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From Gibson and Crooks to Damasio: The role of psychology in the development of driver behaviour models☆

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ABSTRACT

This article presents a brief history and perspective of behavioural model development in traffic psychology. As one specific example of a key behavioural model, Gibson and Crooks (1938), in their classic field theoretical study, offered the first scientific attempt to deal with the issue of compensation. Two central theoretical concepts were developed: "Field of safe travel" and "Minimum stopping zone". The interplay between the two was used to describe and explain risk compensation and illustrated by observing the impact of brakes on driver behaviour: Better brakes could make the field of safe travel – i.e. the distance to the car in front – shorter. Nearly 50 years later, the launch of Wilde's Risk Homeostasis Theory (RHT) gave rise to a profound debate about risk homeostasis and risk compensation. The core issue in the debate was Wilde's strict assertion that all individuals, not only car-drivers, carry an inherent target level of risk that they are seeking to maintain or restore. Gibson and Crooks fell well within psychological theories of the time, while Wilde's RHT emerged more from control theory and economic utility theory than from psychology. In the 1990s neuroscience emerges, especially by Damasio who introduces a paradigm that has proven fruitful as a framework of more recent driver behaviour models. But neuroscience also had its forerunner in Taylor's proposal that driver behaviour is governed by a constancy in Galvanic Skin Response (GSR) which makes driving a self-paced task aiming at keeping the GSR at a constant level. Näätänen and Summala's integrated Taylor in their "Zero-risk model" which has persisted and still prevails as a solid and well accepted model. Psychological learning theory has, however, rarely been adequately dealt with which is quite odd given the prevalence of speeding and risk compensation which cannot escape explanations based on operant conditioning. The paper discusses the emerging role of psychology and psychological concepts that has been proposed and evolved through the development of driver behaviour models since Gibson and Crooks' study of 1938. The views presented are subjective, they do not represent any attempt to describe the objective reality of the time.

☆ Editor's Note: This paper was invited and peer-reviewed for a special section on History of Traffic Psychology. The special section included a wide range of manuscript styles, from those typical of this journal to other styles just as important for sharing the discipline's history. Authors contributed reasoned viewpoints from experience and literature on where the discipline has come from and where it may be heading, to an investigation of trends and topics in the discipline since the early 20th century.

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1. Some personal background

I must emphasize that what is put forward here is by no means any attempt to describe the objective reality of how traffic psychology has emerged. It is indeed a subjective opinion developed after I began working at the Institute of Transport Economics (T∅I) as a research psychologist in 1988. At that time, the issue of risk compensation, and specifically Wilde's Risk Homeostasis Theory (RHT), was heavily debated by my colleagues at T∅I. This topic continued to be discussed into the 1990s at international conferences addressing road safety. The topic of risk compensation was probably at its most intense during these peak years, it has since declined, but not ceased, although the debate has been converted to the broader topic of behavioural adaptation. In my view, risk compensation should be regarded as a special case of behavioural adaptation and is best understood under this umbrella (Vaa, 2013). My work at T∅I started just a couple of weeks before the conference "Traffic safety theory and research methods" was held in Amsterdam in April 1988 (SWOV, 1988). This was a great event, many big names were there: Frank A. Haight, Ezra Hauer, John A. Michon were all invited speakers, and Talib Rothengatter, Wiel Janssen, Ray Fuller, Matthijs Koornstra, John Groeger, and Rune Elvik, all presented their papers. Remember, this was years before the 1st ICTTP-conference in Valencia (1996) and also before the first issue of Transportation Research Part F (1998), meaning that traffic psychology had not yet fully emerged as an independent and leading discipline in road safety research although there were earlier attempts by Näätänen and Summala's book "Road-user behavior and traffic accidents" (1976), Shinar's "Psychology on the road" (1978) and Klebelsberg's "Verkehrspsychologie" (1982). At that time in 1988, at my institute at least, social scientists from several disciplines worked together on joint projects discussing and solving problems of theory and method in a melting pot of different perspectives from which psychological thinking about the behaviour of drivers in the road traffic system evolved.

2. Missing concepts of the 1980s

Having a background in clinical psychology and psychodynamic theory, I missed psychological thinking, especially theories of *personality* and *personality traits*, when I began working with road safety issues. The understanding of the driver was felt as shallow, it was as if a driver was either a sensation seeker or "normal". Discussions of aggression and aggressive driver behaviour were not frequent either, it was not very pronounced until the second half of the 1990s where the debate of "road rage" peaked. The understanding of driver behaviour was felt as being isolated from other disciplines of psychology. One example was the lack of explicit use of Skinnerian *operant conditioning* (Chaplin & Krawiec, 1979), which, as far as I can see, was not represented in any driver behaviour models of the time. A separation of *conscious* and *unconscious* routes to decision-making and the interaction between the two was lacking. Too much focus, in my view, was put on cognitive theories as with Theory of Reasoned Action and Theory of Planned Behaviour to the expense of the role of the unconscious, which I think is inevitable when one wants to understand automated driving, implicit learning, and deep motivation rooted in unsolved emotional conflicts. *Motivation* was addressed in a group of theories labeled "motivational models", but I regard *emotions* as a more important concept. It was then not addressed as much as motivation, but it was central in Taylor's GSR-constancy theory of 1964 as a governing principle in terms of the amount of fear a driver wishes to tolerate, a conception that was further integrated and developed in Näätänen and Summala's Zero-risk-model of 1974. I focus on these concepts and topics as I regard them as essential building blocks, which must be properly addressed in the development of any driver behaviour model. I would regard the model building as incomplete if any of these topics are missing.

3. Background theories and models

Gibson and Crooks (1938) and Damasio (1994) set the frame around the present discussion, but also other theories and models are brought in because they serve as background of the discussion. The models and theories which will serve as basis in the present context are as follows:

- Gibson and Crooks (1938): *A theoretical field-analysis of automobile-driving.*
- Yerkes and Dodson (1908): *The relation of strength of stimulus to rapidity of habit-formation.*
- Miller (1956): *The magical number seven, plus or minus two: Some limits on our capacity for processing information.*
- Taylor (1964): *Drivers' Galvanic Skin Response and the Risk of Accident.*
- Näätänen and Summala (1974): *A model for the role of motivational factors in drivers' decision-making.*
- Wilde (1982): *The theory of risk homeostasis: Implications for safety and health.*
- Damasio (1994): *Descartes' Error: Emotion, Reason and the Human Brain.*

The governing idea here is the topic of risk compensation and how it bridges the gap between Gibson and Crooks' work of 1938 and Damasio's paradigm of 1994. Gibson and Crooks is a real classic, it is the first serious attempt to develop a model of driver behaviour and it foresees several central issues that are still on the research agenda. Taylor's study of 1964 is brought in, not specifically as a classic, but more as a forerunner of findings of neuroscience of the 1990s and because it is a very important base in Näätänen and Summala's zero-risk model of 1974. The objective of the Taylor study was to investigate how the general rate of Galvanic Skin Responses (GSR) varied across road conditions as different as with urban shopping

streets, arterial dual-carriageways, winding country-roads and motorways (Taylor, 1964). Taylor measured GSR as skin conductance in the fingers in a sample of 20 drivers who drove across the wide range of road conditions. Apparently, the level of GSR activity tended not to vary with road conditions. If responses were occurring irregularly, as for example three in five minutes, this would continue irrespective of whether the driver was driving in heavy traffic or open roads, i.e. the GSR depended not primarily on the characteristics of the road or driving conditions, but more on the subjects own, previous experiences of driving. The distribution of GSR per unit distance travelled was found to be similar to the distribution of accidents per unit total distance of vehicle travel, i.e. the accident rate (Näätänen & Summala, 1974). Very little, if any of the variation in GSR was related to road conditions. Taylor concludes that the results support that driving is a self-paced task governed by the level of emotional tension or anxiety which the driver wishes to tolerate (Taylor, 1964). Näätänen and Summala discuss the use of physiological processes underlying psychological states, and Taylor's GSR-study in particular. A critique they raised was that future experimental studies must be designed in a way that enables the isolation of the effect of GSR on the subjective perception of risk, as the GSR is sensitive to many kinds of perceptions, emotions and actions. GSR can also be influenced by what Näätänen and Summala call "biological noise". In sum, however, they conclude that "*...there is some support for the use of the GSR as an indicator of the subjective risk*" (Näätänen & Summala, 1974, p. 249).

More than thirty years later, a neuroscientific study by Bechara, Damasio, Tranel, and Damasio (1997), confirms Taylor by demonstrating the important role of the Skin Conductance Response (SCR, which is just another name of the GSR (Reber & Reber, 2001)) in guiding individuals in decisions involving risk of losing money in a card game, the Iowa Gambling Task (IGT) developed by Bechara, Damasio, Damasio, and Anderson (1994). In this study, 10 controls were compared to 6 patients with damage of the ventromedial prefrontal cortices i.e. a region known to be involved in information processing and decision-making. The patients and the controls were exposed to four card decks, where the disadvantageous decks (A and B) in the long run would lead to an overall loss, while playing from the advantageous decks (C and D) would lead to an overall gain. Control participants began to generate anticipatory SCRs and continued to generate anticipatory SCRs whenever they pondered a choice from the bad decks. Thus, the SCRs seemed to act as warnings of selecting cards from the bad decks, but still in a phase where subjects could not state consciously which of the decks would lead to an overall gain, i.e. the SCRs made the controls "*deciding advantageously before knowing the advantageous strategy*" as Bechara et al. state it (1997). The patients with brain damage in the ventromedial prefrontal cortices did not produce anticipatory SCRs and were unable to decide which decks to choose to make a gain. They did not have the capacity to decide advantageously as the controls had. Bechara et al.'s demonstration of the role of SCR then confirms, in my view, Taylor's earlier findings of the role of GSR in the perception of risk.

4. Gibson and Crooks: "A Theoretical Field-Analysis of Automobile-Driving"

Gibson and Crooks' analysis of car driving is built on Kurt Lewin's "Topological Psychology" (1936). Lewin was an adherent of Gestalt psychology and he described his "field theory" as follows:

> "*The possibilities of a "field theory" in the realm of action, emotion, personality are firmly established. The basic statements of a field theory are that (a) behaviour has to be derived from a totality of coexisting facts, (b) these coexisting facts have the character of a "dynamic field" in so far as the state of any part of this field depends on every other part of the field*". (Lewin, 1940, cited in Woodworth & Sheehan 1971).

Further, Lewin's field is the "*life space containing the person and his psychological environment*" (Lewin, 1938). The psychological environment is the environment as perceived and understood by the person, but, more than that, it is the environment as related to his/her present needs. Many objects which are perceived are of no present concern and exist only in the background of a person's psychological environment. Other objects have positive and negative "valences" – positive if they promise to meet present needs, negative if they threaten survival. Objects of positive valence attract, objects of negative valence repel (Woodworth & Sheehan, 1971).

Gibson and Crooks' article is basically the outcome of discussions between a psychologist (Gibson) and a practical student of driving (Crooks). They look upon driving as a predominantly perceptual task where the analysis of tasks should be carried out on a perceptual level by using concepts as "field of the driver", "valences", and methods described by Lewin. Psychologically speaking, driving a car is analogous to walking or running, except that it is done by means of a tool, *the car*. Locomotion is guided by vision and guidance takes the form of a path through a visual field where driving is perceptually governed by reactions to keep the car in the field of safe travel.

The visual field of the driver is regarded as selective in that the elements of the field which is pertinent to locomotion stand out and are attended to, while non-pertinent elements recede in the background. Within the boundaries of the road, lies, according to Gibson and Crooks' hypothesis, "*...an indefinitely bounded field which we will name the field of safe travel. It coincides, at any given moment, of the field of possible paths which the car may take unimpeded*" (Gibson & Crooks, 1938, p. 454). They emphasize that the field of safe travel is not fixed in physical space. The car is moving, the field is moving with the car through space, the point of reference is not the stationary objects of the environment, but the driver himself. "*It is not, however, merely a subjective experience of the driver. It exists objectively as the actual field within which the car can safely operate, whether or not the driver is aware of it*" (p. 455).

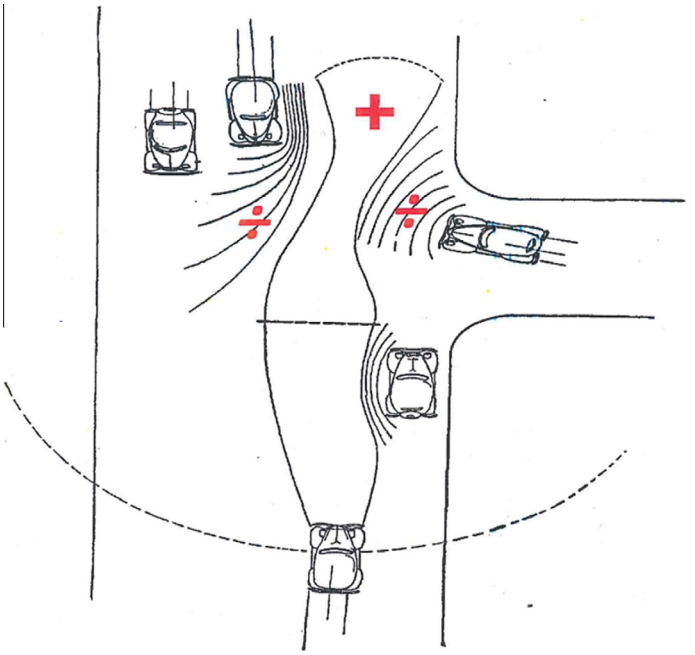

Fig. 1. Field of safe travel, minimum stopping zone and valences (amended, based on Gibson & Crooks, 1938).

Gibson and Crooks go further by asking: What is the relation between contraction (of the field of safe travel) and deceleration? They answer by developing another field concept: *The field of minimum stopping zone*. This is a field within the field of safe travel: "*Phenomenally less precise, but behaviorally and objectively just as real*...and ...*set by the minimum braking distance required to stop the car*" (p. 457). The relationship between these fields is depicted in Fig. 1 where valences are inserted to illustrate fields which attract or repel.

The minimum stopping zone – dashed line in Fig. 1 – is naturally dependent on the speed, the surface of the road, and the brakes. Gibson and Crooks discuss these concepts by asking what happens when the minimum stopping zone approaches the field of safe travel (delimited with the valence "+", making the zone marked "÷" an unsafe zone). At some point "...*a feeling of imminent collision, sometimes approaching panic, and an immediate and maximum braking reaction*" (p. 457). A feeling of danger may be regulated by developing a *field-zone ratio*, which regulates the depth-of-field relative to the depth-of-zone. This ratio tends to be maintained in given traffic conditions and is probably to a large extent habitual. This field-zone ratio can be regarded as an *index of cautiousness* and may be expected to decrease when the driver is in a hurry. It is in this context that Gibson and Crooks state the following:

> "*Except for emergencies, more efficient brakes on an automobile will not in themselves make driving any safer. Better brakes will reduce the absolute size of the minimum stopping zone, it is true, but the driver soon learns this new zone, and, since it is his field-zone ratio which remains constant, he allows only the same relative margin between field and zone as before*" (Gibson & Crooks, 1938, footnote page 458)

There, in a footnote, is the essence of what later would be called *risk compensation*! And this is almost 50 years ahead of another classic study which also addressed the significance of "better brakes": Aschenbrenner, Biehl and Wurms' study of 1987 who experimentally tested the effect of ABS on driver behaviour among taxi-drivers in Munich and who confirmed that risk compensation exists and that it can be explained by ABS, i.e. "better brakes". Let me add here, that in my thinking, it is the very *feeling* that is fed back to the drivers, providing them with improved mastery of the car in situations demanding braking, which explains the change of behaviour. Psychological learning theory has, however, rarely been adequately dealt with although Näätänen and Summala's Zero-risk Model of 1974 is an exception. The lack of adequate application of learning theories is quite odd given the prevalence of speeding and risk compensation which cannot escape explanations based on learning theory. The law of learning which is appropriate here is *operant conditioning* adopting the scheme:

$$S^D \rightarrow R \rightarrow S^R$$

where S^D denotes the *discriminative stimulus*, R the *response* (*operant*), and S^R the *reinforcing stimulus* (Atkinson, Atkinson, Smith, Bem, & Nolen-Hoeksema, 1996). Again, it is hypothesized that it is the *feeling* associated with the improved mastery of the car, which is the reinforcing stimulus, the S^R, which brings about behavioural consequences as a function of ABS. It is necessary to be very exact in the description of operant conditioning laws. Fuller's attempt to conceptualize driving behaviour as predominantly threat-avoidance fails in this respect (Fuller, 1984), in my opinion. The impression one gets when considering Fuller's 1984-conceptualization is that driving behaviour seems to be a continuous avoidance of threats, but that

would not be the common experience of every-day driving. Driving is much more than merely avoiding threats, road traffic is also an arena of social interaction, displaying "the extra motives" (Näätänen & Summala, 1974), experiences of passion and pleasure (Rothengatter, 1988), sensation seeking (Jonah, 1997), and personality traits (Ulleberg, 2001).

Considering Fuller of 1984, it is self-evident that driving involves avoidance of threats, but not conceptualized as a continuous phenomenon. Threats naturally exist, but they are very infrequent. Norwegian accident statistics say, on average, one property-damage-only accident every 10 years, or once every 140,000 km of driving. A conceptualization of driving as a self-paced task motivated by an experience of zero-risk, to use Taylor's and Näätänen and Summala's conceptions, then appears much more relevant than Fuller's conceptualization of 1984.

5. Damasio's paradigm

Why Damasio? As neurologist and representative of neuroscience, he provides a new and broader paradigm which can be applied on the narrower field of road traffic. Damasio represents a paradigm shift which is simple and axiomatic. Consider again the theories and models of Gibson and Crooks (1938), Taylor (1964), Näätänen and Summala (1974) and Wilde (1982) and we may ask: How different are these theories and models? They may all easily be labeled as "*motivational*", but, given advances in neuroscience, we should ask if not emotions might be a better and more fruitful concept. In my view, Damasio represents a paradigm that may integrate all of these models. Damasio's paradigm is more extensively described elsewhere (Vaa, 2007, 2012), so I shall only state what I think is essential in his paradigm. The base is three simple statements, which are all extracted from Damasio (1994):

- *Axiom:* Man's deepest and most fundamental motive is survival.
- *Deductions:* Humans must possess a specialized ability to detect and avoid dangers that threatens his/her survival, and an organ which provides the monitoring of potential threats.
- *Assertion:* The body is the organ and the monitor.

It follows from the axiom that the organism must have an instrument, an organ, enabling it to monitor the environment in which it acts. This organ is the organism itself, the complete body and its inherent physiology and neurology developed by evolution processes where observation and identification of dangers have been of vital importance for the survival.

Damasio separates deliberately between *emotion* and *feeling* and limits the concept of *emotion* to what goes on in the body of the organism, i.e. the myriads of changes in the state of the body that is induced autonomously when the organism is exposed to a given, external event, whilst *feeling* refers to processes of consciously experiencing the changes of the body and the mental states. Damasio defines emotions and feelings as follows:

- *Primary emotions:* Emotions that are innate and unconscious, corresponds to the neurobiological apparatus of the newborn infant.
- *Secondary emotions:* Emotions that are learnt and based on individual experiences, accumulated by the individual – i.e. as they develop into "the emotions of the adult". Predominantly unconscious or pre-conscious.
- *Feelings:* The process of *feeling an emotion,* of *making an emotion conscious*, to feel and transform changes in body states into conscious experiences.

Hence, there are two paths of information processing and decision-making, one path predominantly unconscious through primary and secondary emotions, and one predominantly conscious through the path of feelings (Damasio, 1994; Vaa, 2012).

Damasio postulates a relationship between internal states and external behaviour when the human organism is exposed to certain strain and emotional stress, which forms:

> "*. . . a set of alterations [which] defines a profile of departures from a range of average states corresponding to a functional balance, or homeostasis, within which the organism's economy probably operates at its best, with lesser expenditure and simpler and faster adjustments*" (Damasio, 1994, p. 135)

A central concept in the above citation is the *functional balance*. In the Risk Monitor Model (RMM) I label this balance as *best feeling*, or *target feeling*, which drivers are seeking to maintain or restore. There is no doubt that this seeking drive is motivational, but emotion and feeling are both concepts that come closer to what actually is going on organically in an individual.

6. Miller's cognitive span

G.A. Millers article of 1956 "*The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information*" is one of the most cited papers in psychology (Miller, 1956). The interpretation is that the number of items a human can keep in the working memory is 7 ± 2 (this is probably the reason why most pin-codes consist of only 4 digits), but what is an "item" in this context? Is it digits, letters, words, "objects"? Memory depends also on *chunking*, a term suggested by Miller for the organizing process where bits of information are collected together perceptually and cognitively into larger, coordinated wholes, or 'chunks' (Reber & Reber, 2001). You will probably have difficulties in remembering the 10-digit number 1632615466 when looking for just a couple of seconds, but organizing it as 16326 15466 – or better 16.32.6 and 15.46.6

– a 65-year old Norwegian sports-enthusiast will immediately recognize these numbers as the world-records of 10,000 m speed skating set by Hjalmar "Hjallis" Andersen in 1952 and Knut "Kupper'n" Johannesen in 1960 (they both won gold-medals on 10,000 m speed skating in Olympic Winter Games, Hjallis in Oslo in 1952 and Kupper'n in Squaw Valley in 1960).

Later research on working memory revealed, however, that memory span is not a constant even when measured in a number of chunks. The number of chunks a human can recall immediately after presentation depends on the category of chunks used – e.g., the span is around seven for digits, around six for letters, and around five for words (Cowan, 2001). Cowan has proposed that working memory has a capacity of only about four chunks, the average is said to be 3.8, which means some will have to make a list of what to do or buy if the number of items is more than three (surely true for me).

Why this detour back to Miller, 1956? Firstly, to remind ourselves that the cognitive span of the working memory is limited and indeed limited when drivers make decisions in road traffic. Secondly, that there is a difference between recalling digits in an experimental context and comparing alternatives of what to do as a driver in road traffic. Thirdly, it provides a basis for arguing against the rationalist belief that an individual is able to consider all alternatives, weighing them together, and find the best solution without involving emotions and feelings in the dynamic and continuously changing time-windows, which characterize driving. In my view, it is the opposite, it is what is stripped from the rationalist belief, the emotions and feelings, which provide solutions by guiding the driver to handle the risks as they come and go in the processing of information and decision-making and where cognitive involvement only will be called upon when the context demands it.

7. Damasio: Understanding conscious decision-making

In his Risk Homeostasis Theory (RHT), Wilde develops a model based on control theory/cybernetics and economic utility theory (Wilde, 1982), i.e. not on psychology. Wilde introduces the concept of a *comparator,* which implies that something is being compared (consciously). This must be understood as an ability of the working memory where the target risk can be altered by considering benefits and costs from risky and cautious behaviour. I understand these appraisals as rationalist thinking as in economic utility theory, i.e. fully conscious appraisals with no reference to unconscious processes. There is no reference to unconscious processes at all in Wilde's RHT as I understand it. Another limitation of the RHT is whether a human being is capable of considering cognitive appraisals like

- desired adaptations,
- aggregate accident loss in a population,
- estimation of time-lagged and individually perceived road-accident risks,
- estimation of effects of new countermeasures,
- appraisals of benefits and losses of risky and cautious behaviours,
- bring the outcome of all these appraisals of variables to the comparator

and hold them up against the wished-for target risk of the individual driver who performs them by keeping track of all the results from preceding calculations in the model. My view is that this is simply impossible. There is only one simple answer, which can solve this complicated arithmetic, and that is that the target risk simply is zero. As in Näätänen and Summala's zero-risk model of 1974. This is my understanding and position too.

There are two issues here which connect to Damasio: First, the conception of driving as motivated by a perception of zero risk, would be in agreement with Damasio's axiom that man's deepest motive is survival. The second connection lies in the concept of "cost-benefit analysis". Both Wilde and Damasio use this concept but the inherent essences are different. As said, I understand Wilde's conception as in line with rational thinking by an appraisal of *all* potential benefits and losses of risky and cautious behaviours, while Damasio opposes the rationalist view that human beings consciously consider and weigh all alternatives against each other as if there is a thorough "cost-benefit analysis of the mind". It is rather the opposite, still of what might be called a cost-benefit analysis, but the point is to *limit* the alternatives, and to apply feelings to consider them: Without feelings, no appraisals. Damasio speaks best for himself:

> "*. . ., imagine that before you apply any kind of cost/benefit analysis to the premises, and before you reason toward the solution of the problem, something quite important happens: When the bad outcome connected with a given response option comes into mind, however fleetingly, you experience an unpleasant gut feeling. Because the feeling is about the body, I gave the phenomenon the technical term somatic state and because it "marks" an image, I called it a marker. . ...*
> *. . ...What does the somatic marker achieve? It forces attention on the negative outcome to which a given action may lead, and functions as automated alarm signal which says: Beware of danger ahead if you choose the option which leads to this outcome. The signal may lead you to reject, immediately, the negative course of action and thus make you choose among other alternatives. The automatic signal protects you against future losses, without further ado, and then allows you to choose from among fewer alternatives. There is still room for using a cost/benefit analysis and proper deductive competence, but only after the automated step drastically reduces the number of options*" (Damasio, 1994, p. 173).

This is what I regard as the essence of decision-making in Damasio's terms. And we are back to Miller's average of 3.8 items. Or maybe only 3, or 2, but still a weighing-together, and still by letting feelings tell the difference and provide the conclusion of what to do.

8. Yerkes–Dodson law

Rediscovering Yerkes–Dodson law is in fact a good example of the barrier I sometimes felt between psychology and road safety research. I may be wrong on this, but I cannot remember having seen much reference to it in elaborated driver behaviour models. This is quite strange as it is highly relevant in building models. Yerkes–Dodson's law stems from experiments, which Yerkes and Dodson reported in 1908 when they needed definite knowledge on how the strengths of stimuli were related to learning (Yerkes & Dodson, 1908). Fig. 2 shows Yerkes–Dodson law.

The law indicates that performance increases with physiological or mental arousal, but only up to a point. When levels of arousal become too high, performance decreases. For simple or well-learned tasks, the relationship can be considered linear with improvements in performance as arousal increases. For complex, unfamiliar, or difficult tasks, the relationship between arousal and performance becomes inverse, with declines in performance as arousal increases (Yerkes & Dodson, 1908). I understand the Yerkes–Dodson law as there is an optimum between arousal, or effort, and performance, which could be very relevant for understanding drivers' choice of driving speeds. It may explain why drivers adhere to GSR-constancy in their driving as well as choosing driving speeds in Näätänen and Summala's zero-risk model (Näätänen & Summala, 1974; Taylor, 1964). Many driving speeds may realize a zero-risk condition, but drivers may want to achieve something else too which would be the optimal performance realized in a specific feeling of arousal. Hence, a fulfillment of a 'zero-risk' is not sufficient, there has to be another dimension added to it as well. This is also in line with the elaboration of the RMM: In addition to avoid accidents, drivers seek a certain *target feeling*. This feeling is not the same in all drivers, drivers have their own idiosyncratic target feelings, which is not necessarily experienced consciously (Vaa, 2007). This is also in line with Damasio's statement cited previously: [to choose] "*. . .states corresponding to a functional balance, or homeostasis, within which the organism's economy probably operates at its best. . .*" (Damasio, 1994).

9. Personality traits

As mentioned in the introduction I missed theories of personality and personality traits, and, that I found the psychological understanding of the driver in the 1980s and 1990s too shallow. Labeling drivers as "sensation seekers" or "aggressive" assumes one-dimensionality and neglects the dynamics of intra-psychic activity, emotions and appraisals. Personality traits can be regarded as dimensions of individual differences in the propensity to display consistent patterns of cognition, emotions and behaviour. The most complete mapping of personality traits in drivers has, as I see it, been provided by Ulleberg and is properly reported in this journal earlier (Ulleberg, 2001). What Ulleberg manages to do by applying the validated "BIG-5" test-battery is to link attitudes, motives, behaviour and accidents with personality traits. Through the use of cluster analysis he discerns between six separate subgroups of drivers, each comprising about 15–20% of the drivers. He labels each subgroup by using a key characteristic:

1. "*Considerates*": Slightly more women than men, accident risk lower than average.
2. "*Socially deviants*": 80% men, accident risk above average.
3. "*Anxious*": More than 80% women, accident risk below average.
4. "*Considerate sensation-seekers*": Average accident risk.
5. "*Aggressive*": About 60% men, accident risk above average.
6. "*Adaptable, but egoistic*": About 60% men, average accident risk.

These key characteristics may also provide some images regarding how drivers may act, interact, and contribute, differently in the social system of road traffic: Some by avoiding and solving conflicts, some by creating conflicts, and some by taking personal advantages of what road traffic may afford in terms sensation seeking or strategic maneuvers in an egoistic sense. Any driver behaviour model that aims to be complete, should integrate an understanding of personality traits and how

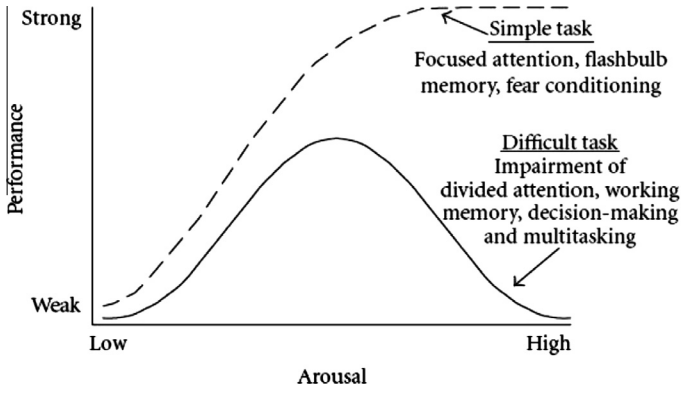

Fig. 2. Yerkes–Dodson law (from Yerkes–Dodson law, 2012).

they influence behaviour in their model. I think Ulleberg provides the most comprehensive and detailed analysis of the impacts of personality traits on behaviour and accidents in traffic. In addition, Ulleberg also discusses the potential impact of *deep motivation*, which I understand as potentially unsolved, emotional conflicts that may be expressed and displayed as aberrant behaviour in road traffic.

9.1. Epilogue

The time-span has been somewhat expanded as compared to my presentation during the International Conference on Traffic and Transport Psychology in 2012, and I should have perhaps used "From Yerkes–Dodson to Ulleberg" rather than "From Gibson and Crooks to Damasio" as a title. New things pop up when you write and think. More important, however, is a rediscovery of Gibson's *Theory of Affordances* presented in his book "*The ecological approach to visual perception*" (Gibson, 1986), a rediscovery also done by Summala (2007). Gibson developed an interactionist view of perception and action which focuses on information that is available in the environment and which rejects the assumption of factoring external-physical and internal-mental processes (Greeno, 1994). It strikes me that this theory of perception may serve as an alternative to the ongoing debate of understanding hazard perception by emphasizing that the road system also has affordances, not only dangers. A revisit to Gibson's theory on affordance might also be worthwhile.

Not many have addressed the pleasure and passions of driving. Rothengatter did it in 1988, but Gibson and Crooks may have been the first also to address this topic of car driving:

> "*Driving 'for pleasure' may be considered, however, in common with most play, the using of a tool – a very ingenious, elaborate, and versatile tool – it is not surprising that like most tools its manipulation, once acquired, may be an end in itself.*" (Gibson & Crooks, 1938, p. 456)

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