Driver distraction from some theoretical perspectives

TRAIL Research School, October 2012

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Abstract

This working paper describes a selection of several driving related theories, concepts and classifications in order to identify important components for a framework of driver distraction. The relative value of classification models such as Michon's (1985) and Reason's error taxonomy (1990) is discussed as well as some of the human factors approaches including workload models such as the task-capability interface model (Fuller, 2005). Furthermore the evolution of motivational models, focusing on how feelings of risk influence driver behaviour are described. The useful components of the models are identified and may be used to form a theoretical framework that is able to deal with the several components of distracted driving.

Keywords

Driving, distraction, models, theory, behaviour.

1 Introduction

For investigating distracting effects of navigation system and mobile phone use while driving it is valuable to have a convenient heading to classify the effects. Therefore, this paper deals with some of the theorising and modelling that has been performed over the years on the topic of driving, thus building on the shoulders of giants.

Driver safety can be seen in the light of interactions between road users, leading to undisturbed passages, (driver is not influenced by another driver) conflicts (drivers are on collision course), and accidents (cars hit), see figure 1, as adapted from Hydén (1987). However, accidents are not too common. Therefore we look at how well drivers perform the driving task, as an indicator of safety. It is assumed that drivers that are distracted by navigation systems and mobile phones are generally less able to attend all elements in traffic (hence: distraction). This, as shown in the coloured adjustment in figure 1, may increase danger (a larger tip of the iceberg). Note that this figure is not meant to indicate any relation between numbers related to accidents.

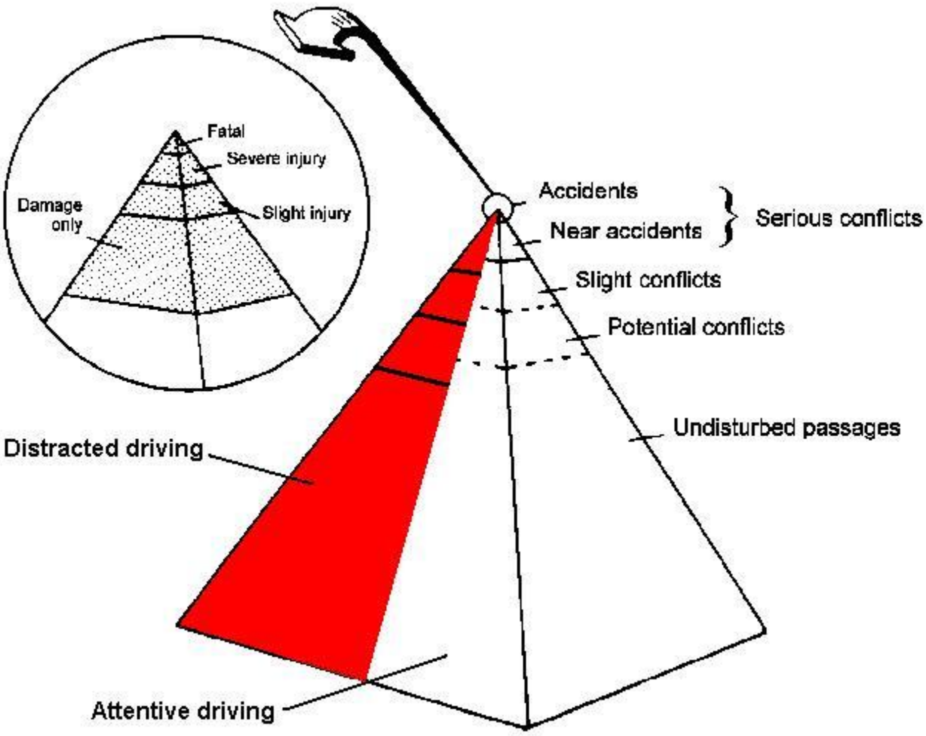

Figure 1: The interaction between road users (adapted from Hyden (Hydén, 1987, p27), adjusted with a distinction for distracted and attentive driving

It is a noteworthy fact that many scholars have tried to deal with the driving task, but no GUT (‘Great Unified Theory’) has been developed yet, as for instance Vaa (2001), Summala (2005), Ranney (1994) and Evans (1991) notice. A major cause for this is the lack of understanding of how drivers actually think and feel, as based on psychological and neurobiological findings, and that the models that do exist provide only aspects of the driving task (Vaa, 2001). Ranney (1994), in an overview of driving behaviour models, blames the absence of a complete model on the complexity of driving, and the fact that research has focused more on hazardous driving behaviour than on everyday safe driving. The same observation is made by Hancock, Mouloua & Senders (2009), who thinks that accidents are too unpredictable to be used to predict the driver's behaviour, as they are on the tails of the distribution. Although they think zero accidents should be the ultimate goal of driver safety research, they see more fit in a driving research focusing on 'a marriage of ecological and quantitative behavioural science'.

Still, there are many models and theories that can be applied to explain to driving behaviour, too many to discuss in detail in this paper. Therefore we decided to look for models and theories that could help understand driver distraction (cognitive as well as visual) and did provide more of a psychological framework than a mathematical model, for experienced drivers. The selected models and theories that fit these interests, and also some necessary to provide context for others are sought to fit in a framework that would answer the question as to what the driving task is about, how driver factors influence driving and why drivers drive the way they do. To the informed reader, this might bear some resemblance to the layouts used by Ranney (1994) and therefore Michon (1985). There is, of course, quite some overlap between the different classes.

2 What is the driving task about?

One very early paper on driving behaviour is Gibson & Crooks's 'theoretical field-analysis of automobile-driving' (1938). They composed the concept of a 'field of safe travel', a tongue-shaped area in front of the car that consists of the paths a car can take safely and is visible to the driver. A driver's goal was then to keep steering the car in the middle of this field, in order to drive safely. The (invisible) borders of the field of safe travel were determined by natural boundaries (i.e. things / conditions that can block vision), inflexibility of higher speeds (skidding), (moving) obstacles, potential obstacles (for example because of a blind corner), and legal constraints (see figure 2). Gibson & Crooks claim that the more experience a driver gains, the more automatic his recognizing and reacting to obstacles becomes, and therefore the safer he drives.

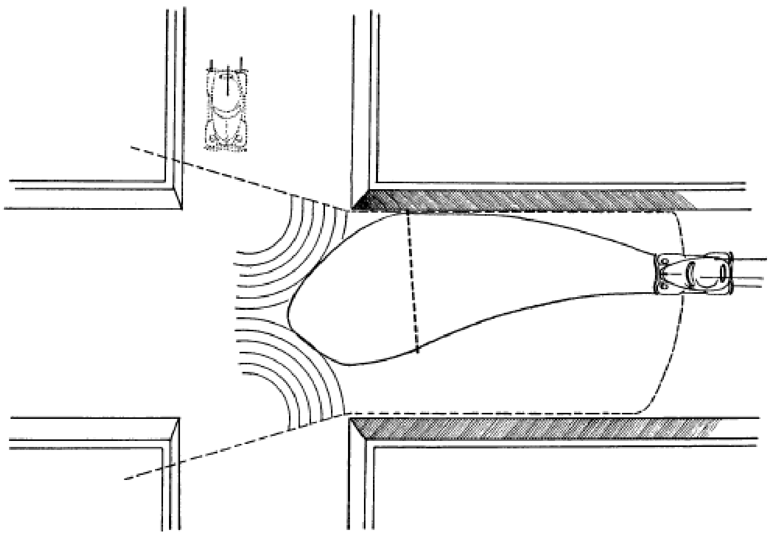

Figure 2: Taken from Gibson & Crooks (1938). Original caption: ***A blind corner constituting a barrier to vision and its effect on the field of safe travel. At this moment the clearance-lines of potential obstacles cut off the field.***

Hancock et al. (2009) notice the resemblance with Situation Awareness. Situation awareness refers to knowing what is going on around you (Endsley, 2000), and consists of three levels. First, perception of cues. Drivers may for instance be hindered by a blind corner, or look in the wrong direction. Second level concerns comprehension, so what people do with the information, how they process it. For drivers, this may relate to the looked-but-failed-to-see phenomenon (Hills, 1980). The third level of situation awareness involves projection, i.e. forecasting future stations, which Endsley (2000) thinks fits especially experts, who may develop into a level of automaticity in performing the driving task. Automaticity has long been recognized to lead to quicker and more accurate performance requiring little attention (Shiffrin & Schneider, 1977) and fewer errors (Reason, 1990).

This kind of automatised processing can be linked to Michon's (1985) classification of the driving task into different levels. Michon describes the driving task as a problem solving task that can be dealt with on the strategic, tactical and operational level. On the strategic level, the planning of the trip takes place, in terms of trip goals, a route, and a cost/risk analysis. This would include choices on whether or not to use a navigation system, planning on when to set the destination, and for example turning off the mobile phone. On the tactical level, the car is manoeuvred, avoiding obstacles longitudinally as well as laterally, overtaking, and turning, determined by the strategic level goals. This could include phoning and destination entry while driving. At the operational level, the vehicle is controlled, by shifting gears, braking, steering. These operations can be influenced by tactical decisions, for instance by braking before a corner, in principle in an automatic fashion. Rasmussen's Skill-Rule-Knowledge model follows similar lines ((Rasmussen, Duncan, & Leplat, 1988), adapted from (Wickens & Holland, 2000)) incorporating three levels of behaviour. Hale et al. (1990) elegantly combined these models into the a matrix of exemplary tasks (see figure 3). They hypothesise that drivers at rule- or skill-based levels operate better (more homogenous and more predictable) that knowledge-based level drivers.

	Planning	Manoeuvre	Control
Knowledge	Navigating in strange town	Controlling a skid on icy roads	Learner on first lesson
Rule	Choice between familiar routes	Passing other cars	Driving an unfamiliar car
Skill	Home/work travel	Negotiating familiar junctions	Road holding round corners

Figure 3: Hale et al.'s (1990) matrix of tasks

While driving, people may fail to act safely. Reason (1990) distinguishes errors from violations, as violations are deliberate deviations from safe practice, whereas. Errors may be classified in slips and lapses (due to inattention), and mistakes (consequence of a wrong choice). Slips may occurs when we perform a largely automatic task in familiar surroundings, which may cause absent-mindedness, and we suddenly become aware that we crossed a line. This may also well occur during a phone conversation. Lapses are quite similar but involve also memory failure (where was I going?). Mistakes may occur in case of planning failure, often at the knowledge or rule level, when objectives are not achieved (we took the wrong way because the map was upside down). It may be clear that some distracting acts are already violations (texting for instance). Figure 4 provides an overview of Reason's (1990) error taxonomy.

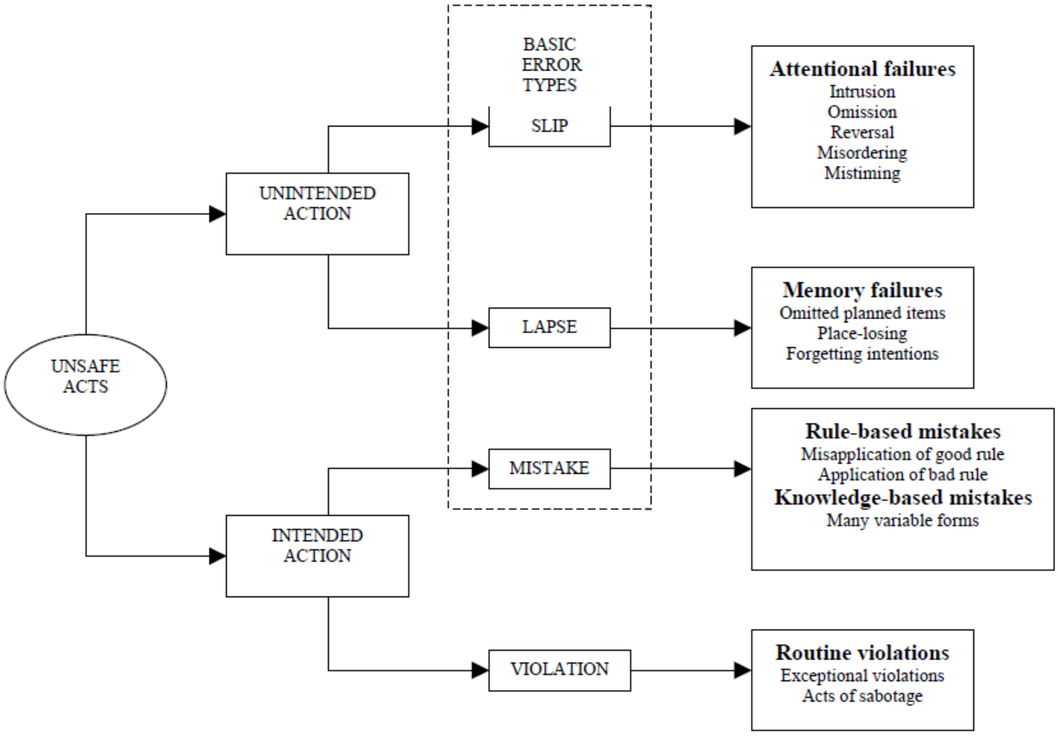

Figure 4: Error taxonomy by Reason (1990), copied from (Salmon, Regan, & Johnston, 2005)

It should be noted that many failures at several levels by several parties are needed for road crash to happen, as Reason argued and showed in the Swiss cheese model, for instance in (Wegman & Aarts, 2006, p31).

Ranney et al. (2000) recommend to think of driver distraction to incorporate four categories:
1.Visual, for instance not looking at the road ahead.
2.Auditory, for example looking at the satnav making a speed check warning sound.
3.Biomechanical, e.g. fetching something out of the glove department.
4.Cognitive, as in daydreaming or thinking intensely about something.
Many distractions may involve more than one of these categories. Texting for instance need the driver's eye, a hand and probably some cognitive input.

The work described above consists of mostly descriptive classification models, and therefore may be of limited value to analyse road safety (Salmon, Lenne, Stanton, Jenkins, & Walker, 2010). Still, the models provide good arrangements of the several levels and components of thinking, doing and erring, and thereby allow for putting driving behaviour into perspective, and identifying where driver distraction fits in. Some underlying mechanisms, providing more detail on how components of the driving task have been theorised about, are described in the next part.

3 How? Driver factors

Performing two tasks simultaneously has long been a topic in research. It was recognised a principle of psychology already by William James (1890) that two (or more) processes of perception cannot easily be performed at the same time, unless the processes are very *habitual* which may refer to automaticity already. Similar observations were done by Kahneman (1973), who noted that a conversation while driving is interrupted when the demands of driving activity become critical. These are important predecessors of Multiple Resource Theory (MRT; Wickens, 2002; Wickens, 2008), that distinguishes four dimensions on which information processing resources may vary, namely:

1. Stages of processing: perceptual vs. cognition (e.g. working memory) vs. responding.
2. Codes of processing: verbal vs. spatial control.
3. Modalities: auditory vs. visual.
4. Visual processing channels: Focal vs. ambient. This was added later, for distinguishing what the driver was looking at from peripheral vision, in which especially orientation and movement can be perceived (Wickens, 2008).

Applied to driving, MRT states that driving performance is least hindered by two tasks when they use different levels along the dimensions. MRT would then predict that the task of driving, which would be primarily visual and spatial , should be reasonably well time shard with speaking, which is auditory and language based

Also interesting for investigating driver distraction may be the SEEV model (Wickens & Horrey, 2009) which was originally developed for airplane pilots(Wickens, Dixon, & Chang, 2003). The model supposes four factors that are involved in acquiring visual information: Salience describes how well an event grabs the attention, for instance by loud noises or bright lights. Effort describes how much it takes to switch attention. Especially when two visual tasks are spatially far apart, it takes more effort to perform them, or more errors are committed or more time is taken. Expectancy refers to top-down attention, that drivers for instances know what to expect and focus their attention on that. Value, or expected value, deals with how important a source of information may be, and is related to the expectancy. The SEEV model may be used to predict, based on value and expectancy, what will be a driver's target of attention.

Related to MRT, the workload the tasks pose on drivers resources plays an important role. Where two single tasks may be performed well separately, (i.e. a driver has sufficient capacity to perform them) a driver may not be able to perform them simultaneously. Thus the driver is distracted (from the primary driving task), that is, he has limited information processing capacity, or high mental workload (De Waard, 1996; Wickens & Holland, 2000). De Waard (1996) shows in his model (figure 5) that mental workload interacts with task performance in a complex way, and that effort may compensate for high workload to a certain level. A distracting secondary task may, in this model, be compensated for by increasing effort, but only to a certain level. After that, performance will deteriorate.

Other factors that influence performance are task difficulty, the demand the task poses. Experience will decrease difficulty, just like well applied strategies and optimal driver state, by deciding the amount of processing resources applied. A complex task will increase difficulty.

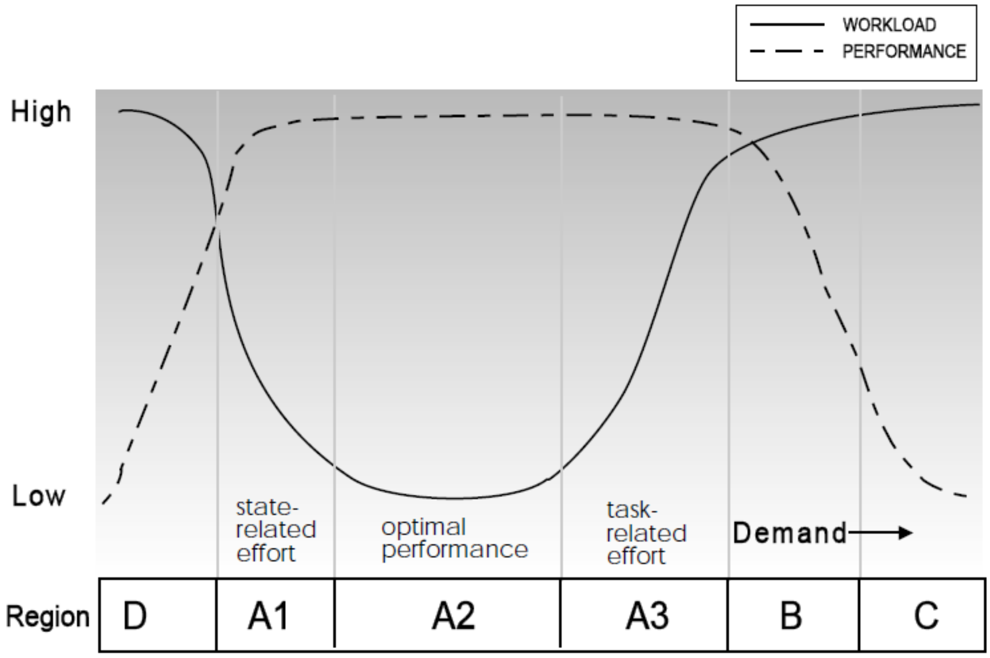

Figure 5: Relation between workload and performance (De Waard, 1996)

In the Task-Capability-Interference model (Fuller, 2005), task difficulty can be inferred from the comparison between capability and task demands. A task is easy if a drivers' capability exceeds the task demands, is difficult if they are equal, and is too difficult to perform if the demands exceed the capabilities. Task demands depend on factors such as road context, vehicle, speed, and other road users, together the objective complexity of the task. Capability may depend on the driver's experience, training, which set the upper limit of a driver's competence, but his capability may be hampered by fatigue, drugs, stress and distraction (Fuller, 2000) and effort (Fuller, 2005). Task demand and to a certain degree also capability may be influenced by drivers on a strategic, tactical and operational level (Fuller, 2005). Fuller's TCI model is visualised in figure 6.

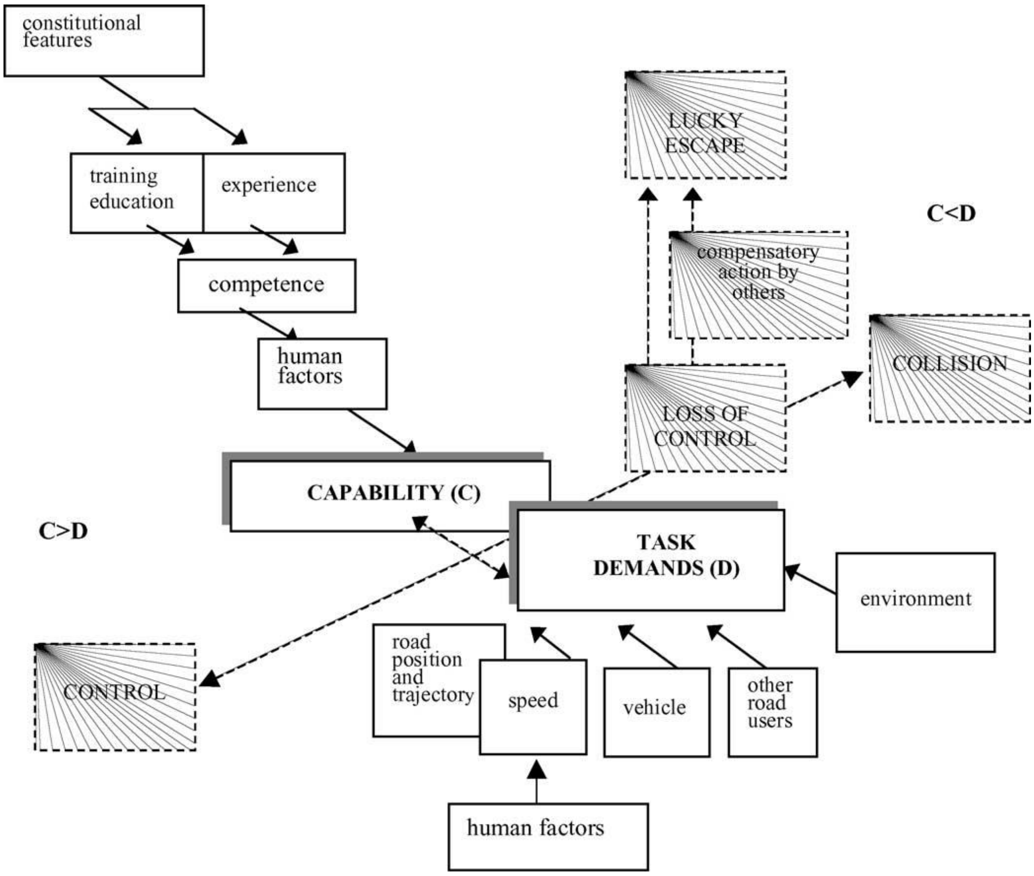

Figure 6: Task-Capability Interface model (Fuller, 2005)

Applying the TCI model to distraction, distraction leads to a deteriorated capability, which may be compensated for by the driver decreasing speed, and thus decreasing task demands. Or, the combined tasks may become too difficult to perform, and the driver experiences loss of control, with all the consequences that will entail. On the other hand, distraction has a more complex way of overlapping with workload, as drivers might use distracting activities to keep from falling asleep due to low workload (Sheridan, 2004).

4 Why? Driver motivations

The main motivation to drive probably lies in the fact that we need to get from A to B, in safe and comfortable fashion. However different drivers make different choices regarding for instance speeding, car make and model, and using in-vehicle technology while driving. Answering the why question in relation to behaviour is what has motivated psychology to arise, and when a complete science focuses on a question, it must be an important one. Motivational driver theories have been the topic of debate for decades, and Gibson & Crooks already mention that a driver '*does all these things because he has learned to do them, not because he is frightened into a continual stat of strained attention.*'

It seems to have started with the findings by Taylor(1964) that drivers adopt a certain level of risk (or anxiety). He used galvanic skin responses which occurred in response to small hazards, which may be considered a measure of subjective risk. Thus, Taylor theorises that increasing subjective risk may lead drivers to increase concentration and attention to hazards, thus decrease objective risk in order to keep down their level of anxiety.

This lead Näätänen & Summala (1974; Summala, 1988) to postulate the zero risk model, claiming that drivers aim to keep subjective risk as low as possible. Therefore indeed increasing subjective risk would lead to safer diving, as driver then adopt strategies to decrease their risk.

The same mechanism was developed in the Risk Homeostasis Theory (Wilde, 1982, 1988), that essentially states that drivers try to keep a constant target level of subjective risk as compared to statistical risk. Over time, this would mean that drivers increase subjective risk in response to safety measures. Although highly criticised for incorporating statistical risk (Evans, 1991, p299; McKenna, 1988), Risk Homeostasis has had its value in preventing accidents from happening (Wilde, 1994), and introducing the mechanism of homeostasis.

In the same decade, Fuller (1984), in response to the zero risk model and the risk homeostasis theory, conducted a behavioural analysis of driving, coming to a threat-avoidance model, that is not so much based on subjective risk (as a subjective probability of having an accident), but merely on likelihood of a *potential* threat. Furthermore, Fuller does not see maintaining a level of risk to be the motivation of driver behaviour, but responding in order to avoid threats in a more general sense, trying to stay within certain safety margins (Fuller, 1984, 2005). This developed the aforementioned into the Task-Capability Interface model (Fuller, 2000, 2005) that claims that drivers strive not for risk but for task difficulty to maintain a certain level.
Still, other authors have noted that just risk can hardly account for all driver behaviour (Evans, 1991). Pleasure could be a motivation for speed choice (Rothengatter, 1988) or for instance a target feeling of sensation, relaxedness, or vigilance (Vaa, 2001).

Later, Vaa (2007) adopted this into his Risk Monitor Model, including the feelings that are conscious experiences of how the body reacts emotionally. This is based on the somatic marker theory by Damasio (1994) that states that bodily reactions such as sweaty hands, muscular contractions, have an influence on our decisions. Thus the Risk Monitor Model describes driving as a continuously changing environment in which the driver aims of the best feeling obtainable (Vaa, 2007), including, next to risk, other feelings such as arousal, joy, relaxation.

Fuller (2011) notes that some of these feelings are past driving safety motivation. He presents the RAT (Risk Allostasis Theory), specifying task difficulty component of the Task-Capability Interface model, focusing on safety. RAT was based on findings that perceived task difficulty was related to feelings of risk (see Fuller, 2011; Mesken, Hagenzieker, Rothengatter, & de Waard, 2007; Stradling et al., 2008), and predicted that a driver's feeling of risk is kept between certain limits, by attuning his behaviour.
Threshold theories, state that task difficulty and feeling of risk ratings are stable until a certain speed is reached, specifically around 50 kmh on residential roads and 110 kmh on a motorway (Lewis-Evans, de Waard, & Brookhuis, 2011). This may offer input for potential changes to these theories (Lewis-Evans, de Waard, & Brookhuis, 2010).

Hancock et al. (2009) see two forms of distraction; the first depends on the drivers' social role that distracts the attention away from the primary driving task, with the vivid example of a mother who has to turn around to reseat her unrestrained child. Another example, linked to this thesis, could be that of a working man taking care of business on his cell phone. The second form of distraction Hancock et al (2009) describe is merely a matter of the driver not focusing on the right aspect of the driving task at the moment this is needed.

Contemplating on all this, there seems value in a distinction of driver distraction being planned, in case of low feelings of risk. Taking into account the aforementioned threshold effects, this may lead to suggest that drivers are inclined to add to task demands by engaging in distracting activities more so when speed is relatively low, perhaps even more so when halted. On the other hand there are distractions drivers are just confronted with, unplanned, for instance incoming phone calls or navigation system warnings, which may be hard to ignore.

5 Implications for distraction

Young, Regan, & Lee (2009) provided an overview of some factors moderating distraction effects (see fig7). From this it is clear that distraction can be dealt with on many levels of driving task performance, and the list is not nearly exhaustive.

It is useful to take into account how a driver's awareness of what is going on around him may deteriorate when driving distracted. He may miss events, forget where he was going and be less able to project what might happen. The automatic nature of many parts of the driving task may play an important role in the sense that experienced drivers could be less hampered by distracting activities.

The overview also shows the usefulness of describing behaviour at several levels; should effects be described in simple operational effects, or also higher level timing distractions, or planning to do avoid distracting activities. In a similar way, describing whether an error is a lapse or a mistake may have important implications for recommendations to change certain practices. Using mobile phones may distract from driving in conversations (cognitive, auditory, perhaps manual), but in a much different way when texting (visual, manual, perhaps cognitive), which has its similarities with operating a navigation system (visual, biomechanical), but not with following route guidance instructions. Multiple Resource Theory may provide interesting directions for predicting whether some distractions are worse in terms of effects on driving performance based on the fact that they are (dis)similar to the visual-spatial driving task. The SEEV model provides important clues about how operators / drivers deal with the visual information provided to them.

The motivational models teach us that the driver may be motivated by fear or risk, at least partly, but that he is also capable of regulating those feelings. The demands of the driving task are heavily influenced by a secondary task, and therefore, drivers may tend to slow down in order to decrease the difficulty of the togetherness of the tasks. It is interesting to see where the theorising is taking us.

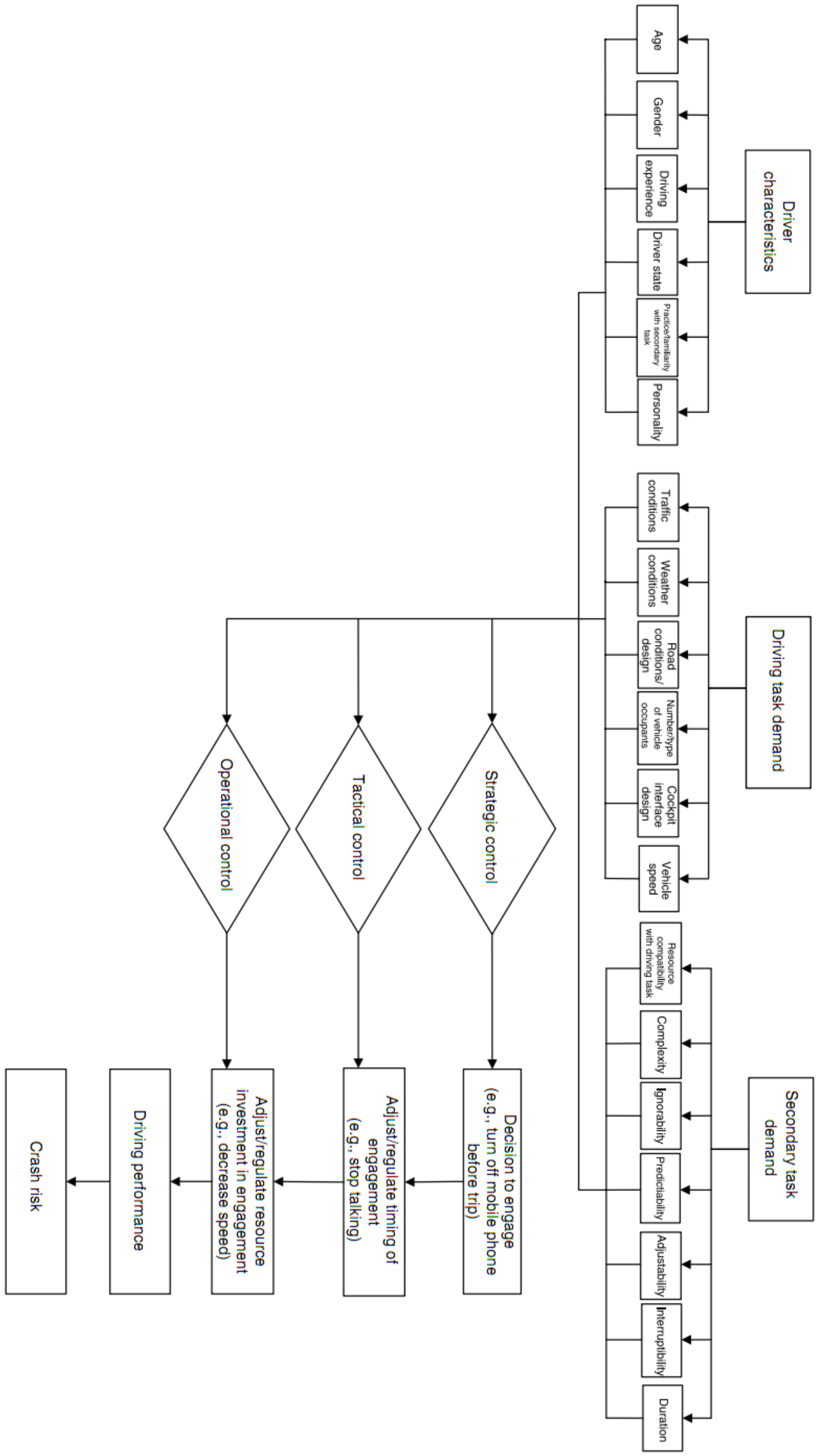

Figure 7: Factors moderating the effects of distraction on driving performance (Young, et al., 2009)

6 Conclusions

The models, theories and ways of thinking about driving described in this paper are on the one hand quite different, ranging from just providing a taxonomy to incorporating vast amounts of possible factors influencing driving.
There are of course many other models and theories that were not included in this paper, for either scientific or practical reasons. For instance, mathematical models did not receive much attention, neither did we pay much attention to subjects like activation level or age and gender differences. However, it is striking that the incredible amount of models still leave a lot of room for so many gaps in our understanding of how distraction works and why.

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