AUTONOMICS

ASSESSING BEHAVIOURAL ADAPTATION TO PHYSICAL RISK

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The investigation of behavioural response and task performance in relation to physical risk is fraught with ethical, legal and practical issues. In these studies, weather conditions have been suggested as a means of operationalising physical risk against the normalized risk taking activity of driving thus allowing ethical, empirical testing of behavioural adaptation.

The article details a combination of data from simulator, closed road track and in-depth accident investigation studies. All three types of data supported the existence of behavioural adaptation with changes in objective physical risk, potentially mediating individual accident likelihood. Issues surrounding the collection, analysis and validity of such data are discussed.

Introduction

The design of research investigating human response to a threat of physical harm is problematic due to self-selection bias (Harrison et al, 2009) and a variety of other ethical and legal considerations (Haigney & Westerman, 2001). Whilst on-road driving behaviour can be regarded as a socially normalised active process of 'threat avoidance' (Gibson & Crooks, 1938; Fuller, 1984; Matthews, 1992) with the influence of demand characteristics (Rosnow, 2002) participant consent (ibid.) and the potential statistical significance bias of journals (Sridharan & Greenland, 2009) it could be argued that reported behavioural adaptation to threat, is – however unwittingly – distorted. As the extent and nature of any behavioural adaptation pathway cannot necessarily be predicted reliably (Wilde, 1988) this raises issues regarding uncontrolled, unassessed, ungeneralisable and unpredicted physical risk exposure for all other road users who have not given consent – in which the participant, the experimenter and any supporting institution may well be culpable (Coolican, 2009).

Since the logistics and pragmatics of overcoming these issues are formidable, the range of legally unambiguous, ethical and analytically sound empirical techniques available to researchers investigating responses to physical risk through driving behaviour is restricted. It would still be possible for example, to observe the driving behaviour of participants through analogous on-road environments however, e.g. closed track (Gkikas et al, 2009b; Han & Yi-Lang, 2006) computer simulations (Blana & Golias, 2002; Jamson, Westerman, Hockey & Carsten, 2004) or non-experimental manipulation (e.g. following involvement in a road traffic accident such as the 'On The Spot' (OTS) Co-operative Crash Injury Study, CCIS (CCIS, 2009).

The use of meteorological condition as means of operationalising physical threat within these techniques allows ethical, socially normalised physical risk for all road users. Objective measurement in terms of weather event intensity and duration is also possible (Edwards, 1998) against which perceived risk, affective and behavioural response may also be assessed.

These original, albeit summarised studies detail data from simulator, closed road track and in-depth accident investigation studies in which physical threat is operationalised through meteorological condition. Data are discussed in terms of their potential contribution to the debate surrounding the possibility of driver adaptive response in the face of threat.

Simulator Study

Given driver concern over conditions of low visibility in fog and darkness (Brisbane, 1992; Andrey and Knapper, 1993) and the increased objective road traffic collision (RTC) risk under such conditions *ceteris paribus* (Andrey and Knapper, 1993; Edwards, 1998) this study will concentrate specifically on the relation between driver behaviour and visibility conditions. The assessment of subjective risk across experimental conditions has been undertaken through of the 'UWIST Mood Adjective Checklist' or UMACL (Lazarus and Folkman, 1984; Matthews, 1992; Matthews et al., 1990). This gives participant ratings on the dimensions of EA (energetic arousal, i.e. alertness through tiredness) and TA (tense arousal, i.e. tension through relaxation).

Forty individuals participated in the study (25 male and 15 female). Mean age in years was 22.8 (sd. 5.64), mean annual driving exposure 13,453 miles (sd. 1.11) and mean driving experience 4.63 years (sd. 4.02). Participants negotiated in the left carriageway along a simulated road via the manipulation of the steering wheel, the accelerator and brake pedals, populated with simulated ‘other vehicles’. Performance variables include: speed, braking, collisions (also referred to as ‘error’) and left headway (distance between participant vehicle and ‘other’ in front of them in the left carriageway). Visibility and contrast per condition followed meteorological definitions as well as empirical chroma contrasts and cycles (Commission Internationale de l’Eclairage, 1992; Meteorological Office,1969).

In this within-subject design, participants in the study were required to complete the UMACL immediately prior to and following counterbalanced visibility conditions with a 2-minute rest period post-condition (Matthews et al., 1992).

Figure 1 shows that statistically significant variation was established for mean speeds across all experimental conditions ($df=3$; $f=8.57$; $p<0.000$). Post-hoc Scheffe analysis, indicated that significant differences existed between the day, thick fog and dense fog experimental groups at the $p<0.05$ level, supporting speed survey studies (Tenkink, 1988; Sumner et al, 1977).

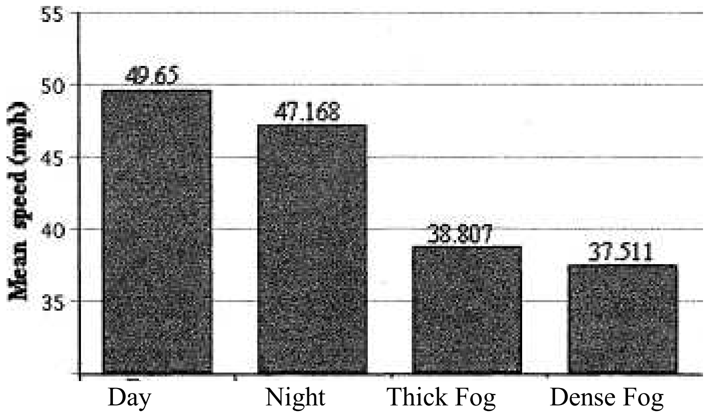

Figure 1: Mean speed across conditions

Mean braking was not statistically significant across conditions (df=3; f=1.125; p<0.933).

The four types of collision recorded were not found to vary significantly across the experimental driving conditions at the 5% level (left carriageway: participant car and 'other' car [df=3; f-0.242; p<0.866]; right carriageway: participant car and 'other' car [d£=3; f-0.193; p<0.900]; left edge of road [df-3; f=0.551; p<0.647; right edge of road [df-3; f=0.799]).

Mean left headway (figure 2) was found to vary significantly across conditions, with the greatest values recorded in the daytime condition falling through to the lowest values in dense fog. Post-hoc Scheffe analyses show that significant differences between groups (p<0.05) lie between the daytime and thick fog conditions.

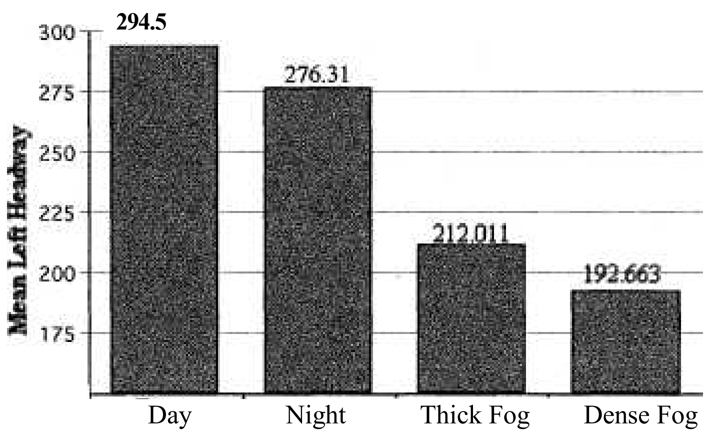

Figure 2: Mean left headway across conditions

Table 1 shows that the same distribution of statistically significant differences across conditions were noted for both post-run EA and post-run TA mood factors, with no significant differences being determined between day and night, or between dense fog and thick fog.

Table 1: Statistically significant variation in post-drive mood dimensions across condition

Mood Dimension	Visibility Condition		
		Day	Night
EA	Thick Fog	t=-2.92;p<0.006	t-3.39;p<0.002
	Dense Fog	t=-3.44;p<0.001	t=-4.55; p<0.000
TA	Thick Fog	t=-3.49;p<0.001	t=-2.59; p<0.013
	Dense Fog	t=-3.92;p<0.000	t=-3.47; p<0.001

Test-track study

For further evidence of weather effects on driver behaviour a closed road-track was employed. The vehicle was instrumented with force/pressure and position sensors on the control-pedals, a video camera mounted on the dashboard and a second camera in the footwell . Forty-eight drivers took part (24 male, 24 female) whose ages ranged from 21 to 84 (mean 31.3) years, mean driving experience was 12 years (min 1, max 48), and mean mileage was 9653 miles/year (min 2000, max 30000). They all held a full driving license (UK/EU or equivalent international) and had 3 or less penalty points.

Participants were asked to drive the instrumented vehicle at their preferred distance behind a confederate vehicle, the latter being fitted with a trailer.

The lead-vehicle accelerated to 30mph and kept a constant speed until releasing the trailer after 0.2 miles (321.86 m) on the main straight of the track. Upon release, the trailer would decelerate at an average rate of $-6.81 m/s^2$. Participants would brake to avoid a collision. Weather conditions were recorded as “clear”, “cloudy” or “rain/wet” as per the Road Accident Statistics (STATS 19) coding system used by police forces in the UK (Department for Transport, 2009).

Weather conditions had a significant effect brake pedal force (F=5.37, p=0.01; figure 3). However, analysis of variance did not provide statistical evidence of weather effects on throttle-off (F=0.61, p=0.94).

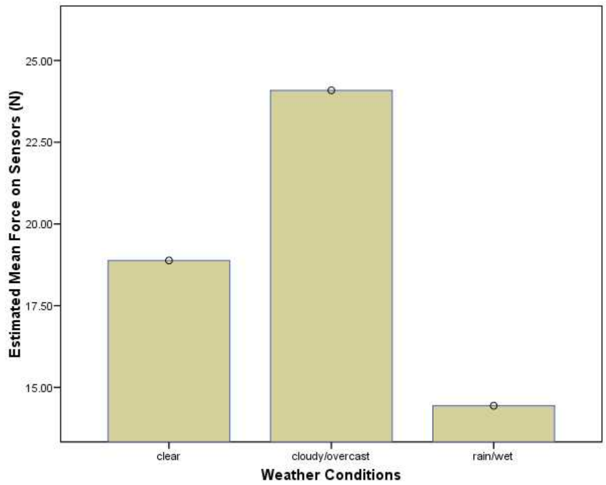

Figure 3: Brake-pedal force against weather conditions

Road-accident data

With the above in mind, the accident files of 3024 road accidents investigated by OTS (op. cit) investigators in Nottinghamshire and Thames Valley areas between 2000 and 2006 were examined. In comparison to conventional accident data, OTS offers much more depth and detail. OTS accident data for example, includes information on events antecedent to and concomitant with the accident for which investigators can also determine the relative influence on accident causation. OTS data has been compared against National Accident Statistics (STATS 19, op. cit) and validated as representative of the UK road accident data .

For the purpose of the current article, not only the weather conditions at the site of the accident but also the estimated contribution of weather related visibility and traction to the incident will be examined.

On average, 120 hours of sunshine/month (approx 33% of daytime), 15 days/month of rainfall over 1mm (approx 50% of time) and just over 1 day/month of snowfall (approx 3% of time) were recorded in the UK region of the Midlands for the period of study .

Evidence that different meteorological conditions were associated with accident occurrence were heavily skewed by weather event frequency. Conditions salient at the OTS accident sites were identified as “clear” in 59.9% of all cases, wet/rainy weather was present at 13.3% of accident cases and about 20% were classified as “other” or “unknown”. Blinding sunlight, windy and foggy conditions were each recorded in about 1% of cases. In terms of meteorological events contributing towards accidents, slippery roads were recorded in 2.1% of accident cases, dazzling sun impaired vision in 0.3% of cases, whilst rain, sleet, snow and fog affected vision affected in 0.1% of accident cases.

The OTS evidence suggests then that while adverse meteorological conditions are experienced relatively infrequently by the UK driver, a lack of a linear association between weather event, accident occurrence or causal link was noted. Whilst no direct behavioural data were available, it would seem likely that behavioural adaption had occurred, since otherwise the shifts in objective risk through changes in visibility and traction would have been realised through the accident data available.

General Discussion

To summarise, in order to investigate behavioural response (if any) to changes in physical risk, driver behaviour – a socially normalized physical risk taking activity - was examined against variable levels of threat afforded by meteorological condition. Data suggest that behavioural adaptation influenced through affective state and perceived risk contingencies, can be realised through mean speed, headway and braking, that it occurs across weather types and that such adaptation may mediate objective accident risk under reduced visibility and traction (Wilde, 1988).

Examination of the simulator data however also suggests that consideration ought also be given to participant mood state and subjective perception of risk contingencies. Some instances of driver adaptation has previously been regarded as ‘irrational’ since the risk of collision rises - such as increasingly close-following in fog (Ayres et al, 2001; Naatanen & Summala, 1976). Such adaption may be explicable through a discrepancy in the 'safe' and 'risky' labels applied to behaviours by experimenters and participants (Haigney et al., 1997; White and Jeffrey, 1980). Participants experiencing reductions in the availability and contrast of visual cues may regard close following as a 'safety' behaviour, maximising the number of cues available to them (Haigney et al., 1995).

Behavioural adaption may also be evident to some extent in the closed track study, with heavier braking indicative perhaps of the realisation of a performance benefit through greater traction relative to wet conditions. This is in line with the theoretical framework of behavioural adaptation .

The OTS accident data suggest that even with objectively decreased vehicle control under wet, foggy and icy conditions, most road accidents take place during clear weather conditions even if the meteorological condition frequency controlled for. This again could agree with behavioural adaption by potentially reducing perceived risk against target (Wilde, 1988) although a number of caveats warrant further investigation. Whilst accident data statistics provide an image of the real-world road safety, behavioural adaption has to be inferred through discrepancies between observed and expected accident occurrence and these are potentially distorted by inclusion and omission error , the possibility of greater number of vehicles on the roads in fair weather, with further confounding from time of year, time of day etc.

It is apparent in these studies that the relationship between the affective, the behavioural and their relationship with error (collision) are suggestive of adaptation but that such relationships are not necessarily linear, or on the face of it 'rational'. Consideration needs to be made of numerous, possibly associated confounding variables which may distort behavioural response overall or second-by-second, skewing the results and/or the statistical analysis - or in the case of a lack of affective data collection - our ability to interpret it. The weight with which various data types contribute towards the debate surrounding adaption ought also be discussed – from the contention that the determination of behavioural adaption with accident statistics is akin to 'proving the null hypothesis' (Wilde, 1988) and through behavioural measures akin to 'proving the existence of God'. (Joubert, 1985)

These issues merit further investigation and are the focus of an on-road driver response research programme throughout 2009-10.

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