# COGNITION AND EMOTION IN DRIVER BEHAVIOUR MODELS: SOME CRITICAL VIEWPOINTS

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## ABSTRACT

Several driver behaviour models have been proposed during the years, the first one in 1938 by Gibson and Crooks' and their theoretical field-analysis of automobile driving. Since then, several authors have contributed to the understanding of driver behaviour by developing models. The most important are considered to be, chronologically:

- Taylor on "Drivers' galvanic skin responses and the risk of accidents" (1964)
- Näätänen and Summalas' "Zero-Risk Model" (1974)
- Ajzen and Fishbeins' "Theory of Reasoned Action" (1980)
- Wilde's "Theory of Risk Homeostasis", (1982)
- Fuller on "Driver behaviour as threat avoidance" (1984)
- Evan's on the role of feedback (1985)
- Ajzen's "Theory of Planned Behaviour" (1985)
- Rothengatter on the role of pleasure (1988)

One can hardly say that the task of modelling driver behaviour has reached any kind of consensus. Models address diverging aspects, several 'favourite' issues and/or concepts are pursued, discussions and disagreement prevail. There is no break-through or "GUT" ("Great Unified Theory") within the traffic safety research regarding the difficult task of modelling driver behaviour.

In the present paper, it is argued that one of the main reasons for this "sad state of the art" is a lack of a thorough and comprehensive understanding of human cognition and emotion, i.e. how drivers think and feel, consciously, pre-consciously, unconsciously. There is no common understanding of driver behaviour that is based on recent achievements in cognitive psychology and neurobiology. In fact, Taylor's early work of 1964 may be more in line with recent achievements in neurobiology than any other of the models listed above. The paper argues that no deep understanding of risk compensation will emerge unless recent developments in cognitive psychology and neurobiology are integrated in the modelling of driver behaviour.

## ASSERTIONS

In my opinion, which by definition naturally is subjective, the state-of-the-art regarding driver behaviour models, can be characterised as follows:

- Disagreement prevail: There is no consensus concerning models, no agreement has been achieved, no break-through or "GUT" (Great Unified Theory) has emerged.
- Existing models address different aspects. Each of the aspects may be significant, but there is no general integration that links the diversity of aspects into a complete and all-embracing model.
- The main cause: A lack of thorough and comprehensive understanding of human cognition and emotion, i.e. how we, the drivers, think and feel. Recent achievements in cognitive psychology and neurobiology have not been applied on prevailing driver behaviour models.
- Most of the models do not link cognition and emotion across conscious, preconscious, and unconscious levels in a significant way (there are exceptions!)
- Hence, prevailing models that could be elaborated further, "are still resting" – i.e. some models may have a significant potential for further development.
- Taylor's early work of 1964 may be more in line with recent achievements in neurobiology than any other of the models listed below.
- No deep understanding of ***risk compensation*** will emerge unless recent developments in cognitive psychology and neurobiology are integrated in the modelling of driver behaviour.

## DRIVER BEHAVIOUR MODELS

The history of driver behaviour models starts in 1938 when Gibson and Crooks' presented their theoretical field-analysis of automobile driving. The list below should hopefully cover most of the driver behaviour theories and models that have been proposed during the years, although a claim of its completeness is by no means stated (title of study in parentheses):

- "Field of safe travel" ("*A theoretical field-analysis of automobile driving*", Gibson and Crooks 1938)
- "Driving as a self-paced task governed by tension/anxiety" ("*Drivers' galvanic skin responses and the risk of accidents*" – Taylor 1964)
- "Zero-Risk Model" ("*A model for the role of motivational factors in drivers' decision-making"* - Näätänen and Summala 1974)
- "The model of subjective and objective safety" ("*Das Model der subjektiven und objektiven Sicherheit"* – Klebelsberg 1977)
- "Theory of Reasoned Action" ( "*Understanding attitudes and predicting behaviour"* - Ajzen and Fishbein 1980)
- "Risk Homeostasis Theory (RHT)", ("*The Theory of Risk Homeostasis: Implications for Safety and Health"* – Wilde 1982)

- "Human Performace Models/Levels" ("*Skills, Rules, and Knowledge: Signals, Signs and Symbols, and Other Distinctions in Human Performance Models*" – Rasmussen 1983)
- "The Threat-Avoidance Model" ("*A conceptualisation of driving behaviour as threat avoidance"* – Fuller 1984)
- "Theory of Planned Behaviour" ("*From intentions to actions: A theory of planned behaviour*" - Ajzen1985)
- "The perceptual and cognitive filter model" ("*The role of perceptual and cognitive filters in observed behaviour"* – Rumar 1985)
- "The feedback model" ("*Human Behaviour Feedback and Traffic Safety*" – Evans 1985)
- "The hierarchical risk model ("*A hierarchical risk model for traffic participants"* – van der Molen & Bötticher 1988).
- "Motivational approach to modelling: The role of pleasure" ("*Risk and the absence of pleasure*" - Rothengatter 1988).
- "Production-rule models/Rule-based models" ("*Explanatory pitfalls and rule-based models"* – Michon 1989)
- "Inner models" ("*Inner models as basis for traffic behaviour*" – Keskinen et al 1992)
- "*The Task-Capability Interface Model*" (Fuller 2000).

*Table 1: Number of published driver behaviour models according to decade*

| ***Period/decade of publication*** | ***Number of models published*** |
|---|---|
| 1938 | 1 |
| 1940-1949 | 0 |
| 1950-1959 | 0 |
| 1960-1969 | 1 |
| 1970-1979 | 2 |
| 1980-1989 | 10 |
| 1990-1999 | 1 |
| 2000 - > | 1 |
| Total | 16 |

The list comprises 16 studies. All of them could be said to represent attempts of modelling driver behaviour, or at least driver behaviour in a more general sense. A lot of effort was put into model development in the 1980's, 10 of the studies were published in that decade, only two since 1989 (Keskinen et al 1992; Fuller 2000). So, what happened? Why all these attempts? At least, they symbolise the great need for developing models and theories, for understanding driver behaviour. This basic, theoretical need still exists, but the field of traffic safety is left with a diversity of models, no consensus is achieved, disagreement prevails.

Did the development of models somehow "get off the track" in the 1980's? It is my assertion that "a right track" was, and still is, represented by the Taylor study of 1964, and Näätänen and Summala "Zero-risk model of 1974, which is based on the Taylor study, while discussions based on Wilde's theory of risk homeostasis of 1982 somehow has resulted in a dead end for the development of driver behaviour models. This view then implies that it should be possible to get the modelling "back on the track". Such a re-orientation is also strongly needed because risk compensation still is not fully understood and accounted for in a satisfactory way.

## DESCRIBING WILDE'S RISK HOMEOSTASIS THEORY (RHT)

Why start with Wilde's theory of risk homeostasis? There are several reasons for this: 1) It has been central for years and it has been at the core of heavy debates since it was first published, 2) It addresses risk compensation which certainly exists and remains as an unsolved problem in traffic safety work, 3) In its radical form it represent a "dead end" theoretically speaking, as it is not suitable for testing, and finally 4) "There is something in it, after all" !

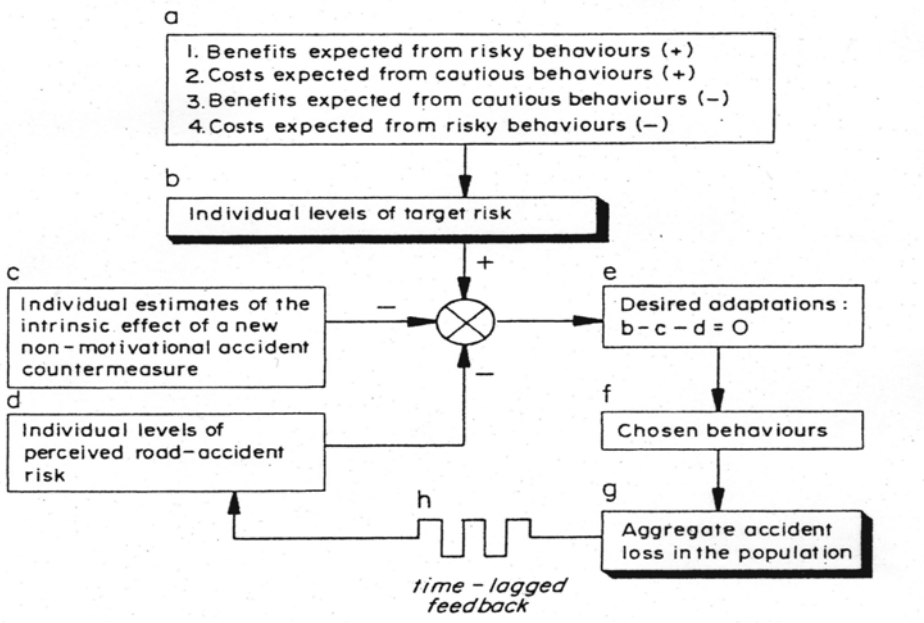


*Figure 1: Wildes Model of Risk Homeostasis (after Wilde 1982; Wilde 1988)*

While Näätänen og Summala (1974) postulate that drivers try to avoid risk by regulating their behaviour according to a perception of zero risk, Wilde postulates the opposite by stating that drivers ***seek*** a certain risk level – "a target risk level" - a risk level that must be

perceived as a certain number > 0 and defined in the ways risk commonly is defined: By exposure, i.e. as number of accidents pr kilometres driven, pr a certain unit of time, or the like. This risk number varies between drivers, it seems partly to be idiosyncratically given, partly a regulator in an homeostatic system. If the driver is confronted with certain changes in the road environment, he will meet the changes by behavioural adaptations that secures that his level of target risk is sustained.

Wilde postulates further that the target level of risk can be increased when expected benefits from risky behaviour, or expected costs from cautious behaviour, increases. It can be reduced when expected benefit from cautious behaviour, or expected costs from risky behaviour, increases.

Wilde's RHT model contains one explicit element called a comparator. This is a place, a function, a process where three input factors are put together and compared: b, c and d (figure 1) resulting in one output factor ***e***:

b: Individual levels of target risk

c: Individual estimate of the (intrinsic) effect of a new (non-motivational) road safety measure

d: Individual levels of perceived road-accident risk

e: Desired adaptation satisfying the formula: b – c – d = 0

According to Wilde, the three input factors are "weighed together" in the comparator, which is a ***bound*** weighing: The theory predicts that the end result should be ***zero***. All three input factors must be comprehended as numbers where the values of b, c and d have the property that

$$b - c - d = 0 \qquad (I)$$

Translated into words it means that the output from the comparator, the result of the weighing procedure, must be chosen so that the property (I) is fulfilled. Translated to behaviour it means that the output factor must be regarded as ***the desired adaptation of the individual driver***, which is such that the risk homeostasis is sustained on an individual basis. I label this description as RGT in its radical form.

## DECOMPOSING WILDE'S RISK HOMEOSTASIS THEORY (RHT)

A problem with RHT, which in my opinion must be read according to the above, is that all input factors, and the predicted output factor, are comprehended as ***numbers***. And, as such, they should be confirmed to exist by individual drivers. Are they? I have never seen any such numbers or calculating procedures being confirmed by drivers, and I have no such numbers or comparing in myself. It they exist, the prediction must take place on a completely unconscious level. The prediction would hence be impossible to test, as the entities are impossible to observe and impossible to measure. The only two numbers that seem valid, as target levels of risk, would be 0 or 1:

- 0: As in Näätänen and Summala's "zero-risk model": Most drivers ("all"?) drivers would state that they seek or try all their best to avoid accidents
- 1: Meaning a probability of p = 1 for an accident: I.e. when a driver deliberately hits another road user, or in cases of road traffic suicides.

These two outcomes are, in my opinion, the only two that are valid as target levels of risk. Looking more closely at the factor d, individual levels of perceived road-accident risk, d seem

to be the time-lagged feedback product (h) of a preceding aggregate accident loss in the population (g). I guess we all have a perception of an "aggregate accident loss", but it is not very accurate. It may be uttered in terms of "speeds are increasing", "traffic is getting worse" or "traffic seem to improve now", but such terms are very crude and not based on any kind of calculation or unbiased knowledge of the situation. I may remember some certain accidents, because of their magnitude or some other characteristic, but I have forgot all the "common ones". Your perception is more like a "feeling", perhaps "a background feeling" more in line with the concepts of Damasio (Damasio 1994). It is more like a perception of the contemporary, of the society you live in, and all the events, accidents included, that happen around you in everyday life. Tversky and Kahneman show that people put much weight into their own experiences (1974). The properties of one small sample may, independent of its size, be considered as being representative of a much larger population. Tversky and Kahneman are however, not referred to in Wilde (1982; 1988). There seem to be no trace in the literature of the asserted weighing procedure between b, c and d, i.e. between target level of risk (b), individual estimates of effects (c), and individual levels of perceived risk (d) constituting the desired adaptations b – c - d = 0 (e). Not even on a strategic level of driver behaviour, i.e. thinking supposed to take place in a highly conscious and rational manner, does it seem possible to observe these kind of cognitive processes.

Target level of risk is certainly not a number, a thought, or an imagination that I bring with me consciously and that put into some weighing procedure when I decide what speed I should choose or what kind of acts I perform as was it a constant, predominant thought or imagination in the dynamics of my thinking. And that is exactly my critique against Wilde: The RHT model does not grasp or mimic the varied dynamics of thinking and feeling, "the streams of consciousness" and fluctuations of automated states so characteristic of everyday driving. The RHT model somehow assumes a powerful, hidden, unconscious force that forces you (and everybody else too!) to act in such a way that the target level of risk is sustained individually for everyone as well as for everybody else at an aggregate level. Such a powerful force somehow resembles the cosmological anti-gravity force, "dark matter", "dark energy" or whatever: The force is there, it makes the universe accelerate in its expansion, but we cannot observe it.

Wilde is inaccurate in his choices and definitions of concepts. "Costs" and "benefits" is central in the model but they are not defined in psychological terms. As they are presented, they adhere more to the limitations of economic utility theory, not to a wider understanding of behaviour in psychological terms.

## WILDE's and RHT's CONTRIBUTION

"There may be something in it, after all". So what's in it? Let me start with the "zero-risk" model of Näätänen and Summala (1974). An experience of "zero risk" will be fulfilled by several speeds, in fact any number in the interval $[0, x_1]$ may satisfy the experience of a zero risk (figure 2):

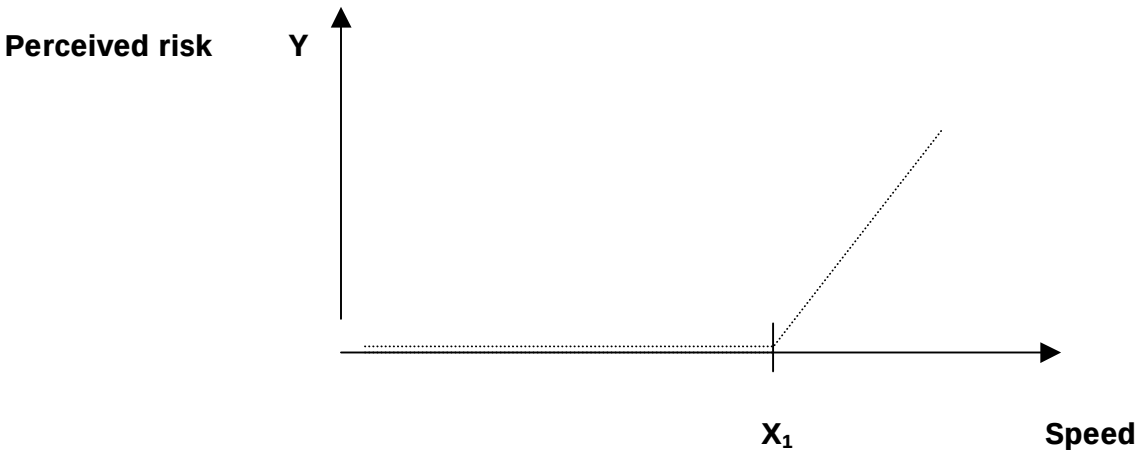


*Figure 2: Hypothetical distribution of perceived risk according to driving speed.*

Why stop at $x_1$ as the chosen speed? Why not choose any speed < $x_1$? Why exactly $x_1$? In my view, Näätäten and Summala does not state or answer this question directly. But let us see what happens if we loosen Wilde's tight and rigid presupposition about viewing target level of risk as a certain number or level that the driver seeks to achieve. Let us suppose that this target is of another nature. Let us suppose instead that drivers are searching a certain feeling, a certain way of driving that suits him well, that gives the driver "the best feeling". This is exactly what I would characterise as Wilde's contribution by his RHT, the introduction of the ***target***. However, the target should not be regarded as a number, but as a certain kind of ***target feeling***. Further, I say that a fulfilment of a "zero-risk" is not enough, there has to be added another dimension to it as well. A dimension, or an experience, that is achieved at the "exact speed of $x_1$ ", but not at speeds lower than $x_1$.

> ***Assertion****: In addition to avoid accidents, drivers seek a certain "target feeling". This feeling is not the same in all drivers, all driver has a unique target, it is not necessarily experienced consciously. Target experiences are defined and characterised by an emotional dimension, either positively or negatively.*
>
> *Candidates for target feelings are:*
>
> - *Vigilant, attentive, highly aware ("arousal")*
> - *Sensation (seeking)*
> - *Joy/pleasure*
> - *Pleasantness*
> - *Relaxed, secure*
> - *Reducing task difficulties to their minimum*
> - *Avoid violations (rule-based drivers: No mistakes, always behave correctly)*

(Other feelings/experiences may be added). Not all drivers enjoy driving, so this "best feeling" that can be achieved may be negatively defined, as the optimal choice where unpleasantness, difficulties etc, are reduced to their minimum in any given situation. It is proposed that the choice is at least two-dimensional. Avoiding accidents, "zero risk", is not the full answer. A certain emotional experience has to be added. Someone will say that to seek a "target feeling" simply is to seek some certain "arousal". Such a view is too narrowminded, also "arousal" can comprise and be characterised by an array of differing feelings.

Car driving is characterised by constantly solving problems, problems that involve thinking, choosing and deciding between different alternatives. All alternatives, scenarios, acts, can be characterised by an outcome that has an emotional value attached to it. In fact, that emotional dimension is the very one that makes drivers, or any other in any other situation where we are confronted with a choice between alternatives, able to evaluate cognitively between alternatives. If there is no feeling, there is no possibility for evaluating the outcomes (Damasio 1994; Overskeid 2000). There is no such thing as reason, thinking, rationality without emotion.

## MONITORING RISK AND THE ROLE OF EMOTIONS

Both Näätänen and Summala's "zero risk" model and Wilde's RHT-model has a unique contribution to the basic elements from which a sound driver behaviour model should be built – i.e. the ***risk monitor*** and the ***target feeling,*** respectively. These two elements, or dimensions, would also be in line with the view put forward in more recent neurobiology (Damasio 1994). Damasio's starting point is the axiomatic statement that the basic motive of all organisms is ***survival***. Correspondingly axiomatic, it follows that the prime task for the organism is the need for monitoring risk (Vaa 2001). Damasio separates between emotion and feeling and limits the concept of emotion to what goes on in the body of the organism, i.e. that the myriads of changes in the state of the body that is induced autonomously in all its parts and organs when the organism is exposed to a given, external event.

The Skin Conductance Response (SCR) or Galvanic Skin Response (GSR) is one of all such autonomous responses in the body. According to Damasio, emotions are responses predisposed to react in certain ways, mostly with respect to the body by preparing the body for action, but the emotional responses are also directed towards the brain through neuro-transmitters in the brainstem which in turn may lead to changes in mental states. Damasio distinguishes specifically between emotions and feelings and limits feeling to processes of consciously experiencing the changes of the body and the mental states. Two experiments, one old (1964) and one recent (1997), are central because they throw light on the role of emotions and how people are guided by them (Taylor 1964; Bechara et al 1997).

### *GSR as an indicator of feeling: The Taylor experiments*

Taylor reported two experiments in which he let a total of 20 respondents drive under various conditions, i.e. road environments considered to exhibit different levels of difficulty, traffic volumes, accident risks etc. In experiment I, each subject covered two routes once each, in day-time off-peak hours, on different days. In experiment II, each subject covered one single route under three conditions: a) day-time off-peak, b) twilight rush-hour and c) night-time off-peak. The order of presentation was randomised and the subjects were allowed at least one practice run on beforehand. All subjects spent a before-period sitting reading in a quiet room while GSR was measured remotely. All routes were divided into sections as homogenous as possible regarding the road conditions within it.

GSR was measured in both experimental groups. Readings of the GSR was taken at the boundaries of all route sections and the subjects were given no idea of the purpose of the experiment. No restrictions were placed on his/her behaviour other than guidance of the route (Taylor 1964). In brief, the experiments showed the following:

- Mean GSR rates during driving were 50 times higher than in the before-situation
- Variation in GSR rate was associated with variables ***unrelated*** to road conditions
- Variance in GSR rate could be accounted for by differences ***between*** subjects
- A GSR consistency ***within*** subjects was seen

- The mean GSR rates were significantly related to experience (GSR was reduced by years of experience)
- GSR rate is an appropriate variable of subjective risk as it is also analogous to a tension or anxiety level.
- ***Driving is a self-paced task governed by the level of tension or anxiety which the driver wishes to tolerate.***
- If GSR rate is raised, a slowing of pace is called for, if there are few hazards, the pace is quickened until they reappear
- ***If perceived hazards are removed or reduced, a driver will simply readjust his behaviour to restore his anxiety level***

***Guided by intuition? The Bechara experiment:***

Can a preconscious, pre-linguistic sort of intuition be experimentally shown to exist? And, if so, how do people apply it? Bechara el al (1997) tested the hypothesis that overt reasoning on declarative knowledge is preceded by a non-conscious activity that uses other neural systems than those which support declarative knowledge.

Normal subjects and patients with prefrontal brain damage and decision-making defects were exposed to a gambling task where they should draw "good" or "bad" cards from a card deck. The players were given four decks of cards, a loan of $2000 in facsimile U.S.bills, and asked to play so that they loose the least as possible and win the most. Turning a card would result in an immediate reward of $100 (decks A and B) or $50 (decks C and D). Unpredictably, however, some cards also would carry a penalty: A large loss of money from decks A and B, and a small loss from decks C and D. Playing mostly from the disadvantageous decks A and B would result in an overall loss, from the advantageous decks C and D an overall gain.

After experiencing losses, normal participants began to generate skin conductance responses (SCR) before selecting a card from the bad decks and they also began to avoid the decks with large losses. Patients with prefrontal brain damage did neither. Several times during the experiment, the subjects were asked how they conceptualised the game and also asked what strategy they were using when choosing cards from the decks. In short, Bechara et al could separate between four distinct phases or periods of the game:

- ***"Pre-punishment period"****:* After sampling from all four decks, and before encountering any losses, subjects preferred decks A and B. No anticipatory SCR was generated.
- ***"Pre-hunch period":*** After encountering losses in decks A or B, usually about card 10, normal subjects began to generate anticipatory SCRs to decks A and B, but yet by card 20 they could not report any clue about what was going on.
- ***"Hunch period":*** By card 50, all normal subjects began to express a "hunch" that decks A and B were "riskier" than C and D. And all normal subjects generated anticipatory SCRs whenever they pondered a choice from A or B.
- None of the patients generated anticipatory SCRs or expressed a "hunch".
- ***"Conceptual phase":*** By card 80, 7 of the 10 normals expressed knowledge about why, in the long run, decks A and B were bad and decks C and D good. They continued to avoid the bad decks and they also continued to produce anticipatory SCRs when the considered sampling from the bad decks.
- The remaining three normals continued to make advantageous choices even if they did not reach the conceptual period.

- None of patients developed anticipatory SCRs, but 3 of the 6 patients also reached the conceptual period and could describe which were the bad decks and which were the good decks. But, despite a correct, verbal explanation of the task and the correct strategy, they failed to generate autonomic responses and continued to select cards from the bad decks.

One possible explanation of the results in this experiment is that the non-conscious, autonomous responses, the SCRs, assist cognitive reasoning in decision-making processes and that the SCRs facilitate the processing of knowledge and logical reasoning that seem necessary for making conscious decisions. Further, it is believed that the SCRs is an indicator of complex non-conscious signalling which reflects access to previous individual experience shaped by learning and the emotional states that have attended them (Bechara et al 1997).

## Conclusion

Referring to the initial assertions, the bottom lines of this paper are the following:

- The project of developing driver behaviour models was once “on the right trafck”, a track that was represented by the Taylor experiments (1964) and the “Zero-Risk” model of Näätänen and Summala (1974).
- Discussions of Wilde’s Risk Homeostasis Theory ended in a blind alley
- By substituting Wilde’s target level of risk by target feeling, the development of driver behaviour models can be put back “on the right track”
- Recent research in neurobiology confirms the Taylor results: We are guided by emotions in our monitoring of risk, processing of information and decision-making
- Risk monitoring and emotions are the corner stones on which driver behaviour models should be built.
- A deep understanding of risk compensation can only be achieved in terms of emotions.

The role of the emotions in driver behaviour models, and the role they play in risk monitoring, must be upgraded. Emotions are the key element of what could be labelled as the risk monitor of organisms. In my view, emotions are the very core in risk monitoring.

> ***Assertion****: Emotions are (part of) the risk monitor. Human emotions are the very instrument that enables man to monitor danger, to consider and evaluate behavioural alternatives in given situations.*

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