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That's close enough - A threshold effect of time headway on the experience of risk, task difficulty, effort, and comfort

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Abstract

Subjective impressions of task difficulty, risk, effort, and comfort are key variables of several theories of driver behaviour. A point of difference between many of these theories is not only the importance of these variables, but also whether they are continuously present and monitored or only experienced by individuals at certain critical points in the driving task. Both a threshold relationship and evidence of constant monitoring of risk and task difficulty have been found for speed choice. In light of these conflicting findings this study seeks to examine a different part of the driving task, the choice of time headway.

Participants (N = 40, aged 19 to 30) drove in a simulator behind a vehicle travelling at 50 km/h at set time headways ranging from 0.5 seconds to 4.0 seconds. After each drive, ratings of task difficulty, risk, comfort, and effort were collected. In addition, participants were asked to drive at the time headway they preferred. In order to assess familiarity, participants also drove on both the left and right hand side of the road and the role of driving experience was also examined.

The results show support for a threshold awareness of task difficulty, risk, effort, and comfort in relation to time headway. Participants' ratings of these variables tended to be low, or nil at large time headways, but then around the 2.0 second mark, began to noticeably increase. Feelings of task difficulty, risk, and effort were also found to be highly correlated with each other. No effect of driving experience or side of the road was found.

1. Introduction

An understanding of driver decision making is an important goal of traffic psychology, and several models have been put forward to do so. But no model has of yet received wide spread acceptance and use in the field. However, variables such as task difficulty, risk, effort, and comfort have all at varying times been suggested as vital components of the decision making process in drivers.

Risk, in particular, has been the main focus of many models. One of the most well known is Risk Homeostasis Theory (Wilde, 1976), which proposed that there is a preferred target level of risk of being involved in an accident that drivers seek to maintain. Other models, such as zero-risk theory (Näätänen & Summala, 1974), the Driving Intensity model (Peltzman, 1975) and Threat Avoidance theory (Fuller, 1984) have also suggested that an awareness of the risk of being in an accident is a central factor in driver decision making.

Other models have focused not on the risk of being in an accident, but on drivers' general feelings of risk – which may or may not be related to their perception of accident risk. These include models such as the Risk Allostasis Theory (Fuller, 2008), and the Monitor Model (Vaa et al., 2000; Vaa, 2003; Vaa, 2007). In the case of the Monitor Model, a feeling of risk is only one of a possible number of feelings thought to drive decision making. However, within the Monitor Model the ability to monitor a feeling of risk is thought to be of great importance due to the assumed evolutionary value of being able to do so and, thus, seems to stand out amongst the other possible best feelings suggested (Vaa, 2003; Vaa, 2007). That risk is assumed to be important in the Monitor Model, relies on the work of Daimasio and his Somatic Marker Hypothesis (Damasio, 1994; Damasio, 2003). The Somatic Marker Hypothesis suggests that certain body states, emotions, result from mostly learnt environmental triggers. These body states then can bias action towards particular outcomes even if the individual is unaware of them. Since the relationship between body states and action is thought to have arisen due to the process of evolution, it is thought that body states that signal risk have a large impact due to their assumed survival value.

Risk Allostasis Theory (Fuller, 2008) also refers to the Somatic Marker Hypothesis and states that individuals have a feeling of risk they prefer to maintain and that they take appropriate actions to do so. Risk Allostasis Theory arose out of Task Difficulty Homeostasis theory (de Waard, 2002) which theorised that individuals seek to maintain a certain preferred level of Task Difficulty, perhaps indicated by the current level of mental workload or effort (Fuller, 2005). As such, in Risk Allostasis Theory, feeling of risk is also thought to be an indicator of task difficulty, due to the strong correlation between these variables (Fuller, McHugh et al., 2008; Kinnear et al., 2008).

Apart from task difficulty, risk, and effort, a feeling of comfort has been put forward by the multiple comfort zone model (Summala, 2005) as a potential primary variable in driver decision making. Within this model, uncomfortable feelings are thought to indicate when drivers are approaching, or exceeding, certain learnt safety margins.

One important point of difference between the theories discussed above is how they view their variables of interest, whether that is risk of an accident or feeling of risk, in terms of driver awareness of these variables. For example, is the variable of interest constantly present and monitored as suggested by Risk Homeostasis Theory (Wilde, 1976), Risk Allostasis Theory (Fuller, 2008) or the Monitor Model (Vaa, 2007)? Or, are drivers only experiencing and acting on these variables once certain thresholds have been crossed, as suggested by zero-risk theory (Näätänen & Summala, 1974), risk avoidance theory (Fuller, 1984), or the multiple comfort zone model (Summala, 2005).

The relationship between ratings of task difficulty, feeling of risk, and assessment of crash risk in relation to speed, was investigated by Fuller, McHugh et al. (2008). In order to do so, participants were required to rate videos of three different roads being driven at a range of speeds. The speeds were produced by digitally altering one piece of film footage for each road and were presented to participants, starting with the slowest speed and then in increasing 5 mile per hour increments after that. It was expected that ratings of task difficulty would increase systematically with speed, in line with predictions made by Task Difficulty Homeostasis. Ratings of feeling of risk and crash risk, on the other hand, were predicted to show a threshold relationship in that they would only start to increase once a certain speed was observed (Fuller, McHugh et al., 2008). As expected, a strong linearly increasing relationship between speed and ratings of task difficulty was found but, surprisingly, this was also the case for ratings of feeling of risk. However, ratings of crash risk did show a threshold type trend. It was also found that ratings of feeling of risk and task difficulty were strongly correlated with each other ($r = 0.81$), a finding that Fuller, McHugh et al. (2008) took to mean that feeling of risk could act as an indicator of task difficulty.

The findings of Fuller, McHugh et al. (2008) therefore seem to support a constant perception and monitoring view of variables such as task difficulty and feeling of risk. However, a recent investigation of the Fuller, McHugh et al. study using a driving simulator instead of video presentation produced a different picture (Lewis-Evans & Rothengatter, 2009). Participants in this study were required to sit in a fixed base driving simulator and either simply watch a road being driven, or had control over the steering of the vehicle while it was driven at a set speed. Like the earlier Fuller, McHugh et al (2008) study, participants were required to give ratings of feeling of risk, crash risk, and task difficulty after each trial. In addition, ratings of comfort, effort, and how typical the speed travelled was, were collected as well. Unlike the Fuller, McHugh et al (2008) study, the speeds the participants experienced in the simulator were presented in random order, and also the participants had an opportunity to drive each of the two roads used at whatever speed they preferred. The results of the driving simulator study confirmed the previous finding that ratings of task difficulty and feeling of risk are strongly correlated with each other, and in addition are strongly correlated with ratings of effort. However, the strong, linear, increasing trend of ratings of task difficulty and feeling of risk with speed was not apparent. Rather, a threshold trend was found, with ratings of feelings of risk, crash risk, task difficulty, and effort staying low, or nil, until a certain speed was reached, and only after this speed did they begin to increase. Ratings of how typical the speed was and of comfort, on the other hand, tended to have more of a U-shaped relationship with speed.

The difference between the results gained by the studies discussed above, means that it is important that more research in this area is carried out. Also, there has been some criticism that studies aimed at testing models of driver behaviour have focused too much on speed as an independent variable (Carsten, 2009). While driving is typically seen as a self-paced task, and a driver's choice of speed is one important way in which they can affect the task, there are other behaviours which drivers can generally freely perform. Selecting and maintaining appropriate time headways to lead vehicles is one such behaviour.

If models of driver behaviour aim to describe the whole of driver decision making then they should be able to explain a driver's choice of time headway, a variable that in many cases is able to be freely varied by drivers. The decision of how close to follow a lead vehicle is made quite often in traffic, especially in built up areas and on motorways, and it is clear that drivers do not always select their time headway appropriately. In New Zealand, for example, rear end crashes are one of the most common crash types (Ministry of Transport, 2008). In 2007, ten percent of all injury crashes in New Zealand were coded as "Rear end", the 3rd most common type of injury crash after "Loss of control while cornering" (22.3%) and "Lost control on a straight" (10.5%). Thankfully, rear end crashes do not often result in fatalities (only 1.6% of all fatal crashes in 2007 in New Zealand), but they are nevertheless still a problem due to their high frequency, if only for their material and economic costs. This situation is likely to be similar in other motorised western countries such as in the USA, where rear end collisions make up approximately 29% of all crashes (National Highway Traffic Safety Administration, 2003). This study therefore seeks to examine the relationship between time headway and ratings of risk, task difficulty, effort, and comfort.

It was predicted, that in line with previous studies, a high correlation between ratings of effort, task difficulty, and risk would be apparent. It was also predicted that a threshold relationship between time headway and ratings of task difficulty, risk, and effort will be found, along with a U-shaped curve for ratings of comfort and whether the time headway driven was typical or not. This is because the constant monitoring of a subjective variable such as a feeling, and comparing it to a set subjective state, seems excessively stressful and demanding. Instead, it is more reasonable to suggest that certain learnt behaviours or environmental situations cause a feeling to be felt and then acted upon (Summala, 1997). Feelings, after all, are said to arise from attention directed towards the emotional body state, which is generally made up of learnt reactions to certain environmental stimuli (Damasio, 1994; Damasio, 2003). In other words, they are not constantly present but rather occur only once certain conditions have been met.

Given that past experience may therefore be important in setting thresholds, it was also decided to examine the effect of familiarity and driving experience. In order to do this all participants were required to complete the driving task on both the familiar right hand and the unfamiliar left hand side of the road. Simply changing the side of the road driven was chosen as a manipulation of familiarity because it is unfamiliar to drive on the other side of the road but, as long as no turning maneuvers are involved, it is not particularly difficult or risky to do so. In addition, both inexperienced and experienced drivers were recruited. It was expected that the threshold point for experienced and inexperienced drivers may differ and that driving on the unfamiliar side of the road may also shift or remove the threshold effect.

2. Method

2.1. Participants

Participants were recruited through posters placed around the University of Groningen and were paid 15 Euros for taking part. This resulted in 40 participants in total, 20 male and 20 female. The participants were recruited and categorised as experienced or inexperienced based on the number of kilometers they had driven in their lifetimes. Experienced drivers had to have driven at least 10,000 kilometers and inexperienced driven less than 10,000 kilometers. The experienced group contained 23 participants (12 male, 11 female) who had driven between 10,000 and 350,000 kilometers in their lifetimes. They had held their licence for an average of 6.5 years (SD = 5.9) and were on average 25.4 (SD = 6.0) years old. The inexperienced group contained 17 participants (8 male, 9 female) who had driven between 300 to 9,000 kilometers in their lifetimes. They had held their licence for an average of 1.9 years (SD = 1.1) and were on average 21.5 years old (SD = 2.0).

2.2. Materials

The University of Groningen fixed based driving simulator was used in the study. The simulator runs STSoftware software and allows participants a 210-degree view of the road environment. A cardboard cutout was placed over the instrument panel to prevent speed information being available to the participants. Participants drove on a residential street, created according to Dutch road design guidelines, which took approximately 3 minutes to drive. The street had on-coming traffic at a rate of one vehicle approximately every 12.5 seconds. Depending on the condition, the on-coming traffic was placed to always be in the opposite lane to that driven by the participants; so in the left lane when the participants were driving in the right lane and the right lane when the participants drove on the left. This was done to prevent any overtaking. Information on the time headway between the participants' vehicle and the lead vehicle was collected at a rate of 10 Hz.

The simulator was programmed with eight different time head-ways between the participants' car and a lead vehicle. This allowed for the speed and time headway of the participant's car to be set by the simulator, similar to driving a vehicle with adaptive cruise control. The time headway ranged from 0.5 to 4.0 seconds, in 0.5 second increments, and the speed of travel for both the participant and lead vehicle was locked to 50 km/h. In all trials the participants retained lateral control of the vehicle. At the start of the drive the participants' vehicle began 10 metres behind the lead vehicle. When the relevant program was started both vehicles would begin to accelerate and the required time headway would be set and maintained for the rest of the drive. In addition to the eight set time headways, participants were also given the opportunity to drive at a time headway of their own choosing behind the lead vehicle. In this case the lead vehicles speed was locked to 50 km/h and participants were instructed to follow the lead vehicle as closely as they felt comfortable.

2.3. Procedure

Participants first filled out a demographic questionnaire containing questions about their age and driving experience. Then they were placed in the simulator and allowed to practice driving, for around 5 minutes on a practice track, in order for them to become comfortable.

Participants were then randomly assigned to one of two groups, counterbalanced across genders and experience level. The first group of participants had to drive all the different time headways, in random order, including the free choice condition, first on the right hand side of the road, and then on the left. The second group carried out the same tasks but drove on the left hand side first and the right hand side second. In all the fixed time headway conditions participants were simply instructed to drive as they would normally while staying behind the lead vehicle. In the case of the free choice time headway condition participants were asked to follow as close to the vehicle in front as possible while still feeling comfortable.

After each drive, during which one following distance condition was experienced, the participants filled in a one page questionnaire (in Dutch). The questionnaire asked for ratings of experienced risk, task difficulty, effort, and comfort on 7-point Likert scales as shown below:

How difficult did you find it to follow the lead vehicle at this distance?

	1	2	3	4	5	6	7	
Not Difficult								Very Difficult

How much risk did you experience following the lead vehicle at this distance?

	1	2	3	4	5	6	7	
No Risk								Maximum Risk

How much effort did it take to follow the lead vehicle at this distance?

	1	2	3	4	5	6	7	
No Effort								Maximum Effort

How comfortable did you feel following the lead vehicle at this distance?

	1	2	3	4	5	6	7	
Very Comfortable								Very Uncomfortable

Participants were also asked to answer two questions about crash risk. One asked participants to give an indication of how many times they thought they would have an accident or lose control of the vehicle if they had to follow a car at the distance shown every day for two months (i.e. 60 times). The second asked the same question, but was phrased as how many times a driver just like the participant would have an accident or lose control. These questions were used to examine the difference between assessing crash risk for the participants themselves versus their perception of crash risk for a hypothetical identical other. The two questions about crash risk were open and participants were free to give any number, including indicating that they didn't think that they or the other driver would have any crash.

The questionnaire also contained one final question asking the participants to indicate if they would typically follow a vehicle at the time headway they just experienced. This was done using a 1-7 point scale with 1 corresponding with "never" and 7 with "always". This scale was reversed for later data analysis.

2.4. Analysis

In order to carry out the analyses two datasets were created. One dataset, referred to as the averaged dataset, simply contained all the averaged ratings given by the participants for each of the fixed time headway conditions, on both the left and right hand side of the road.

The second dataset, referred to as the relative dataset, was created to examine the free choice condition. First, the average time headway chosen for each of the individual participants was calculated for both the left and right hand side drives. Then, using the average following distance for each individual, the ratings from the three set time headways above and below the free choice time headway were collected and placed around the ratings given during the free choice condition. So, if on average the participant had driven with a time headway of 2.3 seconds then the ratings they gave would be assigned as the zero point, and then the fixed distance ratings for 1.0, 1.5, 2.0, 2.5, 3.0 and 3.5 seconds would be arranged on either side of it. Another participant may have driven at 1.75 seconds and in that case the ratings for 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 would also be collected. This was done for each participant and then averaged over all participants to create a dataset where all values were relative to the ratings given during the free following condition. Due to how the data was arranged, it was possible that fewer than 3 fixed time headways fell on either side of the time headway driven by the participant. For example, if the participant drove at a time headway of 1.2 seconds from the lead vehicle, then only the 0.5 and 1.0 second fixed time headways were available below the time headway selected by the driver. In the case of a missing value it was replaced by the average of the remaining data points for that individual participant in order to allow statistical analysis to be carried out.

MANOVA analysis were run for both datasets with the within subjects factors of time headway and side of the road. A difference contrast was used for time headway and all the subjective ratings were included as measures within the MANOVA. Gender and driving experience were included in the analyses as between subject factors. In order to examine the trends of each subjective variable in relation to time headway, individual regression analysis was performed for each subjective variable in both datasets. In the averaged dataset, a regression was first run for the ratings given for the time headways between 4.0 and 2.5 seconds, and then another regression was run on each of the subjective variables for headways between 2.0 and 0.5 seconds. A similar split was performed for the relative dataset, in that regressions were run for each variable for the time headway intervals leading up to their preferred time headway rating, and then again for the time headway intervals leading away from their preferred time headway. Due to the MANOVA analysis revealing a significant effect of side of the road, the regression analysis for both datasets was also run separately for data gathered on the right and left hand sides of the road. Pearson's correlations, again split by side of the road, were run for both datasets to examine the relationship between the subjective ratings.

A MANOVA was also run to examine the difference in average free following distance chosen by the participants. The MANOVA included side of the road as the within subjects factor, as well as gender and driving experience as between subjects factors. Pearson's correlations were also run to examine the relationship between individuals chosen time headway and their subjective ratings of task difficulty, feeling of risk, effort, comfort, crash risk and how typical the following distance was. All analyses were undertaken using SPSS 16.0 for Windows.

3. Results

A MANOVA analysis, with a difference contrast for time headway, was run for both the averaged and relative datasets. For the subjective ratings in the averaged dataset, there were main effects for time headway ($F = 5.47$, $p < .001$), in that the subjective ratings increased as time headway decreased. A significant main effect of side of the road was also found ($F = 3.29$, $p < .05$), as well as a significant interaction effect between side and time headway ($F = 1.38$, $p < .05$). There was no effect of driving experience ($F = .99$, $p = .46$) or gender ($F = 1.53$, $p = .20$) on the ratings however. Post-hoc tests using a Bonferroni adjustment, revealed that there was a significant effect for ratings of feelings of risk, in that ratings of feelings of risk when driving on the right hand side of the road were higher than those given when driving on the left hand side (Mean difference = .21, $p < .01$).

In the case of the relative dataset, MANOVA analysis with a difference contrast for time headway, found that there were also significant main effects for time headway ($F = 5.51$, $p < .001$) and side of the road ($F = 7.0$, $p < .05$), as well as an interaction between side and time headway ($F = 1.60$, $p <.01$). As with the averaged dataset there was no effect of experience ($F = .60$, $p = .77$) or gender ($F = 1.37$, $p = .25$). Post-hoc tests using a Bonferroni adjustment, revealed once again that ratings of feeling of risk were significantly higher when driving on the right hand side of the road (Mean difference = .22, $p < .05$)

3.1. Relationship between subjective ratings and time headway in the averaged dataset

In the case of the averaged dataset, none of the subjective variables recorded were found to increase in a simple linear fashion as time headway decreased. Rather, as shown in Figure 4.1, ratings of risk (feeling of risk and crash risk), task difficulty, effort, and comfort, all tend to be flat and stable until a certain time headway was reached. This time headway is around 2.0 seconds for both the left and right hand sides of the road and it is only after this point that the ratings of these variables begin to significantly increase. There is one exception to this, which is in the ratings of feeling of risk for the right hand side of the road. In this case there is a very small significant trend ($t = 2.24$, $r^2 = .03$, $p < .05$) before the 2.0 second mark, which then increases considerably once 2.0 seconds is exceeded ($t = 8.73$, $r^2 = .33$, $p < .001$). However, it should be noted that if the trend for ratings of risk on the right hand side of the road is examined between 4.0 and 2.5 seconds, rather than between 4.0 and 2.0 seconds, then the small significant trend is no longer apparent. Figure 1 also clearly shows that the ratings of crash risk participants gave for other drivers increase much more rapidly than ratings of crash risk for the participants themselves.

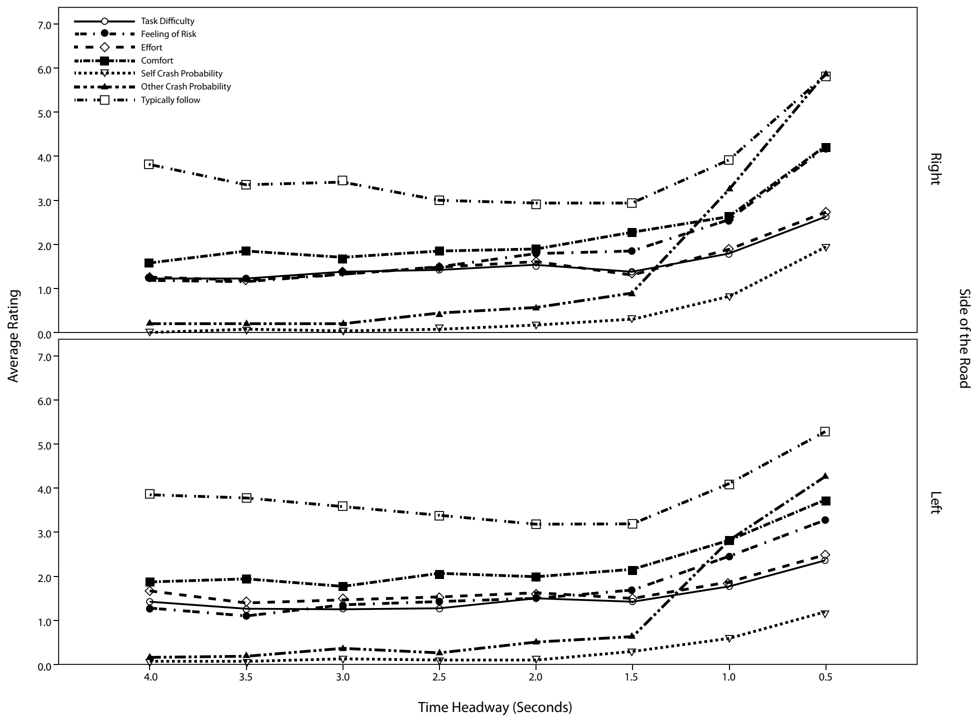

Figure 1. Average ratings of task difficulty, feeling of risk, effort, comfort, crash risk (self and other), and "I typically follow at this distance" in relation to decreasing time headway in seconds and by side of the road driven.

Furthermore, it is only once this 2.0 second mark has been crossed that ratings of task difficulty, feeling of risk, and effort rise above an average rating of 2. As a rating of 1 for task difficulty, feeling of risk and effort indicates the absence of these variables, this suggests that many of the participants were not yet willing to indicate that they were feeling or experiencing any difficulty, risk, or effort until after the 2.0 second mark. The trend for ratings of whether the time headway experienced was typical or not appears to be slightly U-shaped, in that participants indicated that the time headway became more and more typical, until around 2.0–2.5 seconds. Then after 2.5 seconds the participants begin to indicate that the time headway became more and more atypical. This trend is apparent on both sides of the road.

Table 1. Regression analysis of the averaged dataset for ratings of task difficulty, risk, loss of control, effort, comfort and typical follow with time headway for both sides of the road.

Right hand side of the road						
	4.0 to 2.5 seconds			2.0 to 0.5 seconds		
	r^2	Beta	t	r^2	Beta	t
Task Difficulty	.02	.15	1.84	.15***	.39	5.28
Feeling of Risk	.03*	.18	2.24	.33***	.57	8.73
Effort	.02	.14	1.75	.16***	.40	5.50
Comfort	.00	.05	.64	.23***	.48	6.88
Self Crash Probability	.02	.14	1.76	.11***	.33	4.37
Other Crash Probability	.02	.12	1.54	.09***	.29	3.85
Typically follow	.03*	-.17	-2.20	.37***	.61	9.56
Left hand side of the road						
	4.0 to 2.5 seconds			2.0 to 0.5 seconds		
	r^2	Beta	t	r^2	Beta	t
Task Difficulty	.01	-.09	-1.141	.10***	.31	4.15
Feeling of Risk	.02	.12	1.572	.26***	.51	7.4
Effort	.00	-.06	-.71	.10***	.31	4.16
Comfort	.00	.04	.489	.16***	.40	5.55
Self Crash Probability	.01	.11	1.44	.13***	.36	4.79
Other Crash Probability	.01	.10	1.279	.06***	.24	3.09
Typically follow	.01	-12	-1.50	.23***	.48	6.92

* $p < 0.05$ *** $p < 0.001$

As shown in Table 1, the results of a regression analysis of the first four time headways for each subjective variable, and the last four are consistent with the trends discussed above. The r^2 values for the left hand side during the 2.0 to 0.5 second period appear to be slightly lower than those for the right hand side, but other than that the general trend is similar.

3.2. Relationship between subjective ratings and time headway in the relative dataset

As shown in Figure 2 the relative dataset initially appears to show somewhat similar threshold trends to that of the averaged dataset in terms of ratings of feeling of risk, crash risk, and comfort. However, the trend for ratings of effort and task difficulty are different in that they appear to stay flat and stable across all the time headway increments, apart from a peak in the middle at the free choice condition.

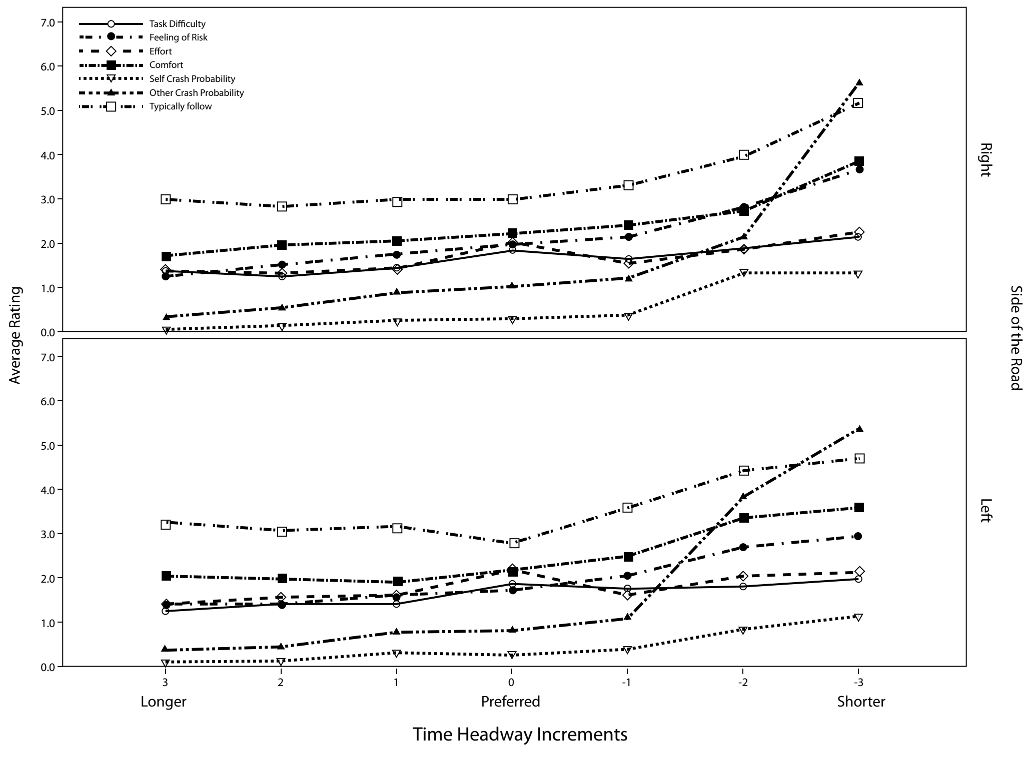

Figure 2. Relative ratings of task difficulty, feelings of risk, effort, comfort, crash risk (self and other), and "I typically follow at this distance" in relation to decreasing time headway in seconds and by side of the road driven. A value of zero on the x-axis corresponds to the average rating given by participants during the free following condition. Each increment above or below the zero point (3, 2, 1, -1, -2, -3) represents a fixed time headway condition below or above the average time headway selected by the participants in the free following condition.

As with the averaged dataset, the trend of the feeling of risk variable when driving on the right side of the road, significantly increases slightly before the free time headway condition ($t = 2.7$, $r^2 = .06$, $p < .05$) and then increases rapidly after this point ($t = 6.33$, $r^2 = .20$, $p < .001$). Furthermore, the ratings for self crash risk and other crash risk when driving on the right also shows a significant increase during the period before the free time headway is reached ($t = 2.00$ & 2.34, $r^2 = .03$ & $.04$, $p < .05$). Also, the trend for the typically drive variable appears to have lost its U-shape when examined for the right hand side drive. Once again the results of a regression analysis, shown in Table 2, are consistent with the trends discussed above.

Table 2. Regression analysis of the relative dataset for ratings of task difficulty, risk, loss of control, effort, comfort and typical follow with time headway for both sides of the road.

Right hand side of the road						
		1 to 3			-1 to -3	
	r^2	Beta	t	r^2	Beta	t
Task Difficulty	.00	.05	.51	.02	.14	1.81
Feeling of Risk	.06**	.24	2.7	.20***	.45	6.33
Effort	.00	.02	.21	.00	.04	0.51
Comfort	.01	.11	1.20	.15***	.38	5.22
Self Crash Probability	.03*	.18	2.00	.05**	.23	2.98
Other Crash Probability	.04*	.21	2.34	.10***	.32	4.17
Typically follow	.00	.01	.10	.21***	.46	6.54
Left hand side of the road						
		1 to 3			-1 to -3	
	r^2	Beta	t	r^2	Beta	t
Task Difficulty	.01	.11	1.16	.01	.07	.85
Feeling of Risk	.01	.10	1.124	.19***	.44	6.12
Effort	.01	0.12	1.30	.00	.03	.34
Comfort	.00	0.03	.35	.19***	.43	6.01
Self Crash Probability	.03	0.16	1.80	.11***	.33	4.38
Other Crash Probability	.03	0.16	1.79	.08***	.29	3.78
Typically follow	.00	0.03	.32	.25***	.50	7.23

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

3.3. Correlations between ratings of task difficulty, risk, comfort and typical time headway

Using a Pearson's correlation, ratings of task difficulty, feeling of risk, and effort were found to be moderately to strongly correlated with each other ($r = .59$ to $.78$, $p < .001$). Ratings of task difficulty, feeling of risk and effort were moderately correlated with ratings of comfort ($r = .41$ to $.65$, $p < .001$). Ratings of feeling of risk were also moderately correlated with participants' ratings of self crash risk ($r = .51$ to $.62$, $p <. 001$) but only had modest correlations with ratings of crash risk for another driver ($r = .14$ to $.28$, $p < .05$). Ratings of effort and task difficulty, on the other hand, were only modestly related to ratings of crash risk, both for the participants themselves and for others ($r = .14$ to $.29$ $p < .05$), except in the case of ratings of task difficulty in the relative dataset for indications of others crash risk when driving on the left, which showed no significant correlation ($r = .10$). Finally, ratings of how typical the following distances were, modestly to moderately correlated with all the other variables ($r = .29$ to $.66$, $p < .01$), with the strongest correlations being with ratings of feeling of risk. Apart from the exception mentioned above for task difficulty, the correlations were relatively consistent across both datasets, and no matter which side of the road the participants drove on.

3.4. Free following time headway

During the free following condition, participants on average drove at a time headway of 1.78 seconds ($SD = .89$) behind the lead vehicle on the right hand side of the road, and 1.67 seconds ($SD = .88$) on the left. MANOVA revealed that there was no significant difference in time headway by side of the road ($F = .86$, $p = .36$), driver experience ($F = 1.03$, $p = .32$), or gender ($F = 1.84$, $p = .18$). Pearson's correlations were also calculated between the chosen time headway and the subjective ratings given after driving at that distance. It was found that, on both sides of the road, ratings of feeling of risk ($r = -.43$ to $-.49$, $p < .01$) and crash risk for other drivers ($r = -.37$ to $-.38$, $p < .05$) were significantly negatively correlated with the time headway. No other variable was significantly correlated with the free choice of time headway.

4. Discussion

As predicted, there was a strong relationship between ratings of task difficulty, feeling of risk, and effort. This is consistent with previous findings (Fuller, McHugh et al., 2008; Kinnear et al., 2008; Lewis-Evans & Rothengatter, 2009), and is not surprising, as risk, difficulty, and effort often occur together naturalistically. Risk is formally defined as the likelihood of an occurrence multiplied by the outcome of that occurrence (Nordgren et al., 2007), and task difficulty is the interaction between the capability of an individual and the demands of the environment. It could, therefore, be argued that task difficulty is simply the first part of the risk equation, the likelihood of the occurrence. Also, task difficulty and effort are intrinsically linked, as capability can be seen as related to the amount of effort available, and the demands of the environment set the amount of effort required for performance (Fuller, 2005). Given that the correlation appears robust across studies, it may be that ratings of feeling of risk, task difficulty, and effort are labels for the same underlying construct. Further research to see if these variables can be separated would be interesting. It does seem, however, that once the threshold had been crossed, the ratings of feeling of risk were more sensitive to decreases in time headway than the ratings of task difficulty and effort.

Also as predicted, the threshold relationship previously described by Lewis-Evans and Rothengatter (2009) for task difficulty, feeling of risk, crash risk, effort, and comfort with speed, was also apparent here for time headway, at least in the averaged dataset. Ratings of task difficulty, feeling of risk, crash risk, effort, and comfort generally stayed low and stable until a certain following distance was reached, around 2.0 seconds, and after this point began to significantly increase. In the case of the relative dataset, however, the trend is not as clear as previously found for speed, where the speed choice made by participants acted as a clear threshold point (Lewis-Evans & Rothengatter, 2009). This relationship is still apparent for ratings of feeling of risk, comfort, and crash risk but ratings of effort and task difficulty in the relative dataset appear to stay flat over the time headways examined. This could be because the instruction given to the participants, to travel as close as possible while still feeling comfortable, was inappropriate. Given that the participants' chosen time headway was on average around 1.67 to 1.78 seconds, it may be that participants obeyed the "follow as close as possible" part of the instruction more so than the instruction to remain comfortable. The resulting relatively close following distance leads to quite a few missing values in the relative dataset as there were not always 3 fixed time headways available to fill the -1 to -3 positions in the relative dataset. This may have affected the trend lines. Perhaps an instruction for the participants to simply follow as they would normally would have been more appropriate.

The fact that a threshold relationship is apparent in this data is particularly interesting given the unusual nature of the task required of the participants. In essence, all the participants had to do was maintain lateral control, on an identical road, several different times. The speed of the vehicle, and its time headway to the lead vehicle were all set and maintained by the simulator, with the exception of the free following condition. It could therefore be argued from an objective position, that in this experiment, following the lead vehicle at a headway of 0.5 seconds is no more effortful, difficult or risky than following at 4.0 seconds. That the participants did indicate that it felt risky, difficult, effortful, and uncomfortable to be close to the lead vehicle, despite the lack of real objective difference in these variables, is suggestive of an effect of previous experience and learnt thresholds being responsible for these feelings. It may be that, as suggested by threat Avoidance theory (Fuller, 1984), zero-risk theory (Näätänen & Summala, 1974), and the multiple comfort zone model (Summala, 2005), that participants have a certain, learnt, headway at which they prefer to follow vehicles. Once this learnt, preferred headway is crossed, uncomfortable feelings that can be labelled as difficulty, risk, or effort, begin to be experienced. The multiple comfort zone model, in particular, takes an approach which is similar to that laid out by Gibson and Crooks (1938) in their Field of Safe Travel model. The multiple comfort zone model suggests that just like individuals have learnt personal spaces around them during everyday life that make them feel uncomfortable if they are breached, they also create a zone of safe travel or safety margin around themselves when driving. When this safety margin is exceeded it indicates to the driver that something is not as usually experienced (Summala, 2005). These safety margins may not actually be related to the objective risk or safety of the situation, however, and are instead learnt based on previous experience.

The typical following distance ratings for the averaged dataset also support an idea of learnt thresholds. Ratings of how typical the time headway experienced was, followed a U-shaped trend, with the bottom of the U being around the same point at which ratings of task difficulty, risk, effort, and discomfort begin to increase. This is in line with a similar result for indications of typical speed of travel found previously (Lewis-Evans & Rothengatter, 2009).

With the possibility of learnt thresholds in mind, this study attempted to test the role of familiarity in determining the threshold point. As such, drivers were required to complete the following distance task on both the familiar (for Dutch drivers) right hand side of the road, as well as the unfamiliar left hand side. It was thought that driving on the unfamiliar side of the road may have shifted or removed the threshold effect, and perhaps increased ratings of difficulty, risk, effort, and discomfort. However, there was very little difference in the results produced by driving on the left hand side of the road, with the general trend for both sides being similar. The only significant increase in ratings was in fact found for ratings of feeling of risk for drivers travelling on the right hand side of the road, and this effect was small. The lack of an effect caused by road type could be because drivers were aware of what was causing any potential feelings of unfamiliarity, and were able to dismiss them as not relevant to the time headway task. Perhaps if a task involving manoeuvres traditionally seen as difficult when driving on an unfamiliar side of the road (such as navigating intersections or roundabouts) had been used there would have been a more marked impact. However, this would then confound the variable of simple unfamiliarity with the increased difficulty and risk of such manoeuvres.

In addition, there was no significant impact of driver experience on the ratings given. This may indicate that drivers learn or establish these thresholds early and that once a threshold has been crossed the reaction is similar no matter how experienced the individual is. In their examination of the relationship between speed, ratings of risk, and task difficulty, Kinnear et al. (2008) also found no effect of driving experience on ratings of these variables.

There are several potential weaknesses with this study. To begin with, it is possible that by asking participants to rate the variables assessed that they become more salient to the participants. This would bias the results towards reporting those variables more readily and perhaps shift participants' threshold point of awareness. However, the finding that even with attention directed towards these variables, participants still often rated them as absent during the larger time headways, does give additional support to the idea that these variables are not usually experienced.

It is also possible that the rating scales used in this experiment were not sensitive enough to pick up underlying changes in the variables assessed. This could also be impacted by the relatively large changes in following distance experienced by the participants. It is possible that steps of 0.5 seconds may have been too large to see the actual threshold point of the participants.

Furthermore, the task that the participants performed could justifiably be labelled as unusual. Driving is usually described as a self-paced task where drivers are free to choose their own speed and time headway, amongst other things. In this experiment, however, drivers were for most of the time locked into the same speed and the control of time headway was completely out of their hands. There are times during driving, however, when the task is not particularly self paced such as when in a stream of traffic. Also the task used in this experiment could be seen as similar to driving with adaptive cruise control, which allows for control of both time headway and speed to be handed over to the vehicle.

1.1 Conclusion

This experiment offers further evidence for driver behaviour models that provide a threshold account for the experience of task difficulty, risk, effort, and comfort while driving. Furthermore, that a threshold relationship is apparent for both following distance and speed, is in part validation of threshold models to embrace the entire driving task. It also appears from the results of this experiment, that experience and learning may play some role in setting the thresholds used by drivers. Ultimately this means that road safety practitioners cannot rely on drivers to always be consciously aware of changes in the driving task brought about by interventions. Rather, if practitioners want to cause drivers to consciously change their behaviour in reaction to the experience of task difficulty, risk, effort, or comfort, then whatever road safety intervention is being implemented must cause the drivers threshold for the perception of these variables to be crossed. This could be particularly challenging given that there is likely considerable variation between, and perhaps within, individuals' thresholds for the perception of these variables.

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