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Abstract

Risk Allostasis Theory states that drivers seek to maintain a feeling of risk within a preferred range (Fuller, 2008). Risk Allostasis Theory is the latest version of Task Difficulty Homeostasis theory, and is in part based on the findings of experiments where participants were asked to rate the task difficulty, feeling of risk and chance of collision of scenes shown in digitally altered video clips (Fuller, McHugh et al., 2008).

The focus of the current research was to expand upon the previous video based experiments using a driving simulator. This allowed participants to be in control of the vehicle rather than acting as passive observers, as well as providing additional speed cues. The results support previous findings that ratings of task difficulty and feeling of risk are related, and that they are also highly related to ratings of effort and moderately related to ratings of comfort and habit. However, the linearly increasing trend for task difficulty and feeling of risk described by the previous research was not observed: instead the findings of this experiment support a threshold effect where ratings of risk (feeling of and chance of loss of control/collision), difficulty, effort, and comfort, go through a period of stability and only start to increase once a certain threshold has been crossed. It is within the period of stability where subjective experience of risk and difficulty is low, or absent, that drivers generally prefer to operate.

1. Introduction

The underlying controlling factors of everyday driving behaviour have been debated extensively for many years (e.g. Michon, 1989; Ranney, 1994; Rothengatter, 2002). Models put forward have included attitude theories such as the Theory of Planned Behaviour (Ajzen, 1991), learning theories such as the threat avoidance model (Fuller, 1984), economic models such as Peltzman's (1975) driving intensity model and motivational models such as Risk Homeostasis Theory (Wilde, 1976; Wilde, 1982; Wilde, 1988), zero-risk theory (Näätänen & Summala, 1974; Summala, 1997) and the multiple comfort zone model (Summala, 2005; Summala, 2007). However, none of the proposed models have yet managed to achieve wide-spread acceptance amongst a majority of traffic researchers. The lack of a well-agreed understanding of the underlying controlling factors of everyday driving creates problems for road safety professionals. If effective interventions are to be put into place, then a good understanding of exactly what guides driver behaviour is important. It is also vital, given that these models could be used when designing interventions, that they are tested in order to determine their validity.

In 2000, Fuller proposed a new model; The Task-Capability Interface (TCI) model, and its accompanying Risk Allostasis Theory (RAT), states that a feeling of risk, as an indication of task difficulty, is the primary controller of driver behaviour (Fuller & Santos, 2002; Fuller, 2005; Fuller, 2007; Fuller, McHugh et al., 2008; Fuller, 2008). The basic premise behind TCI is that driving is an interaction between the demands of the environment in which the behaviour is being produced, and the capability of the individual producing the behaviour. This interaction produces the difficulty of the task being performed which is then perceived by drivers, and if task difficulty becomes too great then loss of control occurs (Fuller, 2000; Fuller & Santos, 2002; Fuller, 2005; Fuller, 2008; Fuller, McHugh et al., 2008). In this way TCI is more a description of the driving task rather than a model which predicts everyday driver behaviour.

It is instead RAT that takes on the aspect of a predictive model. RAT states that individuals have a preferred range of perceived feeling of risk in which they operate and that they will alter their behaviour to maintain the feeling of risk within this preferred range (Fuller, 2008). An individual's preferred level of feeling of risk is determined by their current and long term motivations, along with how capable they currently perceive they are. This means that this range of preferred feeling of risk is not set and may alter as an individual's motivations and perceptions of their capability change (Fuller & Santos, 2002; Fuller, 2005; Fuller, 2007; Fuller et al., 2008; Fuller, McHugh et al., 2008). That preferred feeling of risk is a range, and that it is flexible differentiates RAT from Risk Homeostasis Theory, where target level of risk was seen as less flexible and more of a discrete target (Wilde, 1976).

However RAT, like Risk Homeostasis Theory, does still rely on the constant monitoring of a variable, in this case feeling of risk, which in turn is an indication of task difficulty, and comparing it to a preferred level. RAT in itself is a replacement for Task-Difficulty Homeostasis (TDH) theory in which a preferred range of task difficulty was monitored (Fuller & Santos, 2002; Fuller, 2005; Fuller et al., 2008; Fuller, McHugh et al., 2008; Fuller, 2008). When the model was still called Task-Difficulty Homeostasis the monitoring of difficulty was at one point related to the monitoring of mental workload (Fuller, 2005). Furthermore, it was originally predicted that feelings of risk would act in a threshold manner, acting as a warning to drivers that they were near the edge of their preferred range of task difficulty (Fuller, McHugh et al., 2008). However, since that time TDH has developed into RAT and feelings of risk have become a constantly monitored variable. In particular feeling of risk is not seen as a variable that is only salient after a certain threshold has been crossed, as suggested by zero-risk theory (Näätänen & Summala, 1974; Summala, 1997), but rather is continuously salient in its influence on driver decision making. However, while feelings of risk are continuously salient, drivers may not be aware of their influence on their decision making. This is seen in the following statement:

"... the effects of risk feelings on decision making are not binary (one moment they are irrelevant, the next they become salient): task difficulty and feelings of risk are continuously present variables which inform driver decisions (whether consciously or not). However, only when some threshold point is reached may risk feelings become particularly salient in driver consciousness" Fuller et al. (2008, p. 31).

In combination with this constant monitoring of feeling of risk is a threshold type relationship thought to warn individuals when they are operating outside of their preferred range of feeling of risk. It is also perhaps the point which feelings of risk may begin to consciously effect decision making of drivers. This risk threshold also seems to be around the same time at which individuals report feeling at risk of being involved in a crash (Fuller, McHugh et al., 2008).

That feelings of risk are being constantly monitored and compared to a preferred range opens RAT to many of the same criticisms that had previously been aimed at Risk Homeostasis Theory (Evans, 1986; McKenna, 1990; Summala, 1988; Summala, 1997). In psychology, a feeling is a subjective and conscious experience of an emotion, with emotions being seen as objective physiological and mental states (Damasio, 1994; Damasio, 2003; VandenBos, 2006). That is to say, feeling implies conscious awareness at some level. If this is the case, the most important objection to RAT is that most of the time drivers report feeling no risk during day-to-day driving and it is only when a performance related safety margin is crossed that drivers become aware of any feelings they could label as risk (Summala, 1988; Summala, 1997). In the past these objections have tended to relate to the monitoring of crash or statistical risk. But objections that it would be stressful and demanding mentally to be constantly directing attention towards a subjective variable in order to continuously compare it to a preferred level or range of experience of that variable, are still relevant, even when the variable is "feeling of" rather than "statistical" risk.

Similarly, if mental workload is examined it is true that people do tend to adjust their behaviour in order to operate at an optimum level of workload (Fuller, 2005). However, it seems that it is the absence of under or over load that indicates that an individual is operating at optimal mental workload. This is demonstrated in Figure 1 where a range of measurement tools and their ability to detect mental workload is shown. As can be seen in the figure both objective physiological and subjective assessments of workload are unable to detect operation in the optimal A2 area. Rather operation in this area has to be inferred by the finding that an individual is not operating in any of the under or over load areas which can be detected (de Waard, 1996).



Figure 1. The relation of workload to performance in 6 regions and the sensitivity of different measures to driver mental workload. Shading indicates the measure is sensitive to workload in this region (from de Waard, 1996), pg 101).

In this way mental workload is similar to a threshold type relationship with under and over load thresholds and optimally functioning individuals feeling no load at all, or a stable low load, creating a U-shaped curve (de Waard, 1996).

Fuller (2007; 2008) attempts to address these concerns around the constant monitoring of a feeling of risk, with reference to Damasio's Somatic-Marker Hypothesis (Damasio, 1994; Damasio, 2003). The Somatic-Marker Hypothesis claims that through past experience, specific stimuli become marked by associated emotions, which are underlying body states. Damasio refers to this as a somatic marker and suggests that when the marked stimulus is encountered then this marker is also triggered. These markers can also be in some cases present from birth (Damasio, 1994). Activation of the somatic marker could produce greater attentional capture for these stimuli, resulting in feeling. In addition, as these emotions are

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seen as changes in the body state of the individual, they are also speculated to be able to bias an individual into behaving in a specific way due to the resulting changes in the internal physiology and associated psychology of the individual. In this last way the body states associated with emotions are said to be able to shape behaviour without conscious awareness (Damasio, 1994; Damasio, 2003). Fuller, therefore, has suggested that it is through this process that feeling of risk is monitored (Fuller, 2007). However, Damasio's theory makes a clear distinction between emotions, which are body states and do not need consciousness, and feelings, which are the experiences of emotions (Damasio, 1994; Damasio, 2003). It is the emotions, which are underlying body states, constantly present within the Somatic-Marker Hypothesis. Fuller, however, only uses the term 'feeling', which seems inappropriate, as he seems to be paradoxically suggesting that feeling of risk is constantly monitored, constantly salient and yet not felt.

Placing issues of terminology aside, it is not clear exactly how the Somatic-Marker Hypothesis fits with the contention made by RAT that individuals select a range of feeling of risk at which to operate and maintain operation in this area (Fuller, 2008). Rather than a range, the Somatic-Marker Hypothesis seems to lead to the suggestion that there are set learnt stimuli which, when encountered, trigger an emotion and can then lead to a feeling of experienced risk (or bias behaviours through resulting body changes), assuming that this feeling has been learnt to be associated with the relevant emotion (Damasio, 1994; Damasio, 2003). It is at this point action will be taken to avoid this feeling. Either that or motivational aspects will cause this feeling to be tolerated. This is a learnt threshold avoidance relationship more along the lines of that suggested by zero-risk theory (Näätänen & Summala, 1974; Summala, 1997) or threat avoidance theory (Fuller, 1984), rather than a constant monitoring and maintaining of a preferred level of feeling of risk in an allostatic fashion as suggested by RAT (Fuller & Santos, 2002; Fuller, 2005; Fuller, 2007; Fuller et al., 2008; Fuller, McHugh et al., 2008; Fuller, 2008). Finally, and perhaps of most relevance to this paper, Fuller (2007) acknowledges that the application of Damasio's Somatic-Marker Hypothesis within RAT is speculative and does not currently have direct experimental support.

Rather, the primary experimental support for RAT is a study carried out by Fuller, McHugh et al. (2008), which has been subsequently replicated by Kinnear et al. (2008). This experiment examined the relationship between individuals' subjective ratings of task difficulty, feeling of risk, their assessment of when loss of control would occur and speed. In order to examine the relationships between, participants were presented with digital video footage of three roads; a residential road, a dual carriageway and a rural road, being driven at several different speeds. The differences in speed were achieved by digitally altering the video and, therefore, the footage included no other moving vehicles and no information from in-car speed instrumentation.

Participants were presented with the speeds starting with the slowest and then increasing in 5 mph increments. After each increment they were then asked to indicate how much risk they thought they would feel driving this road at the speed shown, as well as how difficult they thought it would be, and how many times they thought they would lose control of the vehicle or be in a collision.

It was initially hypothesized by Fuller, McHugh et al. (2008) that task difficulty would have a systematically increasing relationship with speed and that feeling of risk and ratings of loss of control would operate more on a threshold fashion, as predicted by zero-risk theory (Näätänen & Summala, 1974). However, the results of the experiment showed that both task difficulty and feelings of risk were highly linearly related to speed ($r^2 = .98$), and that only ratings of potential loss of control showed a threshold relationship. It was also found that ratings of task difficulty and feeling of risk were highly correlated with each other (r = .81, p < .001). This led to the conclusion that a feeling of risk provides continuous feedback to drivers allowing them to maintain the difficulty of the driving within preferred levels. However, the presentation of speeds in steadily increasing 5 mph increments raises the possibility that an order effect is responsible for the strong linear relationships found between task difficulty, feeling of risk, and speed. This means that the systematically increasing relationship of task difficulty and feeling of risk with speed reported could be, at least in part, an artifact produced by the methodology used.

A replication by Kinnear et al. (2008) produced similar results but no threshold effect was found for ratings of loss of control. It is possible that this is because the question used by Kinnear et al. asked about the loss of control of a hypothetically identical other driver rather than of the participants' own driving ability. Previous research has suggested that people assess their own ability as higher, and crash risk as lower, than that of others, even their peers (Harré & Sibley, 2007; McKenna, Stanier, & Lewis, 1991; McKenna, 1993). Therefore it is possible that even though the wording Kinnear et al. (2008) used specified a driver that was just like the participant, the participants may have rated these hypothetical identical others in a more negative fashion than when asked to rate their own crash risk. Kinnear et al. (2008) also presented the speeds in an ascending fashion, again raising the possibility of an order effect. Fuller (personal communication, September 2, 2008) however, has claimed that different speed orders were tested in his original study and produced similarly linear increasing results. This experiment will seek to address both methodological issues by presenting speeds in random order within each trial, and by including two questions on crash risk which follow wordings similar to those used by both Fuller, McHugh et al. (2008) and Kinnear et al. (2008).

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This experiment seeks to expand on Fuller, McHugh et al.'s (2008) findings, by using a driving simulator to examine three vital components. The first is the predicted systematically increasing relationship between speed, ratings of task difficulty, and feeling of risk (Fuller, McHugh et al., 2008). That individuals are sensitive to changes in the difficulty of the task they are performing (in this case increases in speed) is important in order for them to be able to constantly monitor the related comparator variable of feeling of risk. This is necessary in order for them to be able to select a certain level/range of this variable at which to function. That is to say, if a certain target range of feeling of risk is preferred (higher than zero) there must be, assuming no other distractions, a detectable difference in feeling of risk between differing levels of speed in order for drivers to be able to constant monitoring of risk (McKenna, 1988; Näätänen & Summala, 1974; Wagenaar, 1992) and the original predictions of Fuller, McHugh et al. (2008) it is hypothesized that instead a threshold effect will be apparent.

The second component is the strong relationship between the subjective ratings reported. In this experiment, additional ratings of effort and comfort will be added and their relationship to subjective risk and task difficulty examined. Effort was selected as a measure of mental workload, a comparator initially suggested by Fuller and Santos (2002) when RAT was still known as Task-Difficulty Homeostasis. Ratings of comfort have been indicated by Summala (2005) as an important part of his multiple comfort zone model where they are suggested to indicate operation outside of or near the edge of threshold-like safety margins. It is hypothesized that ratings of effort and comfort will also be related to ratings of risk and task difficulty. A rating of how typical the speed experienced is to the participant will also be gained in order to see the effect of previous experience. It is expected that through this scale that drivers will indicate a clear preference for travelling at speeds which they rate as typically experienced.

The relationship between participants' subjective ratings and a chosen preferred or target speed will also be examined. The use of the driving simulator allows for the introduction of a free speed condition where participants can choose their own speed rather than being always restricted to preset speeds. The subjective ratings given at this speed will be compared to ratings for the fixed speeds.

It is predicted that in line with a threshold model of feeling of risk, task difficulty and effort, that ratings at this chosen speed will be lower or the same as the ratings given to speeds before this point and that only speeds higher than this preferred speed show a systematic

increase with speed. In other words, participants will not prefer a certain level of feeling of risk along an increasing continuum but instead rate their preferred speed as having no, or a low and stable, feeling of risk, task difficulty, and effort.

2. Method

2.1. Participants

There were 47 participants recruited from the undergraduate population at the University of Groningen; 25 male and 22 female. Recruitment was carried out through the psychology department's computerised recruitment pool and two course credits were given for participation in the research. The males had a mean age of 21.2 (SD = 2.0), and had held their drivers' licence for an average of 2.8 years (SD = 1.4). Females had a mean age of 20.3 years (SD = 1.2), and had held their drivers' licence for 2.1 years (SD = 1.1) on average.

2.2. Materials

Two sections of road were created in the driving simulator. One road simulated a residential street and the other, a section of dual carriageway. The roads contained no other traffic or adverse weather conditions. In addition, speed limit signs were absent from the roads. The use of a residential road and a dual carriageway were chosen as these were two of the road types used in the previous studies (Fuller, McHugh et al., 2008; Kinnear et al., 2008). The final road type used in the previous studies, a rural road, was not used in this case due to time restrictions. This was deemed acceptable since the previous studies found very similar results across all three road types (Fuller, McHugh et al., 2008; Kinnear et al., 2008).

The experiment was carried out using the University of Groningen's STSoftware driving simulator, which consists of a fixed-base car mock-up with controls linked to a dedicated graphics controller, and allows participants a 210° view of the road environment. A cardboard cutout was placed over the speed instrumentation in order to obscure it.

Nine set speeds, plus a free speed condition, were assigned to each road. The set speed conditions functioned in a manner similar to cruise control and restricted speed to a set value. However, unlike conventional cruise control, participants were unable to set the speed or disable it. In the free speed condition, the participants were able to drive the simulated

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vehicle normally and select their own travelling speed. The set speeds for each road were set in 10 kmph increments and presented to participants in randomized order. The speed for the residential road ranged between 20 and 100 kmph, and for the dual carriageway the range was 80 to 160 kmph.

2.3. Procedure

Participants were asked to fill out a demographic questionnaire that collected information about their age and driving experience. Participants were then tested individually on each road section under various speed conditions. Twenty-three of the participants encountered the residential road first and the other 24 were presented with the dual carriageway first. The participants then had to complete both an observation and driving task. This was again counter balanced between participants. Both the road and task orders were counterbalanced between males and females.

Before starting with the driving or observation tasks, a practice track was presented to the participants to allow them to become familiar with the simulator. If participants felt sick or uneasy with the simulator at this point they were removed from the experiment.

2.3.1. Observation task

Participants experience all nine different speed conditions for each road. All the nine speed conditions were presented for one road before moving on to the next. The order in which the speed increments were presented was determined by random number generation. After each speed condition the participants filled in a questionnaire (in Dutch) on which ratings of predicted task difficulty, feeling of risk, effort, and comfort were gained using 7-point Likert scales. The rating scales used were similar to those used previously by Fuller, McHugh et al. (2008). Below is an example of the bipolar scale used for task difficulty during the observation task:

How difficult would you find it to drive this section of road at this speed?

1 2 3 4 5 6 7

Extremely Easy

Extremely Difficult

In terms of the ratings for risk and effort, a unipolar scale was used where a rating of 1 indicated the absence of the variable being assessed. For example a rating of 1 for feeling of risk corresponded to "no risk". In addition participants were asked to indicate if they would never, seldom, sometimes, nearly always or always typically drive at the speed experienced on the road type shown. In terms of ratings of comfort, a rating of 7 corresponded to extremely comfortable, and a rating of 1 with extremely uncomfortable. For later analysis and presentation this scale was reversed to match the other scales, so in the following results section of this paper comfort decreases as the subjective rating given increases, much as subjective impressions of task difficulty increase as the rating given increases.

In addition, participants were also asked to give an indication of how many times they thought they would lose control of the vehicle or have an accident if they drove the road shown, at the speed shown, every day for 2 months (i.e. 60 times). This was a question worded in a similar fashion as that used by Fuller, McHugh et al. (2008). A similar question asked for a rating of how many times 60 drivers like the participants, would crash if they drove the road shown, at the speed shown. This was worded in the similar fashion as that used by Kinnear et al. (2008). With both questions, the participants were able to freely indicate an appropriate number, including an indication that they or an identical other would not crash at all. Once all the relevant speed conditions for a road section were presented, participants were also asked to give a preferred speed for the road shown and a maximum speed at which they thought they could drive and maintain control of the vehicle. In order to control for order effects, 23 of the participants were given the questionnaire presented in the normal order and 24 in reverse order.

2.3.2. Driving task

This task was similar to the observation task except that the participants had the ability to control the steering of the vehicle. Also, a free speed choice condition was presented to the participants during this task, once for each road type, and the speed at which participants drove during this condition was recorded. After each drive, participants were again asked to fill in a similar questionnaire to the one used for the observation task. The only difference between the questionnaire used here and that of the observation task, was that the questions were worded to ask what was experienced rather than asking participants to give an indication of what they thought they would experience. For example, the question assessing task difficulty was worded as follows: "How difficult did you find it to drive this section of road at this speed?" Other than this change in wording the same rating scales were

used and the same variables assessed. In addition, speed information was collected at a rate of 10 Hz during the free speed condition. Average speed and standard deviation of speed were then calculated for each participant individually and then averaged across all subjects.

2.4. Analysis

The collected subjective ratings were examined by creating two datasets. The first contained the averaged subjective ratings given at each speed category for all participants, for each road, and for both the observation and driving task. Ratings given by the participants for the free speed condition during the driving task were not included in this dataset.

A second dataset was created using the data gathered in the driving task in order to examine the ratings given by participants during the fixed speed conditions relative to the ratings they gave during the free speed condition. The dataset was created by first calculating the average speed each participant drove during the free speed condition. Once this speed was known, then the ratings from the three set speed conditions above and below this speed were collected and arranged around the ratings given for the free speed condition so that it sat in the center. For example if one participant drove at 58 kmph on average on the residential road, then the ratings they gave on that task were set as the zero or center point, and then the ratings for the 30,40, 50, 60, 70, and 80 kmph fixed speed conditions arrayed on either side. So their order of ratings would read: 30, 40, 50, free speed (58 kmph), 60, 70, 80. Another participant may have driven at 63 kmph on average, and therefore their order of ratings would read 40, 50, 60, free speed (63 kmph), 70, 80, 100. This was done for both road types. Once this was done for each participant, the ratings where averaged and the relative dataset created.

3. Results

MANOVA, correlation and regression analysis was carried out on both the averaged and relative datasets using SPSS 14.0 for windows. MANOVA analysis with a difference contrast for speed for the averaged dataset, showed main effects of road type (F = 8.41, p < .01), task type (F = 32.59, p < .001), and speed (F = 71.39, p < .001). Interaction effects were also found between road and speed (F = 13.81, p < .001), task type and speed (F = 7.58, p < .001), and road, task type and speed (F = 2.84, p < .05). Further analysis for each subjective variable by road type and task revealed significant main effects of road type only on ratings of comfort (F = 9.88, p < .01), ratings of loss of control for the drivers themselves (F = 7.21, p < .01) and

ratings of typical speed (F =47.35, p < .001). In all these cases the residential road produced higher ratings than the dual carriageway. Main effects of task type were found for ratings of task difficulty (F = 44.29, p < .001), feelings of risk (F = 42.79, p < .001), effort (F = 65.51, p < .001), comfort (F = 55.85, p < .001), loss of control for self (F = 16.37, p < .001) and for others (F = 14.11, p < .001), but not for ratings of how typical the speed was (F = 1.32, p = .256). Where these significant differences were found the observation task produced higher ratings than the driving task. Despite the differences observed between the tasks and roads, the shape of the trends shown between the observation task and the driving task are quite similar. MANOVA analysis of the relative dataset with a difference contrast for speed, failed to find a main effect of road type (F < 1, NS) but a main effect of speed was observed (F = 45.85, p < .001).

3.1. Relationship of ratings of task difficulty, and risk to speed

Ratings of task difficulty, feeling of risk, and risk of collision/loss of control do not linearly increase with increases in speed. Rather, as shown in Figure 2 it appears that participant indications of



Figure 2. Average ratings of task difficulty, feeling of risk and loss of control in relation to increasing speed across both road and task types.

task difficulty and risk start low or absent and only significantly increase once a certain speed has been reached. The only exception to this is the trend for crash risk on the observation task on the dual carriageway, which appears more clearly exponential in nature. In terms of the rating of loss of control of the vehicle/collision, it is also clear that participants began rating this as higher than zero earlier when assessing an identical other rather than themselves.

 Table 1. Regression analysis for task difficulty, feeling of risk and loss of control with speed across both road and task types

	Residential Road -	– Obser	vation Task				
	20 1	to 40 kr	n/h	50 to 90 km/h			
	r ²	Beta	t	r ²	Beta	t	
Task Difficulty	.00	05	57	.39***	.62	13.22	
Feeling of Risk	.03	.16	1.91	.41***	.64	14.02	
Loss of Control – Self	.00	06	66	.15***	.38	6.84	
Loss of Control – Other	.00	00	03	.19***	.43	7.87	
	Residential Road -	- Driving	g Task				
Task Difficulty	.00	05	33	.48***	.69	15.95	
Feeling of Risk	.00	.06	.70	.51***	.71	17.00	
Loss of Control – Self	.00	06	73	.10***	.32	5.61	
Loss of Control – Other	.00	02	21	.16***	.40	7.29	
	Dual Carriageway	– Obser	rvation Task				
	80 to 100 km/h			110	10 to 160 km/h		
	r ²	Beta	t	r^2	Beta	t	
Task Difficulty	.02	.15	1.73	.21***	.45	8.51	
Feeling of Risk	.01	.10	1.13	.22***	.47	8.80	
Loss of Control – Self	.05**	.23	2.78	.08***	.27	4.73	
Loss of Control – Other	.04**	.22	2.66	.08***	.29	4.95	
	Dual Carriageway	– Drivin	g Task				
Task Difficulty	.00	.00	.00	.32***	.56	11.37	
Feeling of Risk	.00	01	14	.34***	.58	12.05	
Loss of Control – Self	.01	11	-1.27	.10***	.31	5.44	
Loss of Control – Other	.01	10	-1.16	.17***	.42	7.57	

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

Regression analysis of the rating of task difficulty, and risk show no significant relationship between the reported values and speed in the first three speed conditions on the residential road, under both the observation and driving tasks. Similarly, for the dual carriageway, the ratings for the driving task and the ratings of task difficulty and feeling of risk for the first three speed conditions during the observation task, fail to show any significant increasing or decreasing trend and are flat in nature. Ratings of both self and other assessed risk of loss of control do show significant (p < .001) r^2 values (t = 2.78, $r^2 = .05$ and t = 2.65, $r^2 = .05$ respectively) during these first three speed conditions during the observation task for the dual carriageway. After the first three speed conditions the trend in ratings of risk and task difficulty for both roads and across both conditions, begins to show statistically significant increases (p < .001), with r^2 values ranging from .08 to .51 as shown in Table 1.

3.2. Relationship of ratings of effort, comfort and typical speed to speed



Figure 3. Average ratings of effort, comfort and "I typically drive at this speed" in relation to increasing speed across both road and task types.

Ratings of effort, comfort, and indications of typical speed for the residential road showed a U-shaped relationship with speed starting off initially high and then trending downwards until beginning to again trend upwards as shown in Figure 3. This is true for both the observation and driving task. Although, for the driving task the U-shape is less marked, especially for ratings of effort where the downward trends for effort were not statistically significant (p > .05).

The relationship is not as clear for the dual carriageway in terms of ratings of effort and comfort which during the observation task appeared to have a somewhat linear increasing relationship with speed. However, indications of typical speed still show a somewhat U-shaped curve for both the observation task and the driving task on the dual carriageway. Ratings of

Table 2. Regression	analysis for effort,	comfort and '	'I typically o	drive at this	speed"	with speed	across b	oth r	oad
and task types									

Resid	dential Road	– Observ	ation Task					
	20 to 40 km/h			50 to 90 km/h				
	r ²	Beta	t	r ²	Beta	t		
Effort	.05**	23	-2.76	.38***	.61	12.92		
Comfort	.08***	29	-3.54	.34***	.58	11.88		
Typically Drive	.32***	57	-8.07	.44***	.66	14.76		
Resid	lential Road -	– Driving	Task					
Effort	.01	12	-1.45	.43***	.66	14.65		
Comfort	.07***	26	-3.14	.36***	.60	12.50		
Typically Drive	.21***	46	-6.15	.40***	.63	13.55		
i/picaii/ Brito	Dual Carriageway – Observation Task							
Dual	Carriageway	– Observ	vation Task					
Dual	Carriageway 80 t	– Observ to 100 km	vation Task n/h	110	to 160 kr	n/h		
Dual	Carriageway 80 t r ²	– Observ to 100 km Beta	vation Task n/h t	110 r ²	to 160 kr Beta	n/h t		
Effort	Carriageway 80 t r ² .00	– Observ to 100 km Beta .07	vation Task n/h t .78	110 r ² .20***	to 160 kr Beta .45	n/h t 8.48		
Effort Comfort	Carriageway 80 t r ² .00 .00	- Observ to 100 km Beta .07 03	vation Task n/h t .78 32	110 r ² .20*** .18***	to 160 kr Beta .45 .42	n/h t <u>8.48</u> 7.78		
Effort Comfort Typically Drive	Carriageway 80 t r ² .00 .00 .04*	- Observ to 100 km Beta .07 03 21	vation Task n/h t .78 32 -2.53	110 r ² .20*** .18*** .19***	to 160 kr Beta .45 .42 .45	n/h t 8.48 7.78 8.30		
Effort Comfort Typically Drive	Carriageway 80 f r ² .00 .00 .04* Carriageway	- Observ to 100 km Beta .07 03 21 - Driving	ration Task n/h t .78 32 -2.53 Task	110 r ² .20*** .18*** .19***	to 160 kr Beta .45 .42 .45	n/h t 8.48 7.78 8.30		
Effort Comfort Typically Drive Effort	Carriageway 80 f r ² .00 .00 .04* Carriageway .00	- Observ to 100 km Beta .07 03 21 - Driving 06	vation Task n/h .78 .32 -2.53 Task 68	110 r ² .20*** .18*** .19*** .30***	to 160 kr Beta .45 .42 .45	n/h t 8.48 7.78 8.30 10.86		
Effort Comfort Typically Drive Effort Comfort Comfort	Carriageway 80 f r ² .00 .00 .04* Carriageway .00 .00	- Observ to 100 km Beta .07 03 21 - Driving 06 07	vation Task n/h 178 32 -2.53 Task 68 79	110 r ² .20*** .18*** .19*** .30*** .26***	to 160 kr Beta .45 .42 .45 .54	n/h t 8.48 7.78 8.30 10.86 9.81		

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

comfort on the driving task for the dual carriageway also seem to show a slight decrease to start with, although it is not as clear as the trend on the residential road. In terms of ratings of effort for the driving task, it appears to start stable and then only increase once a certain speed has passed. The shapes of the trends are consistent with the results of the regression analysis shown in Table 2.

3.3. Relationship between chosen free speed and subjective ratings

Figure 3.4 shows the subjective ratings given by participants relative to the rating they gave when they were able to pick their own speed during the driving task. The zero point on the x-axis represents the free speed condition and each increment above or below is a speed increment faster or slower. These points differed across participants, so in order for them to be assessed the procedure described in Section 2.4 was used to create the relative data seen here. The subjective rating scales for task difficulty, risk, effort, and comfort stayed low until the chosen speed was reached and then began to markedly increase after this point. Although in the case of ratings of loss of control for an identical other, this value began to increase before ratings of loss of control for the participants themselves. The exceptions to this were ratings of feeling of risk for the residential road, where there was a slight significant linear increase initially ($r^2 = .07$, p < .01), then a dip at the free speed point and then the ratings start increasing again, although considerably more sharply ($r^2 = .25$, p < .001). Ratings of comfort for the residential road also do not follow the general pattern, with more of a U-shaped curve being apparent. Meaning that as the preferred speed was approached participants rated the speed as being more comfortable, and after it was exceeded as increasingly uncomfortable. Indications of how typical the experienced speed was showed a clear V-shaped curve with ratings decreasing as the free speed choice condition is approached and increasing afterward.

The results of regression analysis on the first three speed points and the last three speed points are consistent with the trends shown in Fig. 4 and are given in Table 3.

3.4. Relationship between chosen free speed, maximum speed and preferred speed

When asked to indicate a speed at which they preferred to drive for each of the roads, the majority of individuals (N = 43 for the dual carriageway and N = 44 for the residential road) chose a speed lower than the speed they said was the maximum they would be able to drive before losing control of the vehicle. On average the ratings of preferred speeds were 112 kmph (SD = 17.82) on the dual carriageway. The average maximum speed before losing



Figure 4. Relative ratings of task Difficulty, risk, loss of control, effort, comfort, and "I typically drive at this speed" across both road types. A relative speed of 0 corresponds to the average rating participants gave for the free speed condition. Each increment above or below this point (-3, -2, -1, 1, 2, 3) corresponds to a fixed speed condition above or below the average preferred speed of the participants.

control was rated for the same road at 141 kmph (SD = 27.43). In terms of the residential road, the preferred speed averaged 49 kmph (SD = 11.21). The maximum speed on this road averaged 73 kmph (SD = 16.86).

In comparison to the actual speed participants drove at during the driving task, on the residential road; 43% of participants drove at a speed lower than both their preferred and maximum speeds, 38% drove at a speed higher than their preferred speed but lower than their maximum speed, and 13% drove at a speed faster than both previously rated speeds. The remaining participants had missing data for their self-reported maximum and/ or preferred speeds. The average speed driven by participants on the residential road was

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	Resident	ial Road							
		-3 to – 1		1 to 3					
	r ²	Beta	t	r ²	Beta	t			
Task Difficulty	.00	.05	.60	.22***	.46	6.09			
Feeling of Risk	.07**	.26	3.09	.25***	.50	6.66			
Loss of Control – Self	.00	01	09	.15***	.39	4.96			
Loss of Control – Other	.03	16	-1.90	.13***	.35	4.40			
Effort	.00	.06	.64	.07**	.26	3.06			
Comfort	.00	.10	1.15	.09***	.29	3.50			
Typically Drive	.19***	43	-5.58	.28***	.53	7.26			
	Dual Carriageway								
	Dual Car	riageway							
	Dual Car	riageway -3 to – 1	-	-	1 to 3	-			
	Dual Car	riageway -3 to – 1 Beta	t	r ²	1 to 3 Beta	t			
Task Difficulty	Dual Car r ² .01	riageway -3 to – 1 Beta .09	t 1.05	r² .09***	1 to 3 Beta .30	t 3.53			
Task Difficulty Feeling of Risk	Dual Car r ² .01 .00	riageway -3 to – 1 Beta .09 .05	t 1.05 .61	r ² .09*** .10***	1 to 3 Beta .30 .31	t 3.53 3.78			
Task Difficulty Feeling of Risk Loss of Control – Self	Dual Car r ² .01 .00	riageway -3 to – 1 Beta .09 .05 .02	t 1.05 .61 .24	r ² .09*** .10*** .10***	1 to 3 Beta .30 .31 .31	t 3.53 3.78 3.78			
Task Difficulty Feeling of Risk Loss of Control – Self Loss of Control – Other	Dual Car r ² .01 .00 .00	riageway -3 to – 1 Beta .09 .05 .02 03	t 1.05 .61 .24 -0.38	r ² .09*** .10*** .10*** .10***	1 to 3 Beta .30 .31 .31 .33	t 3.53 3.78 3.78 3.95			
Task Difficulty Feeling of Risk Loss of Control – Self Loss of Control – Other Effort	Dual Car r ² .01 .00 .00 .00 .00	riageway -3 to – 1 Beta .09 .05 .02 03 .08	t 1.05 .61 .24 -0.38 .91	r ² .09*** .10*** .10*** .11*** .06**	1 to 3 Beta .30 .31 .31 .33 .33 .25	t 3.53 3.78 3.78 3.95 2.88			
Task Difficulty Feeling of Risk Loss of Control – Self Loss of Control – Other Effort Comfort	Dual Car r ² .01 .00 .00 .00 .01 .04*	riageway -3 to – 1 Beta .09 .05 .02 03 .08 .20	t 1.05 .61 .24 -0.38 .91 2.32	r ² .09*** .10*** .10*** .10*** .11*** .06** .04*	1 to 3 Beta .30 .31 .31 .33 .25 .20	t 3.53 3.78 3.78 3.95 2.88 2.32			

Table 3. Regression analysis for relative scores of task difficulty, risk, loss of control, effort, comfort and habit with speed across both road types.

* p < 0.05 ** p < 0.01 *** p < 0.001

58 kmph (SD = 11.66). On the dual carriageway 53% of participants drove at a speed higher than their indicated preferred speed but lower than their maximum speed, 23% drove at a speed lower than both of these values, and 19% drove at a speed faster than both these values. The remaining two participants had missing data. On average the speed chosen to drive for the dual carriageway was 117 kmph (SD = 19.04).

3.5. Correlations between task difficulty, risk, effort, comfort and habit

Using a Pearson's correlation, task difficulty, feeling of risk, and effort were found to be strongly related (r = .81 - .91, p < .01) with each other across both road types and task conditions, and to be moderately to markedly correlated with ratings of comfort and ratings of loss of control (r = .44 - .77, p < .01). Ratings of how typical the drive was, were moderately correlated with comfort (r = .47 - .59, p < .05) across both roads and tasks but only had a low correlation to moderate correlation with the other subjective measures (r = .29 - .59, p < .01). Similar correlations were found between the variables if the ratings were examined relative to the participants free speed choice. Although the correlations tended to be slightly lower than those reported for the averaged results.

4. Discussion

The findings of this experiment do not support some of the predictions put forward by Fuller, McHugh et al. (2008). The first is that ratings of task difficulty and feeling of risk should systematically increase with increases in speed. This relationship was found to occur in a very strong linear fashion across all speeds examined by Fuller, McHugh et al. (2008) and Kinnear et al. (2008). However, in the case of this study it appears that before any increasingly relationship is observed the ratings of task difficulty and feeling of risk initially go through a period of stability in which there is no clear increasing or decreasing trend. It is only once a certain speed has been reached, around 50 kmph on average for the residential road and around 110 kmph on average for the dual carriageway, that ratings of these variables begin to increase. Furthermore even once ratings of task difficulty and feeling of risk variables do start to increase with speed, they do not do so as strongly as previously found (Fuller, McHugh et al., 2008; Kinnear et al., 2008) and are only moderately, not highly, correlated with increasing speed. This relationship is similar to the threshold trend found for ratings of crash risk in both this study and the previous observation experiments (Fuller, McHugh et al., 2008; Kinnear et al., 2008). It should also be noted that the average rating for task difficulty and feeling of risk during this period falls between 1 and 2 on the scale used. Given that a rating of 1 on the scale of feeling of risk corresponds to "no risk", this indicates that many of the participants indicated they would not experience, or were not experiencing, any feeling of risk across a range of speeds. This is in contrast to the findings of Fuller, McHugh et al. (2008) whose results suggested the constant presence of some experienced level of feeling of risk which linearly increased with speed. Due to the nature of the difficulty scale used, a similar conclusion is not possible given that a rating of 1 corresponded to "very easy" rather than indicating an absence of difficulty.

Similarly when the relationship of ratings of task difficulty and feeling of risk relative to participants free speed choice are examined, a threshold relationship is again apparent. With the exception of ratings of feeling of risk for the residential road, ratings of feeling of risk and task difficulty are stable with no significant trend with speed until after the free speed condition has past. Again, the average of the ratings given, including those given for the condition where participants were able to drive at their own chosen speed, only moves above 2 after the free speed condition is past. This indicates that many participants did not report any feeling of risk when driving at their preferred speed and also did not experience any feeling of risk during the three fixed speed conditions that would fall before the speed they selected to drive. If participants are aiming for a range of feeling of risk, why then did they drive at the speed chosen when their ratings of this value do not seem to significantly differ from the ratings they gave at earlier, lower speeds? One exception to the threshold relationship found was in the ratings of feeling of risk for the residential road. In this case there is a slight significant increase of ratings with speed as the free speed condition is approached. However, at the point of chosen free speed the ratings dip before starting to increase at a significantly increased rate. This again indicates a preference amongst participants during free driving for feeling of risk to be low or absent.

A similar threshold relationship for ratings of task difficulty and feeling of risk was apparent for ratings of effort, with average ratings of effort only crossing above 2 once a certain speed was passed, or in the case of the relative data set, only once the preferred speed had been passed. Again this indicates that participants generally preferred to drive at a speed at which they indicated ratings of effort were low and stable, or absent.

The threshold relationship for effort ties in well with existing research on human performance and the optimal range of workload under which individuals generally prefer to operate (de Waard, 1996; Recarte & Nunes, 2002). Performance, physiological and subjective assessments of workload are not able to detect operation in this optimal area; rather, the confirmation that an individual is operating optimally comes from the fact that they are not found to be, or do not report that they are, at any of the over, or unload, areas that are able to be detected. When operating at this optimal level drivers are experiencing no, or very minimal and stable, mental load (de Waard, 1996; Recarte & Nunes, 2002). Similarly, ratings of comfort showed threshold effects, either staying stable and then increasing, or showing more of a U-shape where participants rated the driver as more and more comfortable until a certain point and then as increasingly uncomfortable once this point was passed. This is what would be expected according to Summala's multiple comfort zone model (2005).

It should also be noted that participants in this study did not only prefer a speed at which subjective ratings of the variables assessed were absent or low and stable but that they picked a driving speed just before their ratings of the assessed variables started to markedly increase. This could suggest that, as is the case in zero-risk theory (Näätänen & Summala, 1974), and as originally suggested by Fuller, McHugh et al. (2008), that the perception of these variables acts as a warning to participants, causing them to avoid these feelings when driving unless otherwise motivated not to.

The results in this experiment for the relationship between ratings of task difficulty, feeling of risk, and speed are quite different from the strong linear trends reported by Fuller, McHugh et al. (2008) and Kinnear et al. (2008). This could be because, when compared with watching a video on a single screen, the simulated driving task provides more cues for the drivers to make decisions. The simulator allows for presentation of sound and peripheral visual information that may improve speed judgment. It could also be that the use of a simulator during the driving task allowed participants to use more accurate data of their own performance, in terms of lane keeping, to make their judgments. However, the fact that the trends in subjective ratings were quite similar between the observation task, where lane keeping was kept perfectly by the simulation software, and the driving task indicates that this may not be the case.

While the simulator may provide a more ecologically valid environment, the driving task during the fixed speed conditions is somewhat unusual. During the fixed speed conditions, participants were unable to choose their own speed, thereby making the task essentially simply a tracking task with the speed demand being set externally. Driving however, is generally seen to be a self-paced task. Therefore, the validity of the task presented to participants in this experiment could be called into question. There are times, however, during everyday driving where speed will be more or less set and the task reduced to that of simply lane control, such as when driving with cruise control or in a stream of traffic. In addition, during the free speed condition participants were able to have free control over their driving.

Another explanation for the difference in findings between this and previous studies, in terms of the absence of the strong linear increasing trend, could be the order of presentation of the speeds to the participants. The two previous studies presented the speeds in an ascending order starting from lowest to highest, whereas, in this experiment participants were presented with the speeds in a random order for each road and for each condition. It is possible, therefore, that the findings of the previous studies were influenced by an order effect. However, Kinnear et al. (2008) reported a study by Lynn (2006) that showed that

order of presentation had minimal impact on the data, and Fuller (personal communication, September 2, 2008) claimed that other orders were attempted in his original study and the same increasing linear trends were produced. Still, to eliminate any alternative explanation for the effects found, randomisation of speed presentation is to be preferred.

It is also possible that the rating scales used in this experiment were not sensitive enough to detect small changes in the variables assessed, especially at the lower speeds. However the scales used here were similar to those used by both Fuller, McHugh et al. (2008) and Kinnear et al. (2008), which managed to produce strong linear increasing trends with speed. Further research could however explore the use of a broader scale.

With the exception of the observation task for the dual carriageway, this study found the same threshold relationship for ratings of loss of control that was reported by Fuller, McHugh et al. (2008). Participants also generally rated the chance of others losing control of their vehicle as higher than zero before they begin rating their own chances higher than zero. This is likely due to a positive self-assessment bias, with participants viewing their own chances of being involved in a crash as lower than that of others (Harré & Sibley, 2007; McKenna et al., 1991; McKenna, 1993).

As predicted, high correlations between ratings of feeling of risk, task difficulty, and effort were reported. The high correlation between feeling of risk and task difficulty is in line with the previous studies (Fuller, McHugh et al., 2008; Kinnear et al., 2008). This strong correspondence between subjective ratings of risk, task difficulty and effort is not surprising. Risk is more than just the severity of a consequence for an action: it is also the chance that that consequence will occur (Nordgren et al., 2007). Task difficulty, as defined by Fuller (2000) is the demands of the environment being compared against the capability of the individual to meet those demands. Therefore, task difficulty could easily be seen as a chance of failure, one of the vital components of risk. For example, when using a driving simulator, the consequences of failure are very low, however, as shown in this experiment, participants are willing to indicate that they experience risk. In fact, when driving in a simulator participants report they are not concerned with the consequences of accidents but rather are concerned with avoiding accidents (Glendon, Hoyes, Haigney, & Taylor, 1996). This means that participants are reacting to the chance of failure or the difficulty of the task, rather than the consequence when assessing risk. This indicates a strong intrinsic link between the concepts of risk and task difficulty, both objectively and in the subjective assessments of participants. Similarly effort, in terms of mental and physical workload, can be seen as an indicator of task difficulty (de Waard, 2002; Fuller, 2005). As the demands of the environment increase, more effort is

required to match those demands and vice versa. Also, as an individual uses more effort their capacity decreases, therefore, their ability to match the demands of the environment decreases, increasing task difficulty (Fuller, 2000; Fuller & Santos, 2002; Fuller, 2005). Similarly, it is unsurprising that tasks that feel difficult/risky/effortful are often uncomfortable, signal a chance of failure/loss of control and are typically outside of what is usually experienced by an individual.

Finally, when asked to state a speed at which they prefer to drive as well as a maximum speed at which they would be able to retain control of the vehicle, the majority of participants chose a preferred speed lower than their stated maximum. This suggests that, as found in previous studies (Fuller, McHugh et al., 2008; Kinnear et al., 2008) people do not believe that they drive at the limit of their personal performance in terms of maintaining control of a vehicle. This is supported by the fact that given the actual opportunity to choose their speed of travel within the simulator, the majority of participants chose a speed that was at least lower than their stated preferred maximum speed.

There are several potential weaknesses with this study. Firstly, the simulated roads used were probably less environmentally complex than the videos used in the previous studies. This is due to the photo realistic nature of video when compared to the more limited settings available in the simulator. The relative lack of complexity means that perhaps some important cues may have been absent from the simulated environment. However, the use of a driving simulator does allow for tighter experimental control over the stimuli presented to participants. This may help to reduce potential cofounding effects. The absence of other traffic from both this study and the previous studies (Fuller, McHugh et al., 2008; Kinnear et al., 2008) also reduces the ecological validity.

Another problem is related to the very nature of asking for subjective ratings of the variables involved. It is possible that in doing so, the variables increased in salience and, therefore, participants may be paying more attention to these factors than they would while driving their vehicle normally, when they have not been prompted to consider such factors has risk, difficulty, effort or comfort. This does, however, add more weight to the suggestion that these feelings are not present until a certain threshold has been reached, as even with attention drawn to these variables there still appears to be a threshold relationship in the data.

The participants in this experiment were also younger and less experienced on average than those used in previous studies. This may have affected their ratings of the various variables involved. It could be argued that inexperienced drivers are not good at perceiving risk and may, therefore, not be able to constantly monitor this factor and rate it in the linear increasing fashion found by the previous studies. However, the study by Kinnear et al. (2008) included three levels of experience: learner, inexperienced and experienced drivers, and all the three groups produced similarly linearly increasing ratings of risk and task difficulty.

Ultimately the findings of this current experiment seem to support a threshold model for perception of task difficulty, feeling of risk, crash risk, effort, and comfort. These ratings are generally indicated by participants to be both low and stable, or absent, until a certain speed after which they begain to increase. In terms of feeling of risk, these findings are in line with the expectations of zero-risk theory (Näätänen & Summala, 1974), risk avoidance theory (Fuller, 1984), the multiple comfort zone model (Summala, 2005) and earlier predictions of the Task-Difficulty Homeostasis theory (Fuller, McHugh et al., 2008) where the experience of risk acts as a warning to drivers and only becomes salient once certain conditions have been met.

The findings of this study suggest that when designing road safety interventions, practitioners should take into account the threshold relationship in the perception of risk, task difficulty, effort, and comfort. Causing a driver's threshold to be crossed may be useful in creating safer behaviour amongst drivers. The challenge however will be to cross driver's subjective thresholds without actually increasing the real objective danger to the driver and other road users. In addition, since thresholds likely differ between individuals, care should be taken when designing interventions which aim to affect a whole population. Furthermore, the strong relationship between subjective ratings of risk, task difficulty and mental workload means that road safety practitioners should be aware that any intervention which alters one of these variables is likely to impact on the others.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179-211.

Damasio, A. R. (1994). *Descartes' Error: Emotion, Reason, and the Human Brain.* New York: Putnam.

Damasio, A. R. (2003). *Looking for Spinoza: Joy, sorrow, and the feeling brain.* London: Heinemann.

de Waard, D. (1996). *The measurement of drivers' mental workload.* Thesis, University of Groningen.

de Waard, D. (2002). Mental workload. In R. Fuller, & J. A. Stantos (Eds.), *Human Factors for Highway Engineers* (pp. 161-172). Oxford: Pergamon.

Evans, L. (1986). Comments on Wilde's Notes on "Risk Homeostasis Theory and Traffic Accident Data" *Risk Analysis, 6*(1), 103-107.

Fuller, R. (1984). A conceptualization of driving behaviour as threat avoidance. *Ergonomics,* 27(11), 1139-1155.

Fuller, R. (1988). Psychological aspects of learning to drive. In J.A. Rothengatter & R.A. de Bruin (Eds), *Road user behaviour: Theory and Research* (pp. 527-537), Assen.

Fuller, R. (2000). The task-capability interface model of the driving process. *Recherche - Transports - Sécurité, 66,* 47-57.

Fuller, R. (2005). Towards a general theory of driver behaviour. *Accident Analysis & Prevention, 37*(3), 461-472.

Fuller, R. (2007). Motivational determinants of control in the driving task. In P. Cacciabue (Ed.), Modelling Driver Behaviour in Automotive Environments: Critical Issues in Driver Interactions with Intelligent Transport Systems (pp. 165-188). London: Springer.

Fuller, R. (2008). What drives the driver? Surface tensions and hidden consensus. Keynote at the 4th International Conference on Traffic and Transport Psychology, Washington, DC.

Fuller, R., Bates, H., Gormley, M., Hannigan, B., Stradling, S., Broughton, P., Kinnear, N., & O'Dolan, C. (2008). *The Conditions for Inappropriate High Speed: A Review of the Research*

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Literature from 1995 to 2006. London: Department for Transport.

Fuller, R., McHugh, C., & Pender, S. (2008). Task difficulty and risk in the determination of driver behaviour. *Revue Européenne De Psychologie Appliquée/European Review of Applied Psychology, 58*(1), 13-21.

Fuller, R., & Santos, J. A. (2002). Psychology and the highway engineer. In R. Fuller, & J. A. Santos (Eds.), *Human Factors for Highway Engineers* (pp. 1-10) Pergamon.

Glendon, A. I., Hoyes, T. W., Haigney, D. E., & Taylor, R. G. (1996). A review of risk homeostasis theory in simulated environments. *Safety Science*, *22*(1-3), 15-25.

Harré, N., & Sibley, C. G. (2007). Explicit and implicit self-enhancement biases in drivers and their relationship to driving violations and crash-risk optimism. *Accident Analysis & Prevention, 39*(6), 1155-1161.

Kinnear, N., Stradling, S., & McVey, C. (2008). Do we really drive by the seats of our pants. *Driver Behaviour and Training*, Vol. III (pp. 349-365). Andershot: Ashgate Publishing Limited.

Lynn, P. (2006). *The relationship between driver experience and driver decision making in an Irish population.* Unpublished Thesis, Trinity College Dublin,

McKenna, F. P. (1988). What role should the concept of risk play in theories of accident involvement? *Ergonomics, 31*(4), 469-484.

McKenna, F. P. (1990). In defence of conventional safety measures: A reply to G.J.S. Wilde. *Journal of Occupational Accidents, 11*(3), 171-181.

McKenna, F. P. (1993). It won't happen to me: unrealistic optimism or illusion of control? *British Journal of Psychology, 84*(1), 39-50.

Michon, J. A. (1989). Explanatory pitfalls and rule-based driver models. *Accident Analysis & Prevention*, *21*(4), 341-353.

Näätänen, R., & Summala, H. (1974). A model for the role of motivational factors in drivers' decision-making. *Accident Analysis & Prevention, 6*(3-4), 243-261.

Nordgren, L. F., Van Der Pligt, J., & Van Harreveld, F. (2007). Unpacking perceived control in risk perception: The mediating role of anticipated regret. *Journal of Behavioral Decision*



Making, 20(5), 533-544.

OECD. (1990). *Behavioural Adaptation to Changes in the Road Transport Systems.* Paris: OECD.

Peltzman, S. (1975). The effects of automobile safety regulation. *The Journal of Political Economy, 83*(4), 677-725.

Ranney, T. A. (1994). Models of driving behavior: A review of their evolution. *Accident Analysis* & *Prevention, 26*(6), 733-750.

Recarte, M. A., & Nunes, L. (2002). Mental load and loss of control over speed in real driving.: Towards a theory of attentional speed control. *Transportation Research Part F: Traffic Psychology and Behaviour, 5*(2), 111-122.

Rothengatter, T. (2002). Drivers' illusions—no more risk. *Transportation Research Part F: Traffic Psychology and Behaviour, 5*(4), 249-258.

Summala, H. (1988). Risk control is not risk adjustment: The zero-risk theory of driver behaviour and its implications. *Ergonomics, 31*(4), 491-506.

Summala, H. (1997). Hierarchical model of behavioural adaptation and traffic accidents. In Rothengatter, & E. Carbonell Vaya (Eds.), *Traffic and Transport Psychology: Theory and Application* (pp. 41-52). Oxford: Elsevier Science.

Summala, H. (2005). Traffic psychology theories: Towards understanding driving behaviour and safety efforts. In G. Underwood (Ed.), *Traffic and Transport Psychology* (pp. 383-394). Amsterdam: Elsevier.

VandenBos, G. R. (2006). *APA dictionary of psychology.* Washington D.C, United States of America: American Psychological Association.

Wagenaar, W. A. (1992). Risk taking and accident causation. In J. F. Yates (Ed.), *Risk-Taking Behaviour*, Englewood Cliffs, NJ: John Wiley & Sons.

Wilde, G. J. S. (1976). Social interaction patterns in driver behavior: An introductory review. *Human Factors, 18*(5), 477-492.

Wilde, G. J. S. (1982). The Theory of Risk Homeostasis – Implications for Safety and Health.

Risk Analysis, 2, 209-226.

Wilde, G. J. S. (1988). Risk homeostasis theory and traffic accidents: Propositions, deductions and discussion of dissension in recent reactions. *Ergonomics, 31*(4), 441-468.