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Development and validation of a self-report measure of bus driver behaviour

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Abstract

There are likely to be individual differences in bus driver behaviour when adhering to strict schedules under time pressure. A reliable and valid assessment of these individual differences would be useful for bus companies keen to mitigate risk of crash involvement. This paper reports on three studies to develop and validate a self report measure of bus driver behaviour. For Study 1, two principal components analyses of a pilot questionnaire revealed six components describing bus driver behaviour and four bus driver coping components. In Study 2, test-retest reliability of the components were tested in a sub-sample and found to be adequate. Further, the ten components were used to predict bus crash involvement at three levels of culpability with consistently significant associations found for two components. For Study 3, Avoidance coping was consistently associated with celeration variables in a bus simulator, especially for a time pressured drive.

Key words: bus driver, traffic safety, crash, driver behaviour

<u>Relevance for Ergonomics Research and Practice</u>

The instrument can be used by bus companies for driver stress and fatigue management training to identify at risk bus driver behaviour. Training to reduce the tendency to engage in avoidance coping strategies, improve evaluative coping strategies and hazard monitoring when under stress may improve bus driver safety.

INTRODUCTION

It has been well documented that bus driving can be a highly stressful occupation (Bartone, 1989) resulting from high and conflicting demands and lack of control over work pace and driving situations (Evans and Carrere., 1991; Carrere et al., 1991; Evans., 1994). Factors intrinsic to the job such as time pressure, long shifts and responsibility for passenger safety can all contribute to bus driver stress. Apart from its toll on health and well being at work (Taylor and Dorn, 2005) there is also good reason to suppose that bus driver stress and fatigue may be lead to an increased risk of being involved in a bus crash (Greiner et al., 1998). Driver stress may impair performance, or distract the driver from maintaining safety through potentially dangerous coping strategies such as reacting aggressively to other traffic or engaging in self-distraction.

One way of measuring emotional reactions to driving is with the use of the Driver Stress Inventory's (DSI: Matthews et al., 1996; 1997) five scales of Aggression, Dislike of Driving, Hazard Monitoring, Thrill Seeking and Fatigue Proneness. The DSI scales have been found to be associated with self reported crashes (Matthews et al., 1991) and violations, performance decrements and/or risk taking amongst both commuter drivers (Dorn and Matthews, 1995) and professional drivers (Öz et al., 2009; Kontogiannis, 2006; Dorn, 2005) and correlated with different aspects of simulated driving behaviour in an expected direction according to the transactional theory of driver stress (Matthews et al., 1998).

The transactional theory of driver stress (Matthews, 2002) predicts that personality factors interact with situational traffic demands to elicit cognitive processes that mediate the effects of driver stress vulnerability on both subjective outcomes (e.g., emotional distress) and objective behavioural outcomes dependent upon specific stress responses. For example, Dislike of Driving is associated with tense moods and a perceived lack of control and is associated with driver error, whereas Aggression is associated with risk taking, anger and negative appraisals of other drivers.

Coping with driver stress as measured via the Driver Coping Questionnaire's (DCQ) (Matthews et al., 1997) reveals five distinct driver coping strategies based on original coping research by Lazarus and Folkman (1984). Task-focused Coping involves active attempts to increase vigilance when driving is difficult or demanding (Matthews et al., 1998). Reappraisal measures the extent to which the driver evaluates what mistakes were made (Matthews et al., 1998). Emotion-focused Coping involves a strategy whereby the driver ruminates over their performance and self-blames for the difficulties they encounter. This behaviour appears to distract drivers from the primary task of driving safely (Matthews and Wells, 1996). Confrontive Coping involves the mastery of traffic through self-assertion or conflict (Matthews, 2001). Finally, Avoidance Coping was originally described by Cox and Ferguson (1991) as a strategy whereby the driver attempts to ignore the stressor most frequently through self-distraction and is associated with reduced attention to the driving task (Matthews et al., 1998). The latter three coping styles are maladaptive responses to driver stress. Machin and Hoare (2008) showed the importance of ineffective coping on negative outcomes with maladaptive strategies of Confrontive and Avoidance Coping explained some of the relationship between bus driver workload, negative affect and physical symptoms.

Both the DSI and DCQ were developed on commuter drivers and do not take into account the specific risks of driving a bus for work. Developing an instrument to measure bus driver behaviour based on the DSI and DCQ foundation may be a useful tool for bus companies when assessing safety intervention effectiveness, monitoring driver behaviour over time as part of a risk management programme, or in the selection, recruitment and training of bus drivers. Such an instrument can be used to identify the behavioural responses that can increase the risk of bus crashes and/or lead to poor health outcomes through ineffective coping strategies.

Research to develop a self-report measure of bus driver behaviour began by understanding whether the original DSI component structure could be replicated for a bus driving sample. A slightly modified version of the DSI was administered to 543 UK bus drivers and an exploratory Principal Components Analysis (PCA) was performed (Garwood and Dorn, 2003). The results indicated minor differences between the component structure for commuter drivers and bus drivers for both the DSI and the DCQ. For the DSI, all five components were replicated with the exception being that Thrill Seeking and Dislike of Driving were reversed in their loadings but retained the original items. The DCQ also indicated considerable overlap with all five original components being replicated. The study confirmed the robustness of the original DSI and DCQ component structure in defining bus driver behaviour. Garwood and Dorn (2003) point out that even though the component structure for the DSI and DCQ had been replicated for bus drivers, there were likely to be many issues pertinent to the demands of bus driving not currently included in either instrument.

Bus driving can be differentiated from commuter driving in several ways; bus driving is paced to a strict schedule; requires frequent stopping and starting; involves interaction with the general public and mostly takes place in busy built-up areas. However, there are also similarities in responses to traffic independent of the work context given that most drivers, professional or otherwise, report some element of vulnerability to driver stress (Öz et al., 2009). Building on their work, Dorn and Garwood (2005) conducted in-depth interviews with bus drivers to generate items relevant to bus driving which formed the basis of a pilot questionnaire for Study 1. The pilot questionnaire, incorporating new items and relevant items from the DSI and DCQ PCA, was distributed to a representative sample of bus drivers working for a major UK bus company for Study 1 described here.

There is reason to suppose that coping strategies may be related to driving behaviour under time pressure, but the role of coping on bus driving behaviour has not been studied hitherto. Coping appears to play an important role in mediating behavioural change (McDonald and Davey, 1996). Considering ineffective coping strategies that are likely to be associated with undesirable outcomes, previous research has found that high Emotion-focus as a coping strategy leads to attentional impairment and seems to reduce risk-taking through heightening awareness of mistakes. Confrontive Coping, on the other hand, aims to relieve frustration through intimidating behaviours such as gesturing at other drivers, tailgating, and risky overtaking. Finally, Avoidance Coping may be related to behavioural changes in driving as bus drivers attempt to ignore the stressor through self-distraction and may reduce their attention to driving safely.

For the present paper, Study 1 reports on two PCAs (bus driver version of the DSI and bus driver version of the DCQ) that are envisaged as resulting in an instrument that defines the behavioural and emotional factors that are characteristic of bus driving referred to hereafter as the Bus Driver Risk Index (BDRI). The methodology for the development of the BDRI scales described in Study 1 is in line with the development of the original DSI and DCQ (Matthews et al., 1997). Study 2 was concerned with a test-retest reliability of the BDRI scales (in a sub-sample) then the predictive power of the BDRI for bus crashes was assessed for validation purposes. For Study 3, the scales were correlated against repeated measurements of drivers' celeration behaviour (a term used to define a variable measuring overall speed change; af Wåhlberg, 2008a) in a bus driving simulator to validate the BDRI coping scales against an objective measure of driving performance. Of special importance is how time pressure to maintain a schedule impacts on behavioural outcomes and coping responses and whether these behaviours and coping strategies are associated with bus crashes.

STUDY 1: PRINCIPAL COMPONENTS ANALYSES OF THE PILOT QUESTIONNAIRE

METHOD

Participants

A sample of 315 bus drivers (297 males and 18 females) recruited from a major UK bus company and aged between 19 and 71 (mean age = 46.3, SD = 10.3) volunteered to complete the pilot questionnaire. An opportunity sampling approach was taken. Drivers who were available to participate were included. Length of service ranged from 0-39 years (mean length of service = 9.0. SD = 9.0).

Materials and Procedure

The pilot questionnaire consisted of three sections: Section 1 covered background and demographic information. Section 2 covered bus driver emotional response relating to traffic events and situations, including 45 items from the original DSI (Garwood and Dorn., 2003) and 60 items constructed from bus driver interviews (Dorn and Garwood., 2005). Participants responded to an 11-point scale ranging from 'never' to 'always'. Section 3 included 32 items from the DCQ (Garwood and Dorn, 2003) responded to using a 6-point scale from 'never' to 'always'. In section 3, participants were instructed to answer on the basis of how they usually deal with driving a bus when it is difficult, stressful or upsetting. The pilot questionnaire was distributed to several bus depots across the UK via the depot manager with the support of the trade union. Ethics approval was obtained from Cranfield University's ethics committee and bus drivers were informed of their ethical rights in an accompanying letter. The letter also explained the purpose of the research and the trade union support. A stamped addressed envelope was also provided for the questionnaire to be returned to Cranfield University to ensure the bus company could not identify individual responses. Bus drivers completed the questionnaires either during their breaks or at home.

Treatment of Results

There is considerable disagreement surrounding the minimum sample requirements for a PCA. DeWinter et al (2009) showed that sample size depends on level of communality (the portion of the variance that is accounted for by common factors), loadings, number of variables per factor and the number of factors (Mundfrom et al., 2005: Gagné and Hancock, 2006; MacCallum et al., 1999; Marsh et al., 1998; Velicer and Fava, 1998). The size of the sample in the present study is classified as satisfactory according to the guidelines provided by Comrey and Lee (1992) as samples of 300 or more produce robust factor analyses, with minimal differences emerging as the sample size increases.

The pilot questionnaire was analysed using separate PCAs for both bus driver behaviour and bus driver coping. Each scale was analysed for internal consistency and item discrimination analysis was carried out and confirmed the robustness of the scales. The use of a PCA to determine the component structure is consistent with the procedure used in the development of the forerunner to the DSI – the Driver Behaviour Inventory (DBI: Glendon et al., 1993) and the Driver Stress Inventory (DSI: Matthews et al., 1997), the PCA exploring individual differences in driver stress vulnerability in a Japanese sample (Matthews et al., 1999), as well as other variants for particular professional driver groups. The commercial name for these variants is the 'Driver Risk Index' offered via Cranfield University's company called DriverMetrics for assessment and educational purposes. Variants include the Police Driver Risk Index (Gandolfi and Dorn, 2005; Gandolfi, 2007) and the Fleet Driver Risk Index (Dorn and Gandolfi, 2007).

An oblique rotation was used for the PCA, consistent with the development of the DSI and DCQ, as there is a theoretical basis for the assumption that the factors will be quite highly correlated. Creation of a simple structure solution (incorporating the removal of items which load onto more than one component) is deemed preferable, in order to create a set of components consisting of pure variables each of which load onto only one component (Tabachnick and Fidell, 1996 p.587).

RESULTS

A PCA for Section 2 items of the pilot questionnaire was conducted and 75 items remained once items loading on multiple components were removed. Components with eigenvalues greater than 1.5 were extracted and rotated using the Direct Oblimin rotation. This provided a six-component solution based on a scree plot and explained 35.49% of the variance. Items exceeding a loading of 0.3 were used with no cross-loadings. The PCA was re-run after the removal of the items, and inter-item and item-total correlations calculated.

Components that were largely replicated from the original scales retain their component names but new components also emerged and were named based on their interpretation. The alpha coefficient for each of the six final components is shown in Table 1, second column and range from .70 to .92 and within the recommended level of .70 (Nunnally, 1978).

Tables 1 and 2 about here

Table 2 shows the final items and the origin of the item for the principal loadings on the six components, in the rotated component matrix. Component One is labelled Fatigue Proneness as it includes seven of the original eight DSI Fatigue Proneness items and the remaining five items relate to how the bus driver feels when they have been driving for a long period without a break. Component Two is labelled Hazard Monitoring as seven of the fifteen items were from the original DSI and the remaining eight items relate to making quick decisions, planning ahead, looking ahead and bus driver confidence. Component Three is called Relaxed Driving as the items relate to being relaxed at work, relaxing after work, being happy and cheerful and not taking things personally. Component Four is labelled Patient Driving as the items pertain to being patient, not driving angry and not feeling frustrated or annoyed with other road users. Component Five is called Anxious Driving, with four of the six items being from the DSI Dislike of Driving component. Component Six is labelled Thrill Seeking as five of the items were originally from the DSI Thrill Seeking component and the other two related to bus driving-specific thrill seeking behaviours such as the tendency to seek an adrenaline rush.

When the PCA was run for a second time after removal of items, the factor structure was largely replicated, explaining 45.78% of the variance. The only major differences were that the item “It is important to be considerate to passengers and other drivers” moved from the Hazard Monitoring factor to the Thrill Seeking factor, on which it achieved an insufficient item-total correlation (0.07) and was removed, and the item “When I have to stick to a timetable I feel under pressure even if I know that I can do the job in the time allowed”, originally from the Patient Driving factor, failed to load onto any factor in the second PCA and was also removed.

An exploratory PCA of the 32 items was also conducted for Section 3 of the pilot questionnaire pertaining to bus driver coping strategies. Components with eigenvalues greater than 1.5 were extracted based on a scree plot and rotated using the Direct Oblimin rotation. Items exceeding a loading of 0.3 were used with no cross-loadings. Table 3 shows examples of the principal loadings on the five components. The solution explained 56.2% of the variance. As before, components that were largely replicated from the original scales retain their component names but new components also emerged and were named based on their interpretation.

Table 3 about here

For the selection of items, those exceeding a loading of 0.3 were used, with no cross-loadings in order to achieve a clean and easily interpretable solution that could be scored in a straightforward manner. Component interpretability was also an extraction criterion. Component One is labelled Evaluative Coping with the component being made up of items that previously loaded onto the DCQ’s Reappraisal and Task Focus Coping components. The nine items relate to changing behaviour, gaining something worthwhile from the drive and learning how to cope with stress. Component Two is labelled Emotion Focus Coping with all seven of the DCQ's Emotion Focus Coping items and describes the tendency to self-blame if a mistake is made. Component Three is labelled Risky Coping, relating to taking risks and not changing behaviour when faced with difficult situations. Component Four is named Antagonistic Coping, measuring coping when getting angry with other drivers, swearing, flashing the lights and using the horn. Component Five is labelled Avoidance Coping with five of the original seven items from the DCQ's Avoidance component and describes the tendency to employ self-distraction strategies when the demands of driving a bus are perceived as exceeding the capacity to cope.

When the PCA was run a second time after the items had been removed, the factor structure remained quite stable. The only key difference was that the Risky Coping factor did not retain any items that were exclusive to the construct therefore in the interests of retaining simple structure, the factor was removed.

The results of both PCAs enabled 53 items to be discarded from the pilot questionnaire and relevant items only were retained for the final BDRI incorporating measures of both bus driver behaviour and coping. The inter-item and item-total correlations were calculated and comfortably exceeded the recommended cut-off of 0.3 (Hair et al., 1998). It should be noted that unless a cross validation study is conducted it cannot be determined whether the same factor structure would re-appear given similar data. The full BDRI including Section 1 covering situational risk questions such as bus driving experience and crash involvement is available from the authors for research purposes. The BDRI was then administered to a fresh sample of bus drivers for Study 2 and 3.

STUDY 2: BDRI RELIABILITY AND VALIDATION USING COMPANY BUS CRASH INVOLVEMENT

METHOD

Participants, questionnaire and procedure

For Study 2, a total sample of 557 bus drivers (519 males and 38 females, with no overlap with Study 1 participants) employed by a major UK bus company and aged between 19 and 71 (mean age = 46.5, SD = 10.4) completed the BDRI under the same procedure as described in Study 1. Length of service ranged from 0-39 years (mean = 8.9, SD = 9.1). An opportunity sampling approach was taken. Drivers who were available to participate (and who had not previously participated in study 1) were included. Of these 557 drivers, a sub sample of 131 drivers completed the BDRI again if they gave their permission to be contacted on the back of the BDRI. The second BDRI was completed between two and three months later to assess test-retest reliability.

Bus Crashes

Bus crash data for each driver were supplied by the bus company and obtained from the company's database of incidents that occurred throughout the UK over a 40 month period just prior to completing the BDRI. Drivers not working for this whole period where excluded. An incident is defined as all incidents resulting in damage or injury, including collisions with other vehicles, objects or pedestrians as well as passenger falls inside the bus. Bus drivers must report all incidents. Culpability for incidents is determined by the driver's manager and an insurance team, considering information such as the driver's incident report, photographs and witness reports. Three types of culpability are used for the present analyses; none, some and sole[1]. The driver's crash record is therefore represented by three variables; number of 'All crashes', 'All responsible crashes', and 'Solely responsible crashes'. The sample had a range of 0-14 All crashes (mean 2.9, SD 2.7), 0-12 All responsible crashes (mean 1.3, SD 1.5) and 0-9 Solely responsible crashes (mean 1.2, SD 1.4). Mileage data was not collected for each driver, but to set the crash risk in context, the average mileage for a 5 day rota for bus drivers working for the bus company is 630 miles per week.

Statistical methods

The main research question here was whether the BDRI scales were associated with bus driver crash records. The most informative measure to answer this question is the amount of explained variance, which implies a correlation and/or multiple regression needs to be performed on the data. Usually, these methods are not suitable for crash data, due to the latter's skewed distribution in low-risk, short time period samples. The present data, however, was not so skewed (only nineteen percent of the drivers had no crashes) and made a logistic regression approach feasible. Also, the Pearson correlation is very robust, showing no tendency to being affected by distributions that are more skewed than those of the variables used in the present study (af Wåhlberg and Dorn, 2009).

As a simple complementary method, t-tests were run between drivers with and without crashes. This type of analysis is not sensitive to non-linear effects, which could in principle

[1] This choice was based upon the theoretical view that only incidents that are due to the bus drivers' behaviour can be predicted by variables such as the BDRI scales, while those that are not caused by the drivers in the sample are error variance. This view has been tested and supported (af Wåhlberg, 2008b; 2009; af Wåhlberg & Dorn, 2007). However, the judgement of culpability remains a problem. For the company that supplied the data, it has been shown that their criterion is somewhat too lenient, with about 10-20 percent of incidents being mislabelled as non-culpable (af Wåhlberg & Dorn, 2007).

be present, although this has rarely been shown in individual differences in traffic safety research.

In traffic safety research, it is often found that basic demographic variables such as sex, age and experience have some associations with risk. To further test the usefulness of the BDRI components, a control for such variables was needed to show whether the scales had any predictive power.

Therefore, the present study used several different methods of differing refinement and power; Pearson correlations and independent-samples t-tests for the zero-order relations, and partial correlations to hold various demographic variables constant.

RESULTS

Firstly, test-retest correlations for all the BDRI components were calculated for those drivers who completed the instrument twice (see Table 1) and the components were found to have good to moderate reliability properties with r ranging from .68 to .86. All components were reasonably normally distributed.

Next, Pearson correlations were run between the three crash variables and the twelve BDRI components and the results can be seen in Table 4. Thereafter, independent t-tests, using 'none' versus 'some' crashes as a grouping variable, were calculated with the number of crashes as a predictor of differences in group means for the BDRI components. It was found that Hazard Monitoring was significantly correlated with all three crash variables and that t-tests discriminated between those with and without crashes for this component.

Table 4 about here

Next, demographic variables were tested for associations with crashes; sex, age, years of employment and years since gaining a Passenger Carrying Vehicle (PCV). Out of these fifteen correlations, only three were significant at $p<.05$ ($N=528$), with PCV license versus full blame incidents being the strongest at $r=-.102$. It would therefore seem that there is little influence of these variables on accidents in the present data.

Partial correlations were run between the BDRI components and crashes, controlling for age and number of years since gaining a PCV licence. The results of this analysis were very similar to the previous correlations; very slight increases in correlations were observed for Fatigue Proneness, Hazard Monitoring and Evaluative Coping.

STUDY 3: ASSOCIATIONS WITH DRIVER CELERATION BEHAVIOUR IN A SIMULATOR

INTRODUCTION

To further validate the BDRI, a bus simulator was used to gather driving behaviour data under standardized circumstances, a very different source of data as compared with crashes. The problem with using a driving simulator is the wide choice of outcome parameters. The choice should include variables that are strongly related to individual differences in traffic safety if the BDRI can be said to be a valid measure of bus driver behaviour and risk.

There is no generally accepted way of measuring driver behaviour in a simulator. The most commonly used variables are speed, braking, lateral movement and lane position (see for example Matthews et al., 1992; Emo et al., 2004), but there are few studies investigating their basic psychometric properties, such as reliability, and association with on-road performance (e.g. Godley et al., 2002; Lee, Cameron and Lee, 2003), and even less published evidence of their validity in terms of predicting actual road safety (Edwards et al., 1977; Cox et al., 1999; Deery and Fildes, 1999; Szlyk et al., 2002; Lee, Lee, Cameron and Li-Tsang, 2003; Szlyk et al., 2005). These studies have tested a wide array of variables, with little overlap between studies and small effects found, and there is therefore no good evidence that any type of simulator driving variable can predict crash record (af Wåhlberg, 2009).

The variable of driver celeration[2] behaviour (a measure of speed changes during movement of the vehicle) has been predicted to be the strongest possible predictor of individual differences in crashes (af Wåhlberg, 2008a). It has acceptable reliability (af Wåhlberg, 2003; 2004), and has been tested as a crash predictor with some success (af Wåhlberg, 2007a; 2007c), with a predictive power that increase strongly when data are aggregated (af Wåhlberg, 2007b), i.e. longer measurements of driving and/or several measurements per driver are used.

Furthermore, it has been shown to be superior to various speed measures (mean, maximum, standard deviation) and other acceleration variables (af Wåhlberg, 2006a; 2006b). Even more important, driving behaviour as measured by celeration correlated between different situations, when bus driving en route and when driving with an instructor. The

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[2] This term has been coined to denote measurements made according to the theory and methodology specified in af Wåhlberg (2008). In contrast to the physical measures of acceleration and deceleration, it therefore carries a certain theoretical meaning.

strength of the association was similar to that found between different measurements en route (af Wåhlberg and Melin, 2008). This is important when simulator-based variables are used, as such measurements can often be questioned regarding their ecological validity.

One of the interesting features of the celeration variable is that it is relatively weakly influenced by the amount of traffic and passengers, i.e. celeration is largely determined by driver's disposition, not by the amount of congestion (af Wåhlberg, 2003; 2007c) despite the fact that bus drivers are often late during rush hour. i.e. are under time pressure, something that could be expected to influence their behaviour. However, this effect has been measured as a correlation between celeration behaviour and number of vehicles passing and passengers, for different drivers. The size of the effect as a difference within drivers has not been estimated. This means that even though the individual disposition is the strongest determinant of individual differences in celeration behaviour, there could be a sizeable difference in behaviour due to time pressure, if this effect is similarly strong for all drivers.

For the present study, the simulator procedure involved repeated drives, with one drive under time pressure (see further information in the method section) and the analysis set out to investigate whether celeration behaviour changed under this condition and whether the BDRI components were associated with this change. Behaviour under a time pressured drive is of interest because bus drivers are often behind on their time schedule, a situation that might induce them to mobilise ineffective coping strategies (as measured by the BDRI) and drive at risk to try to catch up (while their mean speed is actually lower than when they are not behind schedule in actual driving – see af Wåhlberg, 1997). If this especially risky response could be predicted from the BDRI coping components, it may prove useful for educational purposes to assist bus drivers in the use of more effective coping strategies to reduce the risk of being involved in a crash.

For validation purposes, the main focus for Study 3 was therefore to determine whether the BDRI coping components could predict driving performance on a bus simulator under normal driving and under a stressful time pressured drive. Furthermore, an investigation of whether celeration behaviour in a simulator has similar psychometric characteristics as in real driving regarding reliability, i.e. a strong increase in between measurements correlations when data are aggregated into longer periods of time, was undertaken. This is important for better decisions about how long simulator-based driving assessments should be and something that does not seem to have been studied hitherto.

METHOD

Sample

The drivers used as participants for this study were newly recruited and had not yet started operational driving. Therefore, there was no overlap of participants that took part in Study 1 and 2. Before taking part in the study, all drivers completed the standard three weeks of in-vehicle training at the bus company's driving school and were about to take their PCV driving test. Seventy-one trainee bus drivers with a mean age of 36.0 years (SD = 8.3 years) were tested on three simulator drives. Eighty seven percent of the participants were male and 13% female. Participants had held a full UK car driving licence for a mean of 14.9 years (sd = 8.1 years). Their mean celeration in the first half or the first drive was 0.260 meters per second squared (SD = 0.074 meters per second squared). In their first three months as a bus driver (post-training) they were involved in a mean of 0.63 collisions (sd = 0.85), although one participant was not included in the collision analysis.

Procedure

The BDRI was sent to bus depot managers to hand out to bus drivers using the same procedure as described in Study 1. On the back of the questionnaire drivers were asked to volunteer to take part in the simulator component. If they provided their details, the drivers were contacted individually and allocated a time to undertake the simulator study. All participants then sat the simulator component between 1 week and 1 month of completing the questionnaire. Participants were required to drive a fixed base bus simulator with a mock up bus cab in the centre of 180º curved screen, six metres in diameter and 2.75 metres high. Performance measures were captured every tenth of a second. Participants were required to take part in an orientation drive for about 10 minutes followed by a scenario with multiple exposures to a high rate of hazardous and time critical encounters with traffic, pedestrians, junctions, varying road configurations and traffic control devices (signs and markings). Bus drivers were also asked to stop at the bus stops to 'collect passengers' and then move off from the bus stop when it was safe to do so. This scenario took about 15 minutes to complete. Participants were then asked to drive the same route, but this time informed that they were running late on the schedule and that they needed to complete the run as soon as possible. Participants took approximately 10 minutes to complete the timed drive.

Calculations

The theoretically specified celeration parameter when measured can be approximated in several ways, for example by using only longitudinal acceleration values. In the present study, no approximation was needed, due to the sensitivity of the equipment, and the celeration values used were therefore the mean of all absolute acceleration values for the specified route (see next paragraph) for each driver (this measurement method and calculation is specified in af Wåhlberg, 2008a). Celeration for a driver is computed as the mean of all speed changes of the vehicle on the stretch of road, when the vehicle is moving (v>0). Whether the measurement is undertaken in one or several dimensions (lateral, longitudinal and other) does not matter, because all data are amalgamated into one variable to describe net speed change.

For the present study, each of the three drives in the simulator was divided in half (by distance), yielding six variables. These variables were used to calculate the reliability for simulator celeration behaviour over time to investigate whether this behaviour changes under time pressure conditions, and how this parameter might relate to components of the BDRI.

RESULTS

Celeration behaviour reliability and time pressure effects

First, it was investigated how the stability of celeration behaviour changed with increased aggregation of data, starting with the mean of each half drive, yielding six variables. It was noted at this stage that there was a strong outlier problem. For each variable, the maximum value was four or five standard deviations above the mean, while the minimum was two or three times lower. Four cases were therefore excluded, each more than three standard deviations above the mean. These four values tended to be multivariate outliers, and decreased the associations between variables rather strongly. All statistical tests used this reduced sample.

Thereafter, all correlations between half drives (distance) were calculated (see Table 5), which yielded a mean r of .53 (N=15). In the next step of the analysis, the two halves of each drive were averaged, and these values correlated. The results were correlations of .72 (1/2), .58 (1/3) and .67 (2/3) (N=67, all $p<.001$), with a mean of .66.

Table 5 about here

Thereafter, the differences (means 0.20, 0.21 and 0.17 meters per second squared) between drives were tested, using related samples t-tests. The time pressure drive (drive number 2) had significantly higher celeration values than the first drive ($t=-3.2$, $p<.01$, $d=0.28$) and third ($t=-9.5$, $p<.001$, $d=0.87$) drives, and there was also a difference between the first and third drives ($t=6.6$, $p<.001$, $d=0.68$)(all $N=67$, $df=66$).

Celeration, time pressure and BDRI

The differences in celeration behaviour between the time pressure drive and the self-paced drives were calculated. Thereafter, these values, the celeration per drive, and celeration averaged over all drives, were correlated with the BDRI coping components and celeration of drives 1 and 3 (to find the association of the difference with the drive that was not used for the difference calculation). These values are shown in Table 6.

Table 6 about here

DISCUSSION

It can be noted that two of the three maladaptive coping strategies measured by the BDRI coping scale, Emotion Focused and Avoidance coping were associated with a deterioration of driving performance, as measured by celeration, when under time pressure. Avoidance was consistently and significantly associated with celeration across all drives. Also, the correlations between drives 1 and 3 versus the difference against the time pressure drive indicated that those drivers who tended to drive forcefully to begin with, did this even more when under time pressure.

Several methodological limitations of Study 3 need to be discussed, apart from the general problem of simulator validity, described in the introduction for this study. It could be argued that the first drive in the simulator should not be included in the analysis, as the drivers were learning how to operate in this new environment. However, the correlations between the half drives were not very different from each other, and quite comparable to those for on-street performance of bus drivers (e.g. af Wåhlberg, 2007b). If the first drive had added a large error component, this should not have been the case.

Also, the time pressure drive may have lacked ecological validity, not only due to the simulator as such, but due to the fact that the drivers may not have experienced any real stress, as they knew the situation was not real. The only observation that can be safely concluded was that most drivers (64%) did indeed try to drive faster, as the expected difference on celeration did occur.

GENERAL DISCUSSION

Based on previous research and the results of Study 1, the BDRI contains items pertinent to driving a bus for work and measures the characteristic ways of responding to traffic and driving situations as a bus driver. Study 2 demonstrated that the BDRI contains fair to good psychometric properties in terms of coherence and stability over time. Furthermore, some predictive capacity concerning crashes seems to be evident. Consistent effects for Hazard Monitoring and Evaluative Coping on bus crashes in an expected direction were also found (Dorn and Matthews, 1995; Matthews et al., 1998). Previous research on validating the DSI have used self reported crashes, the present paper investigated the predictive value of the BDRI for actual bus crashes. When comparing the present findings to research validating other driver behaviour questionnaires such as the Manchester Driver Behaviour Questionnaire (MDBQ; Reason et al., 1990), it should be emphasized that recorded crashes have been used as a criterion rather than self reported ones. When self-reported predictors, are used to predict self-reported crashes, the effect tends to be inflated, due to common method variance (af Wåhlberg, 2009; af Wåhlberg, 2010; af Wåhlberg, Dorn and Kline, in press). The MDBQ is the most popular driver behaviour questionnaire in use but has not provided any validation with regards real crashes. So, although the present associations between the BDRI and real crashes may be weak, validating driver behaviour questionnaires in this way is preferable as it avoids the problem of common method variance.

Unfortunately, the use of recorded accidents make the statistical power of the analysis weaker, due to low variance, although for bus drivers this is not a severe problem, unless very short time periods are used. Also, the validity of recorded crash data is often questioned. Again, this is less of a problem when working with bus drivers and companies that keep acceptable records, as compared to crash data from police sources, where strong under-reporting is known.

Previous research on professional drivers has found that Task Focus (on which the new Evaluative Coping component uncovered here is based) and Hazard Monitoring are predictive of components of simulated driving performance such as efficient responses to hazards (Dorn, 2005). Increased scores on Hazard Monitoring and Evaluative Coping are associated with active attempts to anticipate danger by using more efficient visual search strategies whilst driving (Dorn, 2005) and the associations found between these components for a bus driver sample and bus crash involvement suggests an adaptive response in line with the transactional theory of driver stress (Matthews, 2002). Increased vigilance to hazards leads to safer decision-making in driving (Crundall and Underwood, 1998; Crundall, et al., 2003) and in turn, appears to be associated with lower risk of being involved in a bus crash as reported in Study 2. However, Hazard Monitoring was not related to celeration behaviour in laboratory-based Study 3. Also, the link between laboratory celeration behaviour and real road celeration behaviour has not been found which weakens the value of the present results. This does not negate the value of training hazard monitoring skills perhaps by using video-based traffic simulations as a method to improve a bus company's safety record (Isler et al., 2009).

Sleep-related problems and similar variables have also been found to be associated with traffic incidents (Dalziel and Job, 1997; Maycock, 1997; Hanowski et al., 2003; Taylor and Dorn, 2005; see McDonald, 1989 for a review) and the link reported here between Fatigue Proneness and bus crashes can be explained with reference to this research. However, Fatigue Proneness was not associated with all the crash variables. This may be because the scale does not tap all aspects of bus driver fatigue. A comparative study of different sleep and tiredness-related scales would be required to develop this scale further.

The lack of significant associations between the remaining BDRI components and crash record may be due to the fact that behavioural precursors to collisions are multifaceted and dependent upon rather specific individual differences in the emotional responses to traffic. Another major consideration, of course, is that exposure was not controlled for in the analyses and further research on the link between the BDRI components and crash involvement would need to take into account the number of hours spent driving. Although, personality-based emotional reactions to bus driving are unlikely to explain all the variance in bus crashes (Matthews et al., 1991) this does not negate the value of the BDRI for understanding general behavioural responses, especially for educational purposes. This is exemplified in the findings for Study 3. Here, the results showed that the Avoidance Coping component was significantly associated with celeration in a bus simulator but Avoidance was not found to be related to crashes in Study 2 perhaps because simulated driving is a more sensitive measure than are crashes of driver behaviours. As Avoidance coping is associated with attempts to ignore the stressor through self-distraction, one possible interpretation of this finding is that under time pressure, avoidance strategies may serve to distract bus driver attention resulting in a greater incidence of forceful speed changing behaviours (af Wåhlberg, 2008a). The findings for Emotion Focus Coping on the other hand, suggest that increased self-blame as a coping strategy leads to poor attention to the task with more erratic use of speed rather than increased risk taking. However, it is likely that different driving task conditions will generate different patterns of associations between the simulator parameters and the BDRI components. For example, a scenario containing an unpredictable and annoying road user preventing bus drivers from making progress on their route is likely generate responses related to Confrontive Coping. Further research would need to establish the different driving task conditions under which the BDRI components predict bus driving behaviour.

The present findings support Machin and Hoare's (2008) conclusion that maladaptive coping strategies are associated with negative outcomes amongst bus drivers and lend further support for previous research on the transactional theory of driver stress and its application to professional drivers (Öz et al., 2009; Kontogiannis, 2006; Dorn, 2005). As predicted by the theory, maladaptive coping responses to the stress of bus driving impact on driver behaviour.

Importantly, we demonstrate that celeration can be reliably measured in a simulator using rather short time periods. This is true even if the excluded outliers are included; there is still a strong increase in reliability with increased driving time and/or occasions.

The implications are that simulator-based celeration measurement might be particularly relevant for professional driver behaviour assessment for training and selection purposes, as it is probably highly related to actual on-road celeration behaviour (af Wåhlberg, 2003) which previous research shows is associated with crashes. As celeration behaviour is indicative of safety, the present results suggest that a simulator can be used to assess a newly recruited bus driver for operational driving. What is lacking in terms of evidence for this chain of reasoning is a direct link between celeration behaviour in a simulator and on the road celeration behaviour.

Practical Applications

The results for the timed drive condition suggest that Avoidance Coping is a strategy that can be detected by the BDRI, whereupon this can be used to target drivers that may be more prone to greater levels of speed change in response to time pressure for educational purposes. Poor scores on Hazard Monitoring, Evaluative Coping and Fatigue Proneness might also identify those bus drivers in need of training.

Regardless of the predictive power of the various components of the BDRI, what it does provide is a summary of the facets of bus driver behaviour, organizing these otherwise rather fragmented components of reactions and actions into more understandable wholes. The value of this instrument would be especially useful for identifying and raising awareness of personal tendencies when driving for work. Using the scores on the instrument, certain behaviours can be targeted for training for individual drivers, identifying areas where he or she differs from the norm. The BDRI is currently being used by bus companies to enable safer behavioural strategies to be embedded using Cranfield trained driver coaches. Bus drivers are given individualised BDRI profile feedback to develop personal goals to avoid the development of risky behavioural and psychological responses to time pressure. A more effective strategy for dealing with driving a bus on a strict schedule can be coached. The present data also suggest there are implications with regards to scheduling by bus companies given that time pressure and congestion in built up areas appear to interact with individual differences. Unrealistic scheduling placing demands on bus drivers may increase the financial cost of crashes for organisations.

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Table 1. Component labels, alpha coefficients (Study 1).

Bus Driver Behaviour Components	**Alpha**	**Bus Driver Coping Components**	**Alpha**
Fatigue Proneness (11 items)	.92	Evaluative Coping (8 items)	.82
Hazard Monitoring (15 items)	.87	Emotion Focus Coping (7 items)	.76
Relaxed Driving (9 items)	.85	Antagonistic Coping (3 items)	.73
Patient Driving (13 items)	.82	Avoidance Coping (3 items)	.78
Anxious Driving (6 items)	.71		
Thrill Seeking (7 items)	.70		

All alphas significant at p<.001.

Table 2. Exploratory factor analysis (PCA) of bus driver stress

	Loading	**Origin of item**
Factor One: Fatigue Proneness (FP)		
Less focussed/aware of what is going on around me	-.74	Study 1
Reactions to other traffic increasingly slow	.70	DSI: FP
More drowsy or sleepy	-.71	DSI: FP
Feel less in control	-.78	Study 1
More uncomfortable physically	-.67	DSI: FP
More drowsy or sleepy	.63	DSI: FP
My vision becomes less clear	.57	DSI: FP
Increasingly bored or fed up	.56	DSI: FP
Overtaking becomes increasingly risky and dangerous	-.56	DSI: FP
I feel like it is harder to concentrate	.67	Study 1
I feel mentally drained	.68	Study 1
Factor Two: Hazard Monitoring (HM)		
I usually make an effort to look for potential hazards when driving	.68	DSI: HM
I try very hard to look out for hazards even when it’s not strictly necessary	.65	DSI: HM
I try and predict what other people on the road are going to do	-.66	Study 1
I always keep an eye on parked cars in case somebody gets out of them, or there are pedestrians behind them	.67	DSI: HM
When driving a bus it is important to be able to make quick decisions and act on them	-.51	Study 1
I view driving as a continuous learning curve	.45	Study 1
I feel confident in my ability to avoid an accident	-.51	Study 1
I make a point of carefully checking every side road I pass for emerging vehicles	-.56	DSI: HM
It is important to be confident in your own bus driving ability	-.34	Study 1
I make an effort to see what’s happening on the road a long way ahead of me	-.66	DSI: HM
As a bus driver it is important to learn from my mistakes	-.56	Study 1
I make a special effort to be alert even on roads I know well	-.60	DSI: HM
When I come to negotiate a difficult stretch of road I am on the alert	-.50	DSI: HM
When driving a bus it is important to plan ahead at all times	.57	Study 1
Factor Three: Relaxed Driving (RD)		
I find it easy to relax when I finish work	.75	Study 1
It does not usually take me a few hours to fully relax after the end of my shift	-.70	Study 1
I find it easy to relax at work	.68	Study 1

I find it easy to forget about work/problems when I have finished my shift	.70	Study 1
I am happy and cheerful when driving a bus	-.51	Study 1
I find it easy to leave my problems behind when you start your shift	.55	Study 1
When people verbally abuse me when I am at work I take it personally even when it's not my fault	.39	Study 1
I find it easy to be laid back when driving a bus	.60	Study 1
A bus driver's job is what you make of it, it can be as easy or as hard as you like	-.52	Study 1
Factor Four: Patient Driving (PD)		
It does not annoy me to drive behind a slow moving vehicle	.63	DSI: AGG
Are there times when I am late when I take a risk that I wouldn't usually have taken	-.51	Study 1
I do not get frustrated when I am running late due to factors outside of my control	.56	Study 1
I do not get annoyed when the traffic lights change to red as I approach them	.56	DSI: AGG
I lose my temper when another driver does something silly	.45	DSI: AGG
It upsets me when I get told at the last minute to do a shift or route that I was not expecting	.38	Study 1
When I am in a hurry other drivers usually get in my way	.40	DSI: AGG
I find myself cursing other drivers and passengers in my head when they do something stupid	-.50	Study 1
It is better to drive a bit faster than to be late	-.40	Study 1
I become annoyed if other vehicles follow very closely behind mine for some distance	.39	DSI: AGG
At times I feel like I really dislike other drivers who cause problems for me	-.42	DSI: AGG
Driving usually makes me feel aggressive	-.46	DSI: AGG
Factor Five: Anxious Driving (ANX)		
I am disturbed by thoughts of having an accident	.45	DSI: DIS
I find myself worrying about mistakes and things I do badly when driving	.45	DSI: DIS
It worries me to drive a bus in the dark	-.46	Study 1
I am disturbed by thoughts of the bus breaking down	.42	DSI: DIS
When driving on an unfamiliar road, I become more tense than usual	-.33	DSI: DIS
When driving a bus I find it difficult to concentrate on lots of things at the same time	.37	Study 1
Factor Six: Thrill Seeking (TS)		
I enjoy the sensation of accelerating rapidly	.71	DSI: TS
I get a thrill out of driving fast	-.69	DSI: TS
I enjoy cornering at high speed in the bus	.58	DSI: TS
I like to raise my adrenaline levels while driving	.46	Study 1
I would like to risk my life as a racing driver	.45	DSI: TS

I sometimes like to frighten myself a little when driving	-.37	DSI: TS
It is better to be late than to have an accident	-.39	Study 1
AGG = Aggression; FP = Fatigue Proneness; HM = Hazard Monitoring; TS = Thrill Seeking; DIS = Dislike of Driving		

(BDRI loadings >0.3 on the rotated component matrix)

(35.49% of the variance explained)

Table 3. Exploratory factor analysis (PCA) of bus driver coping

	Loading	Original Scale
Factor One: Evaluative Coping (EVAL)		
Looked on the drive as a useful experience	.84	RE
Felt that I was becoming a more experienced driver	.72	RE
Made an extra effort to drive safely	.61	TF
Thought about the benefits I would get from making the journey	.73	RE
Tried to gain something worthwhile from the drive	.49	RE
Made an effort to stay calm and relaxed	.57	TF
Felt I was learning how to cope with stress	.59	RE
Concentrated hard on what I had to do next	.60	TF
Factor Two: Emotion Focus Coping (EF)		
Worried about my shortcomings as a driver	.74	EF
Blamed myself for getting too emotional or upset	.72	EF
Criticised myself for not driving better	.73	EF
Worried about what I was going to do next	.63	EF
Wished that I was a more confident and forceful driver	.59	EF
Wished that I found driving more enjoyable	.51	EF
Thought about the consequences of having an accident	.62	EF
Factor Three: Antagonistic Coping (ANTAG)		
Let other drivers know they were at fault	.74	CC
Flashed the lights or used the horn in anger	.65	CC
Showed other drivers what I thought of them	.65	CC
Factor Four: Avoidance (AV)		
Told myself there wasn't really any problem	.78	AV
Refused to believe anything unpleasant had happened	.74	AV
Went on as if nothing had happened	.71	AV
RE = Reappraisal; TF = Task Focus Coping; EF = Emotion Focus Coping; CC = Confrontive Coping; AV = Avoidance		

(BDRI loadings >0.3 on the rotated component matrix)

(Coping: 56.2% of the variance explained

Table 4. Correlations between BDRI components and crash variables for a bus driver sample. No correction for number of comparisons applied.

Variable	N	All crashes	All responsible crashes	Solely responsible crashes
Fatigue Proneness	526	.08*	.04	.04
Hazard Monitoring	536	-.09*	-.10*	-.09*
Relaxed Driving	533	-.04	.03	.02
Patient Driving	545	-.03	.02	.02
Dislike of Driving	548	.03	.05	.05
Thrill Seeking	544	.06	.03	.02
Evaluative Coping	538	-.09*	-.06	-.08*
Emotion Focus Coping	541	.04	.01	.00
Antagonistic Coping	551	.05	.00	-.02
Avoidance	534	.05	.04	.03

* $p<.05$

Table 5. Correlations between celeration behaviour in different sections of the simulator drives and different drives. N=67. Sections 2A and 2B were driving under time pressure.

Drive	1A	1B	2A	2B	3A
1B	.63***				
2A	.60***	.53***			
2B	.42***	.70***	.45***		
3A	.48***	.39***	.65***	.39***	
3B	.36**	.62***	.41***	.58***	.54***

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

Table 6. Correlations between the coping components of the BDRI, simulator celeration behaviour and time pressure effects (differences between drives). N=67.

Variable	Evaluative Coping	Emotion Focus Coping	Antagonistic Coping	Avoidance	Drive 1 celeration	Drive 3 celeration
Drive 1 celeration	.03	-.11	.05	.19	-	.55***
Drive 2 celeration (time pressure)	.08	.07	.03	.42***	.68***	.64***
Drive 3 celeration	.16	-.15	.00	.20	.55***	-
Overall celeration (1+2+3)	.10	-.06	.04	.32**	-	-
Celeration difference 2-1	.06	.23	-.02	.31*	-	.16
Celeration difference 2-3	-.07	.24*	.04	.33**	.31*	-

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