very important in view of the habitual, even somewhat stereotypical nature of driver behaviour. A general implementation of this approach is provided by engineering means, such as limited-access roads, channelized level junctions, etc. However, as such measures also provide additional outlets for drivers' motivational tendencies, they are typically followed by a behavioural change. This change typically tends to decrease the effectiveness of the safety measure in question, compared to the expected benefit, but there is no reason to suppose that it would completely nullify the intended effect, especially if a limiting mechanism such as a speed limit is included. A specific application of this approach is the elimination from the system also of delusive features, e.g. curves which appear less curved than they are (cf. Shinar *et al.* 1980).

A careful analysis of the traffic system surely reveals many such implications of the theory for improving driving subtasks. However, not all of them are curable via simple and inexpensive environmental changes. For example, Leibowitz (1986) points to the differential impairment of central and peripheral vision at night, which results in directional guidance by peripheral vision being unaffected whilst recognition of hazards in central vision is seriously degraded. Because the 'primary function of driving' (i.e. vehicle steering) is working adequately, drivers are not alerted to the need to shift their thresholds for hazard avoidance and, consequently, driving speeds at night are usually too high. This is one example of many species-specific perceptual processes which result in inappropriate feelings of control, adaptation to risks, and distorted decision making on the road. Consequently, traffic authorities in various countries have tried, in vain, to convince drivers that night driving is more hazardous than they think. A low night driving speed is usually specified by traffic law which in Finland, for example, requires speed to be adjusted so that vehicles can always be stopped within the distance that drivers can see. An additional specific requirement is that, when shifting from high to low beam, speed must be adjusted accordingly. In fact this is a very difficult requirement to meet in practice. For example, Björkman *et al.* (1967) have shown that conforming to this night-driving rule would, under certain conditions, require maximum speeds to be as low as 25 to 42 km/h!

Clearly there are some insoluble problems in lowering 'fear thresholds'. However this does not mean, as has sometimes been erroneously concluded, that we must force people to drive in fear or under emotional stress. Most drivers will surely prefer to behave below their fear threshold! Nevertheless, we have plenty of evidence that neither informative nor 'scare' campaigns change driver behaviour appreciably (Näätänen and Summala 1976a, Kantola, 1986). Their knowledge and conscious analysis of traffic risks do not really seem to have beneficial effects on their behaviour. In fact, traffic risks seem even more problematic than the risks of, say, smoking. As Kantola (1986) has pointed out, every successfully terminated trip reinforces behaviour which the driver feels has been safe and rational. From his point of view, traffic risks do not accumulate as do the risks of smoking. (But from the point of view of society, traffic risks are of course cumulative!) We should therefore be quite pessimistic about the possible contributions that driver education can make to traffic safety (Näätänen and Summala 1976 a). Our best chances might be in modifying the novice drivers' habitual behavioural patterns from the very beginning of his driving experience and in focussing on the automatization of hazard perception skills in specific situations, since the growth of self-confidence in driving tends to eliminate conscious attention to safe driving practices.

As pointed out above, drivers are quick to use any opportunity provided by new outlets for their motives if the system changes (environmental, vehicular or statutory). The key to effective safety countermeasures is thus to prevent drivers from changing their behaviour in response to system modifications: that is, to prevent them from satisfying their motives. The psychological implication of the zero-risk theory is that *we need behavioural restrictions in the traffic system:* quite contrary to what the proponents of the 'risk homeostasis theory' state (e.g. Adams 1985).

It is most important to note that the typical behavioural response to environmental improvements is a speed increase. In the light of the highly automated, habitual nature of driving any other changes (e.g. in attentiveness) are of minor importance. This means that, as we must be pessimistic about our chances of improving drivers' risk control skills, *a necessary condition for efficient traffic safety work is speed regulation.* This is the main mechanism by which we can limit manifestations of human motivational tendencies. It is the best way of preventing drivers from adopting travel speeds and behavioural patterns which they feel are safe and rational, but which are actually unsafe and irrational from the point of view of both society and also the individual driver.

8. The case for speed limits

There is ample evidence for the beneficial effects of speed limits on safety (e.g. Salusjärvi 1981; Transportation Research Board 1984, Nilsson, 1986). The following example, described by Summala (1985 a), also shows how these effects crucially depend on political decision making.

When the 1973 energy crisis forced European countries to introduce general maximum speed limits on highways, some countries already had speed limits which had been adopted for safety reasons. This made possible a 'quasi-experimental' analysis of the effects of speed limits on fatality trends.

Figure 2 shows that three of the four (continental) Nordic countries experienced very similar trends in road fatalities, at fairly similar levels, until Sweden first introduced summer-time speed limits in 1960 and, some years later, made these limits permanent. Trends in Denmark and Finland continued until they too introduced speed limits in 1973. (Finland, in fact, introduced general speed limits a few months before the energy crisis, in response to President Kekkonen's request in a speech made on 1 January 1973.) Thereafter, these two countries quickly experienced the same trend and even the same level in road fatalities that had occurred in Sweden and Norway. Technical and other improvements jointly introduced in these countries were approximately similar in effectiveness when this imposition of speed limits prevented drivers from offsetting their beneficial effects by driving faster. (Note that Norway has had low speed limits on highways since the early part of the century.)

Figure 3 shows a similar comparison between the United Kingdom, which introduced speed limits early on, and three other Western European countries which are reasonably similar with respect to political, geographic and economic criteria. Again, the trend of fatalities in the United Kingdom differed from that of the other countries when it alone adopted general speed limits. The other countries did not

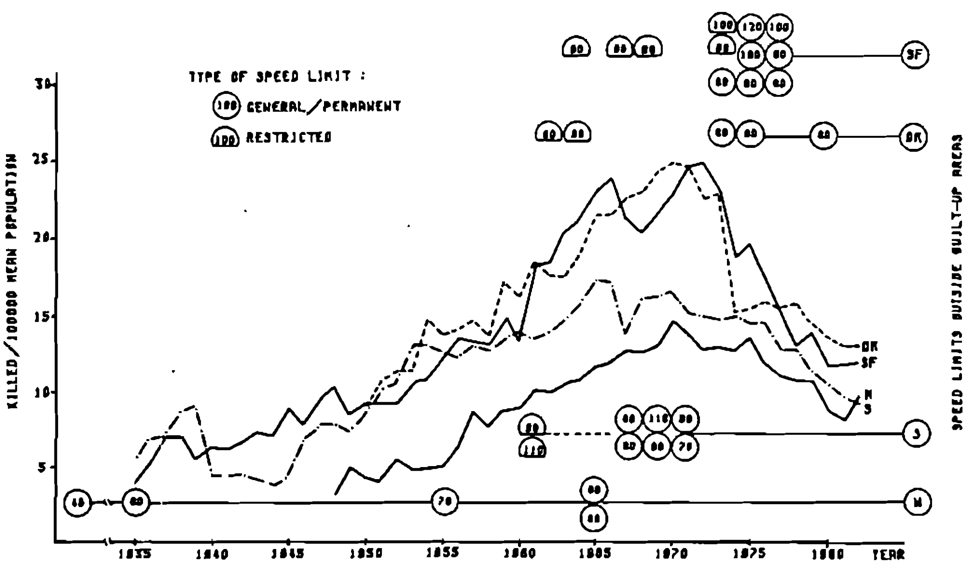

Figure 2. Road-fatality trends per 100 000 population and general speed limits outside built-up areas for 1935–1982 in Finland (SF), Denmark (DK), Sweden (S), and Norway (N). Note that the fatality trend in Norway and Sweden differs from that in Finland and Denmark which introduced general speed limits only in 1973. (Adapted from Summala 1985 a.)

follow the United Kingdom trend until after the energy crisis compelled them to accept speed limits.

This experience demonstrates that speed limits have immediate safety-promoting effects on actual speed levels. Specifically, they reduce higher speeds and thus reduce speed variance, which further results in a reduction in overtaking and also in close following (Summala 1980 b). But what also happened was that these speed limits blocked the outlet for any motivational tendency to increase speeds in response to safety improvements within the traffic system.

Savings in fatalities from the introduction of these speed limits were enormous and continue to be so. In Finland, the present fatality rate suggests that 500 people are saved from death annually by comparison with the number of deaths recorded before speed limits were introduced. If the Finnish fatality trend had continued to follow that of Sweden during the 1960's and 1970's, a total of around 4500 lives would have been saved, which is equal to *the total number of road fatalities in 7·5 years, at the present rate*. The failure to achieve this saving in lives was due solely to the delay in political decision making; since at the time when Sweden and the United Kingdom introduced general speed limits there was already sufficient reliable evidence of the positive effects of speed limits on road safety.

9. The researchers' responsibility

Requests for additional or stricter restrictions on driver behaviour are not guaranteed to win friends among drivers, the motoring press, traffic organizations, or even among those traffic-safety workers who would prefer educational and other non-restrictive means of improving road safety (claiming that 'the benefits can be expected in the long term, with new driver generations'). However, since the effectiveness of general speed limits was demonstrated in the early 1970's, many professionals in the field of

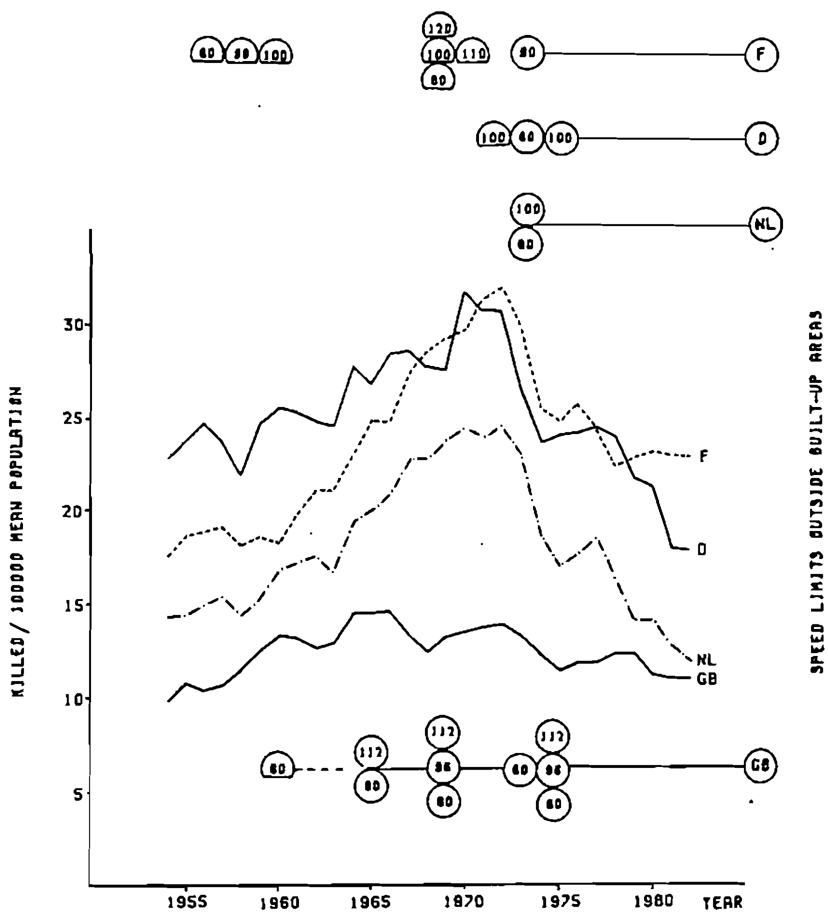

Figure 3. Road-fatality trends per 100 000 population and general speed limits outside built-up areas for 1955–1982 in France (F), Western Germany (D), the Netherlands (NL), and the United Kingdom (GB).

Note that the U.K. differs from the other three countries both in fatality trends and in speed limits.

traffic have tried to convince themselves and others that, in fact, they were promoting speed limits; but they had to compromise their views because of powerful public opinion, or the interests of motoring organizations. Drivers' opinions also quickly changed towards favouring speed limits (Peltoniemi 1982). However, after a period of reflection on this issue there are now signs of renewed pressure to increase traffic speeds in many countries. For example, in September 1986 the U.S. Senate voted to amend the 55 mph maximum speed limit, and there are indications of strong resistance to restrictions or more effective enforcement of limits among both drivers and many traffic professionals.

European countries have a long tradition of protecting their citizens from danger whether from violence, disease or consumer risks. They have strict statutes concerning health checks, just as they have strict statutes concerning certain types of traffic behaviour (see for example, the law on night driving mentioned earlier). The difference between these health and traffic statutes is that the latter are not enforced effectively. To be consistent, we should prevent drivers from incurring hazards which, according to the zero-risk theory, they are not able to take into account adequately. Society could introduce effective, largely automatic enforcement techniques to regulate driving speeds, both in urban and rural areas. This would not be different in principle from society's response to other epidemics such as mandatory vaccination against diseases of which the population are barely aware.

Some writers assert that the primary aim of the traffic system is to provide mobility, not safety. This may be true, but there is an optimum level of 'safe mobility' and reliability within the transport system which would call for much lower speeds than our present limits if driving time, accident and vehicle operating costs were properly calculated (Summala 1985 b). Furthermore, the time costs in these efficiency calculations are accumulated from the time losses of individual drivers for specific trips, typically amounting to only tens of seconds, or a few minutes, in medium-sized European countries. We pay dearly for these seconds or minutes, and for drivers' freedom to choose their speed, in terms of fatalities, injuries, wasted fuel and extra road-construction costs. In fact, we are paying in casualties for the drivers' convenience and freedom to travel at their preferred speed.

Future developments in traffic safety appear to be constrained by claims for individual freedom. Even many safety workers conform to these claims and preach, accordingly, either educational optimism or 'homeostatic' pessimism. However, if drivers are not able to take road risks into account to the degree which would be rational from the point of the individual or society, then society must do it by the introduction of traffic constraints. This task places a tremendous responsibility on researchers in this field.

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Näätänen et Summala (1974, 1976 a) sont à l'origine de la théorie du "risque zéro" qui stipule que les processus perceptifs, cognitifs et motivationnels permettent au conducteur de s'adapter aux risques sur la route, alors qu'ils ont tendance à rouler plus vite et à adopter un comportement plus risqué. En termes de la théorie de la décision, il y a une forte distorsion à la fois dans la distribution des probabilités subjectives liées au comportement du conducteur et dans la fonction d'utilité relative à la vitesse. Les conducteurs, cependant n'ajustent pas le risque. Avec l'expérience, la conduite devient une activité habituelle, fortement automatisée pour laquelle le contrôle du risque consiste à se maintenir dans les limites de la sécurité. Du fait de cette adaptation au risque, les conducteurs ne sont pas capables de prendre en compte le risque à un degré qui serait rationnel de leur point de vue et de celui de la société. L'enseignement principal de cette théorie est que nous devons contrecarre la tendance des conducteurs à adopter des vitesses de plus en plus grandes et, de ce fait, éviter qu'ils ne s'adaptent à des risques plus élevés. Les moyens pour ce faire étant limités, nous devons considérer que les limitations règlementaires de la vitesse sont indispensables pour la prévention des accidents de trafic.

Die Null-Risiko-Theorie, ursprünglich von Näätänen und Summala (1974, 1976 a) vorgestellt, postuliert, daß sich Fahrer aufgrund menschlicher Wahrnehmung, kognitiver und motivierender Prozesse an die Risiken im Straßenverkehr gewöhnen, solange sie zu schnellerem

Fahren und objektiv risikoreicherem Verhalten motiviert werden. In entscheidungstheoretischer Hinsicht sind sowohl die subjektive Einschätzung der Wahrscheinlichkeit von Folgen des Fahrverhaltens sowie die Geschwindigkeits-Nutzen-Funktion äußerst verzerrt. Wie auch immer, Fahrer regulieren nicht das Risiko. Mit Erfahrung wird das Fahren zu einer gewohnten, weitgehend automatisierten Aktivität, in der die Risiko-Kontrolle auf der Einhaltung von Sicherheitsgrenzen beruht. Aufgrund dieser Gewöhnung an das Risiko und der damit verbundenen Motive können Fahrer das Verkehrsrisiko nicht mit einem Maß in Betracht ziehen, das von ihrem eigenen Standpunkt und dem der Gesellschaft aus vernünftig wäre.

Die wesentliche Bedeutung der Theorie ist, daß wir diese Tendenz verhindern müssen, daß Fahrer zu höheren Geschwindigkeiten motiviert werden und sich auf diese Art an größeres Risiko im Straßenverkehr gewöhnen. Die primären Möglichkeiten, das zu erreichen, sind restriktiv. Geschwindigkeitsbeschränkungen sind deshalb eine notwendige Bedingung für eine effektive Verkehrssicherheitsarbeit.

ゼロ・リスク理論は元々 Näätänen と Sumala（1984，1976a）が提唱し，人間の知覚，認知および動機過程により，運転者がより速い速度と客観的によりリスクの高い行動に動機ずけられながら道路上のリスクに適応すると仮定する。決定理論的には，運転者の行動の成果の主観的確率分布と速度一効用関数の両方ともひどく狂っている。運転者は，しかしリスクを調節していない。経験を積むと，運転は単に習慣的で，かなり自動的な活動となり，そこではリスク制御は安全率の維持に基づくことになる。このリスク適応性と関連する動機により，運転者は事故の観点からも社会の観点からも合理的と思われる程度に交通リスクを考慮することができない。本理論の意義は運転者が高速に動機ずけられ，したがって交通系で大きなリスクに適応するこの傾向を防止しなければならないことである。これを達成する主な手段は制限的である。速度制限はしたがって有効な交通安全運動の必要条件である。