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The effects of instruction and environmental demand on state anxiety, driving performance and autonomic activity: Are ego-threatening manipulations effective?

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ABSTRACT

A small yet emerging body of research on the relationship between anxiety and driving suggests that higher levels of state anxiety may lead to more dangerous driving behaviours. The aim of the current research was to investigate the effects of increased state anxiety on driving behaviours within a simulated environment using instructional sets to manipulate anxiety levels. In Study One, whilst a set of safety-related instructions were able to increase state anxiety, this did not result in changes to driving behaviours. In Study Two, ego-threatening instructions were not able to successfully increase state anxiety. This has implications regarding instructional sets in research, including their task relevance and the necessity for a motivational incentive. However, when changes in anxiety were considered regardless of instruction group, Study Two found changes in SDLP and skin conductance levels related to state anxiety increases. As these effects were context specific, it is argued that some of these changes may be due to poorer processing efficiency, leading to suggestions about the types of behaviours that may need to be trained in potential therapies for those who show high state anxiety levels whilst driving.

1. Introduction

Recent research has shown that emotions can play a significant role in increasing the likelihood of dangerous driving behaviours and crashes. There has been a particular focus on the role of anger, or road rage. It has been consistently suggested that increases in anger can lead to a greater likelihood of aggressive behaviours (Deffenbacher, Huff, Lynch, Oetting, & Salvatore, 2000), which can include physical violence and verbal aggression. It has also been associated with less safe driving behaviours (Deffenbacher, Lynch, Filetti, Dahlen, & Oetting, 2003) and an increase in traffic violations and fines (Gonzalez-Iglesias, Antonio Gomez-Fraguela, & Angeles Luengo-Martin, 2012).

However, it has also been noted that multiple emotions associated with negative affect can lead to more dangerous driving behaviours (Dula & Geller, 2003); one example of this is anxiety. Anxiety is described as a feeling of tension or unease at the prospect of a threatening, but not guaranteed, event (Rachmann, 2013). It can be measured and researched as a clinically diagnosed disorder, as a general trait, or as a state. Changes in those who are more anxious, in comparison to other negative emotions, include greater attentional biases towards threat (Bradley, Mogg, Falla, & Hamilton, 1998; Bradley, Mogg, & Millar,

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2000) and increases in sympathetic arousal, which are indexed by increases in skin conductance levels (Globisch, Hamm, Esteves, & Ohman, 1999; Kissel & Littig, 1962).

Whilst it has not been as extensively researched as anger, it is argued that there should be an increase in research investigating the relationship between anxiety and driving. On-road research has suggested it is one of the more frequently reported emotions, in comparison to anger and happiness (Mesken, Hagenzieker, Rothengatter, & de Waard, 2007). Moreover, recent UK statistics suggest that in 2015 over 1800 crashes, 16 of which were fatalities, were caused due to the driver feeling nervous, uncertain or panicked (Department for Transport, 2016). This suggests that feeling anxious whilst driving may lead to changes that could indicate or result in accident risk. On-road research may provide support for this suggestion. For example, Mesken et al. (2007) found increases in self-reported anxiety were associated with increases in heart rate. Based on the literature on the relationship between heart rate and driving (Lenneman & Backs, 2009; Mehler, Reimer, & Coughlin, 2012), this could suggest that levels of demand are too high for those with higher levels of anxiety. One study observed participants' levels of state anxiety whilst completing mock and real versions of the British Driving Test, and found that those higher in state anxiety not only had a higher heart rate, but were more likely to fail their real test (Fairclough, Tattersall, & Houston, 2006).

The fact that participants with higher state anxiety were more likely to fail their driving test suggests that anxiety may result in behaviours that make a person too unsafe to independently drive on real roads. However, it is worth noting that for ethical purposes, on-road research often requires the presence of an additional researcher in the car. This in itself may unintentionally increase state anxiety levels. On this basis, it may be more of an advantage to complete research into anxiety's effects on driving within a simulated environment. Additionally, if it is hypothesised that someone with higher levels of state anxiety will behave more dangerously on the roads, then it is safer to test this in an environment where the risk of harm to themselves or others is minimal. Whilst it is acknowledged that the choice of simulator or participants may impact the resulting validity of observed driving behaviours (Mullen, Charlton, Devlin, & Bédard, 2011), simulator research has often demonstrated that higher levels of reported state anxiety result in changes including reduced horizontal scanning (Briggs, Hole, & Land, 2011), increased reaction times to respond to traffic lights (Salvia et al., 2012), and a higher frequency of speeding violations (Roidl, Frehse, & Hoeger, 2014).

One method that is commonly used to increase levels of state anxiety, prior to completing a driving simulator task, is to provide participants with a task or set of anxiety-relevant instructions. For example, one study asked participants to spend five minutes describing their least favourite body part, whilst a comparison group were given five minutes to listen to relaxing music (Morton & White, 2013). Results suggested that whilst the task was sufficient in increasing levels of anxiety, it only resulted in one behavioural change, which was an increased time to brake at pedestrian crossings. Other studies using similar methods to induce emotional states have found the manipulation to be a success without any subsequent changes in driving behaviour (Jeon, Walker, & Yim, 2014). This could lead to the conclusion that whilst the tasks given are anxiety-provoking, they may not be strong or relevant enough to transfer to the actual driving situation. Tasks that have found changes in behaviour as well as increases in state anxiety have often used instructional sets designed to promote competitiveness. In such studies, participants are told prior to completing a task that their results will be placed in a league table alongside others. Studies that used these instructions suggest that drivers are less proficient at processing information (Murray & Janelle, 2003), have significant increases in heart rate (Mullen, Faull, Jones, & Kingston, 2012), and increases in pupil diameter which suggest that the task becomes more effortful for the driver (Wilson, Smith, Chattington, Ford, & Marple-Horvat, 2006).

The aim of the two studies in this paper was to investigate the effects of task-relevant instructional sets on state anxiety, and its subsequent effects on driving behaviour in simulated environments. In the first study, a set of safety-related instructions were provided to participants before they completed two motorway driving tasks. In the second study, a set of ego-threatening instructions were provided before participants completed a series of drives in environments varying in visual complexity and vehicle handling levels. Both studies also included a final instruction informing participants their results would be placed in a league table alongside other participants in the study. As well as changes in driving behaviour, based on the aforementioned literature, measures of eye movements and skin conductance were also taken. The studies were conducted to provide research implications on the appropriate use of instructional sets in state anxiety research, theoretical implications on the behavioural, attentional and autonomic changes that may be associated with changes in state anxiety, and practical implications regarding specific driving behaviours that may need to be improved in response to state anxiety increases. Based on the previous driving and anxiety literature, it was hypothesised that relevant instructional sets would result in increases in state anxiety, and that this increase in state anxiety would in turn lead to changes that would indicate dangerous driving behaviours.

2. Study One

2.1. Methods

2.1.1. Participants

Thirty-eight undergraduate students participated in the study. They were aged between 18 and 26 years old ($m = 19.7$, $sd = 1.66$), and 25 were female. They had held a full licence for an average of 2.25 years ($sd = 1.78$) and reported driving an average of 3178 miles per year (*sd* = 4662.5). Six reported that they had previously been involved in a minor accident, four reported being involved in a major accident, and one had previously received a driving conviction. Ethical approval was obtained from the University of Nottingham, and participant consent was obtained prior to experimentation. Course credit was provided as an inconvenience allowance.

2.1.2. Design

Study One contained one within and one between-subjects factor. The within-subjects factor was the time at which participants completed a car following task. The two drives were initially completed once as a 'baseline' drive, and after instructions were given, again as a 'test' drive.

The between-subjects factor was the type of instructions administered between baseline and test drives. Those in the experimental group were given a set of safety-related instructions that aimed to increase state anxiety levels. Participants in this group were told that during the test drive, they would be left alone in the simulator and that the stairs leading up to the simulator's dome would be removed, in order for its motion base to be activated (details of the simulator's structure are provided in Section 2.1.3). Because of this, they were then told what to do in the event of a fire alarm; they were told to wait until the researcher had collected them from the dome, but in the event this did not happen they were allowed to use the emergency escape ladder on the back of the dome's door. Participants in this group were then informed that their performance was being ranked in comparison to others in the study. The researcher would then leave the participant in the simulator dome, and close the door whilst the mobile stairs were manoeuvred out of the way, and then turn on the simulator's motion base, which would raise the dome several feet. It is important to note that whilst participants in the experimental group were made to believe that motion was being used during their test drive, the motion base was not activated for either group during any of the drives. Those in the control group were simply informed they would be completing the same drive again, the simulator's door remained open for them and the motion base was not activated. To test the manipulation's reliability, state anxiety scores were compared before and after instructions had been given. Allocation to either condition was randomised before entering the simulator.

Two separate drives were completed in order to obtain a variety of dependent variables that may be indicative of dangerous driving. Firstly, a car-following task was administered to obtain a measure of time headway (in seconds). Secondly, a 'free driving' task was also administered to collect information on average and standard deviation of speed (in mph) and the standard deviation of lane position (SDLP). Physiological data collected across both drives included mean skin conductance levels (in μS) and horizontal spread of search (in degrees).

This resulted in four drives that were to be completed by each participant: one baseline following task, one baseline free driving task, one test following task, and one test free driving task. All of these took place on the same stretch of simulated motorway. Baseline drives were always completed before experimental drives, however, the order in which the following and free driving tasks were completed within these conditions was counterbalanced.

2.1.3. Driving simulator

The four drives took place in NITES 1, a high-fidelity simulator based at the University of Nottingham. NITES 1 is a simulator with a 6 degrees of freedom Bosch Rexroth motion platform. On top of the motion platform is a 4.5 m fibreglass dome containing a standard BMW mini. This mini has its engine and wheels removed, but contains all remaining components expected within a car. In place of the wing mirrors are two 7″ TFT-LCD screens, which display scenario images at a 800 × 480 WVGA resolution. Other images for the scenario are projected onto the inside of the dome's wall using six projectors mounted onto one gantry system. These provide a 270° single image for the driver's main window, and a single image projected onto the back of the dome, which can be seem from the car's rear view mirror. Audio was provided from an external sound amplifier, which was routed to the mini's speakers.

Two eye tracking cameras were placed on the dashboard, in front of the participant, to record eye movements. Eye movements were tracked using FaceLab 5.0, and were calibrated using a series of points projected to the central and peripheral areas of the driver's field of view.

Driving scenarios were created using XPI Simulation editor software. The initial practise drive and the four main drives were completed on a section of a motorway, with traffic passing in both directions. In all scenarios participants began on the hard shoulder and had to drive into the lane on their right to merge into traffic. The motorway speed limit was 70mph, and the drive lasted approximately five minutes, meaning that participants drove approximately six miles (the time taken depended on individual speeds). Scenarios were projected onto the simulator screens using XPI ADS.

2.1.4. Questionnaires

Anxiety was measured using the State-Trait Anxiety Inventory (Spielberger, 1983). The STAI consists of 40 items, 20 each regarding state (STAI-Y1) and trait (STAI-Y2) respectively. Each item is rated on a 4-point Likert scale ranging from 1 to 4. In both cases, 1 refers to 'Not at all' and a score of 4 indicates an item 'Always'. Scores may range from 20 to 80, with a higher score indicating a greater presence of anxiety. State and trait measurements were taken before entering the simulator, and the STAI-Y1 was administered again after instructions had been given. Mean trait anxiety scores were 38.78 (*sd* = 8.81), and the mean state anxiety score before the instruction manipulation was 34.26 (*sd* = 8.72). Simulator sickness questionnaires (Kennedy, Lane, Berbaum, & Lilenthal, 1993) were also administered after the practise drives to monitor sickness levels.

2.1.5. Physiological recording

Physiological data were recorded using a wireless Bionomadix physiological recording device that allowed transmission of GSR100C information. Two finger straps to measure skin conductance were plugged into the device; these were filled with an isotonic gel (GEL101, Biopac Systems Inc., Goleta CA, USA) and attached to the participant's second and fourth fingers on their right hand. These interacted with an MP150 system, that was attached to a laptop recording physiological data using Acqknowledge version 4.1.

2.1.6. Procedure

Participants completed both the parts of the STAI, along with the driver demographic questionnaire. They were then taken to the simulator, took part in a practise drive and completed the SSQ. The researcher then gave the participant instructions. If the participant was completing a following task, they were told to imagine that they were driving on the M1, on the way to the experiment. They were unsure of the correct route, so they would need to follow a police car. This car would move into the middle lane and the participant would need to follow them, remain there when it was safe to do so and keep a safe distance from the car. If the participant was completing a free driving task, they were to imagine that they were driving to the experiment along the M1, they were going to arrive at their destination on time, and they should drive as they normally would. After the baseline drives, depending on which instruction group they had been assigned to, they were then either told they would be completing the two drives again, or they were given the anxiety induction instructions. After the STAI-Y1 had been completed a second time, the researcher left the dome, closed the door, and moved the stairs if the participant was in the experimental group. The test drives were then completed.

2.2. Results

Driving behaviour and eye movement data were extracted from XPI ADS using the IOS Data Extraction Tool. Using MATLAB R2012A, the first and last 100 m of each drive was removed to account for starting the car and stopping the simulation. The remaining data were parsed and the chosen dependent variables were averaged and placed into separate arrays according to their respective driving conditions. To obtain time headway information, vector distances between the participant's car and the car to be followed were calculated, before using this information, along with information on the participant's speed and distance travelled, to calculate time headways.

Skin conductance data were pasted into an Acqknowledge journal. A script created in MATLAB R2012a was then used to remove any motion artefacts and calculate skin conductance values for each of the four drives. Due to excessive motion artefacts across all four drives, data from three participants were excluded from physiological analysis. Due to problems with raw physiological recordings, data from one participant's free driving tasks were excluded from analysis, and data from one participant's following tasks were excluded from analysis.

All data were analysed using IBM SPSS version 21. Unless otherwise stated, a series of 2×2 ANOVAs were conducted, with instruction group and type of drive (either a 'baseline' drive or 'test' drive) for both following and free driving tasks. Across both studies, all effect sizes are reported as partial eta squared and all error bars represent one standard error above and below the mean. Due to problems with recording, eye tracking data from 25 participants is reported for both the free driving and following tasks.

2.2.1. State anxiety manipulation

A 2×2 mixed ANOVA was conducted, with instruction group and time of STAI-Y1 administration as between and within-subjects factors respectively. Groups did not significantly differ overall in levels of state anxiety ($F(1,36) = .032$, $p = .859$, $\eta_p^2 = .001$), nor did time of administration affect overall state anxiety ($F(1,36) = .084$, $p = .774$, $\eta_p^2 = .002$). However, there was a significant interaction between the two ($F(1,36) = 7.47$, $p = .010$, $\eta_p^2 = .172$). Follow-up tests reveal that whilst there are no differences between state anxiety scores in the control group ($t(18) = 1.61$, $p = .125$), for the experimental group state scores were significantly higher after the manipulation had been given ($m = 35.26$) than before ($m = 32.26$) ($t(18) = -3.02$, $p = .007$) (see Fig. 1).

2.2.2. Behavioural data

All behavioural, attentional and physiological data were analysed using a series of ANOVAs. However, across both following and free driving tasks, no significant main effects of time of drive or instruction group were found, nor were there any significant interactions (all $ps > .05$). The exception to this was a significant main effect of time of drive on horizontal spread of search during the following task ($F(1,23) = 23.83$, $p < .001$, $\eta_p^2 = .505$). In this context, horizontal search was significantly higher during test drives ($m = 13.93°$) than during baseline drives ($m = 11.43°$) (See Fig. 2).

2.3. Discussion

The main significant finding from Study One was that using safety-related instructions successfully increased state anxiety levels in participants. This finding supports the growing body of research that encourages the use of instructional sets to increase levels of anxiety. Another interesting point to note is that the majority of previous research that uses instructional sets to increase anxiety attempts to make said instructions purely ego-threatening. This means that the instructions given

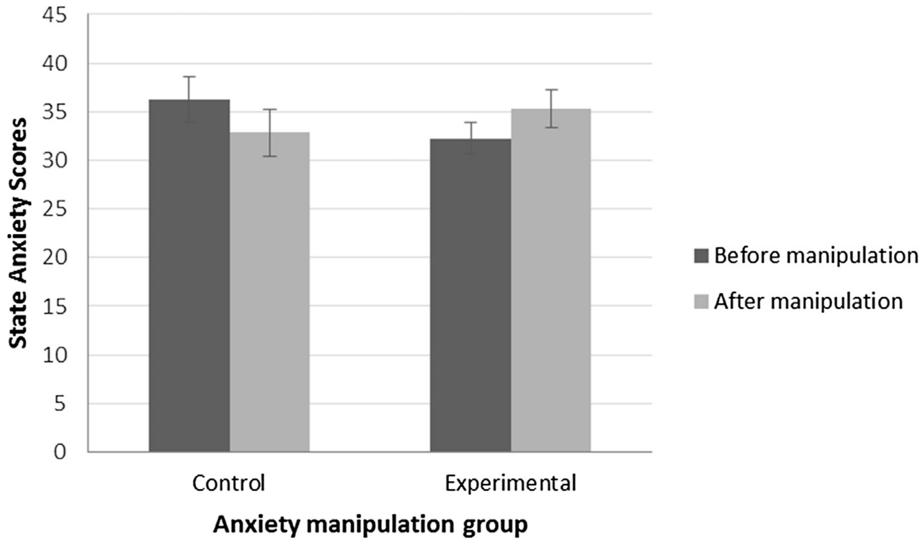

Fig. 1. State anxiety scores according to manipulation group, before and after the time of manipulation.

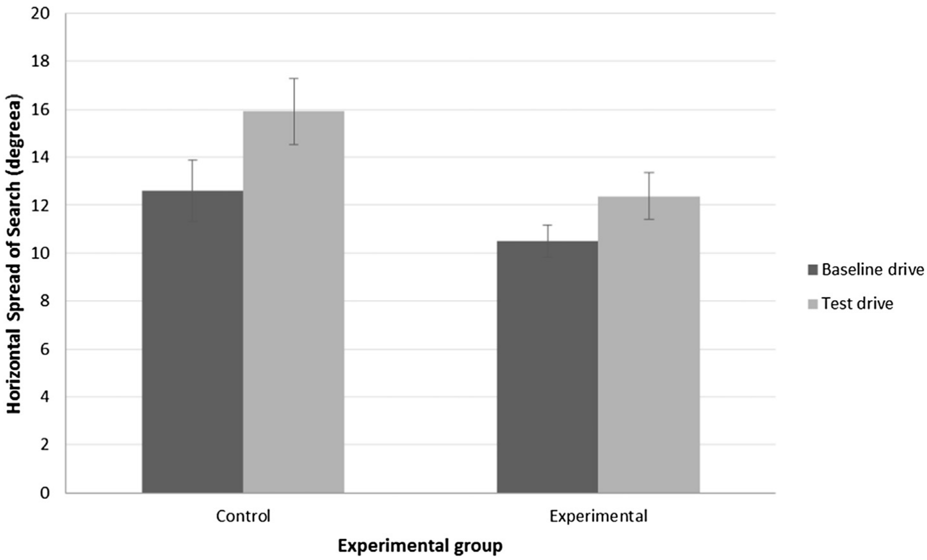

Fig. 2. Horizontal spread of search during the following task, according to instruction group and time of drive.

may make the participant believe their performance on the following task may have some consequence on them as an individual. Whilst some of the instructions given in the current study could be described as ego-threatening, for example by stating that results would be placed in a league table, the majority of the instructions given to the high anxiety group focused on the safety procedures that needed to be followed in an emergency. This may imply that safety-related concerns could also elevate state anxiety levels, at least within a simulated environment. Whilst participants may have some awareness they are not in a real driving environment, the threat of an emergency related to simulator use may still have real consequences for the individual, hence this may cause concerns and elevate state anxiety.

However, despite increases in state anxiety, this did not result in any changes in driving behaviours or autonomic activity. The only significant finding was an increase in horizontal spread of search during the test following drive in comparison to the baseline following drive. This may reflect an increase in experience based on the fact that the drive had already been completed once. Research suggests that more experienced drivers use a greater horizontal spread of search in comparison to novices (Crundall, Chapman, Phelps, & Underwood, 2003). Thus these current findings could reflect an increase in experience due to a repeated exposure of the car following task. However, based on this explanation it is less clear why the same effect was not found during the free driving task.

It is possible that the instructional set given in Study One was not sufficient enough to translate to behavioural changes (Jeon et al., 2014). Future research may wish to repeat the use of such instructions to confirm this suggestion. In comparison, instructions that have been purely ego-threatening have consistently increased state anxiety and some of the physiological and attentional changes already described. In transportation research, previous ego-threatening instructions have misled participants by claiming that driving performance in the simulated environment will reflect real-world behaviours (Murray & Janelle, 2003), or that performance on the driving task will reflect real measures of the participant's intelligence (Schmidt-Daffy, 2013). Additional ego-threatening instructions have also suggested that results will be emailed to other study participants as well as being placed in a league table (Allsop & Gray, 2014).

An alternative reason for the lack of significant behavioural findings from Study One is that motorway driving may be seen as relatively undemanding. Whilst being asked to drive on the motorway can be a task that is representative of everyday driving, the UK's Driver and Vehicle Standards Agency have argued that motorways are monotonous roads to drive on and are one of the statistically safest to drive on (Driver & Vehicle Standards Agency, 2014). By increasing the levels of demand imposed on the participant whilst driving, this should increases levels of perceived workload and may result in compensatory behavioural changes such as speed reductions (Platten, Schwalm, Hulsmann, & Krems, 2014). There are several methods that can be used to increase levels of demand; within the environment itself, this can include changes in visual complexity and vehicle handling levels. Visual complexity can be increased using several methods, such as including a visual task on an in-vehicle information system (Engstrom, Johansson, & Ostlund, 2005) or increasing levels of traffic density (Teh, Jamson, Carsten, & Jamson, 2014). Both methods result in the use of compensatory behaviours. However, in urban environments where additional types of hazards need to be monitored, this can result in more dangerous changes in behaviour, for example increased braking times in response to an unexpected pedestrian (Edquist, Rudin-Brown, & Lenne, 2012).

Vehicle handling levels, on the other hand, can be manipulated by comparing driving along straight road sections to driving in situations requiring left and right turns. Whilst there is less focus in driving research on the effects of vehicle handling, it is argued to increase levels of demand for the driver, on the basis that they must allocate attention to others who are driving in multiple lanes and directions (Chang, Lin, Fung, Hwang, & Doong, 2008). Thus, increases in vehicle handling requirements have resulted in increases in self-reported levels of workload (Stinchcombe & Gagnon, 2010).

Taking these points into consideration, the aim of Study Two was to use ego-threatening instructions to increase levels of state anxiety in participants, and measure how this increase in anxiety would affect driving performance in situations with varying levels of visual complexity and vehicle handling requirements. Based on the previous literature, the same predictions as those discussed in the introduction were deemed relevant for Study Two.

3. Study Two

3.1. Methods

3.1.1. Participants

Forty-four undergraduate and postgraduate students took part in the study. They were aged between 18 and 24 years, with an average age of 20.82 ($sd = 1.67$). Twenty-eight were female and 16 were male. All of them had a full driver's licence, and had been in possession of it for an average of 3.26 years ($sd = 1.63$). Eight had previously been in a minor road accident, three had been in a major accident, and six had previously received driving convictions. As with Study One, ethical approval and consent was obtained prior to commencing the study. However, whilst course credit was provided to participants in Study One, those who completed Study Two were provided with an inconvenience allowance as an incentive to take part.

3.1.2. Design

A mixed factorial design was used in this study, with one between-subjects factor and two within-subjects factors. The between-subjects factor was the induction of high state anxiety in an experimental group, compared to controls. All participants were told that they were to complete a series of four drives, and that they would have to complete a questionnaire after each drive that assessed how easy or difficult they found the task. However, those in the experimental condition were also informed that their performance was being monitored. This was highlighted by showing participants the eye tracking, simulation and video camera monitors available to the researcher just outside the simulator. They were then informed that their performance in the simulated drives would be indicative of real-world driving performance, thus poor performance on the drives would indicate that the participant was a poor driver in real life. These instructions were based on those given in previous research (Murray & Janelle, 2003). Finally, they were told that their performance would be ranked amongst other participants in the study. Overall, these instructions were believed to be more ego-threatening than those presented in Study One. The STAI-Y1 was re-administered after instructions to assess the manipulation's efficacy. Those in the control condition were not told any of this information, and instead simply completed the STAI-Y1 straight after their practise drive.

The two within-subjects factors manipulated were the levels of visual and behavioural-based complexity, and these aimed to change levels of workload. In both cases, demands were either low or high. Visual complexity was manipulated by changing levels of traffic and pedestrian density. When levels were low, there were very few cars and pedestrians within the scenario, and when levels were high, a large number of cars and pedestrians were within the scenario. In conditions with low levels of vehicle handling, participants were simply required to drive along a straight road. When vehicle handling levels were high, participants were required to make three left and three right turns, at various junctions and intersections.

This resulted in four possible drives that were to be completed: one with low visual complexity and vehicle handling levels, one with low visual complexity and high vehicle handling levels, one with high visual complexity and low vehicle handling levels, and one with high visual complexity and high vehicle handling levels. Examples of the least and most demanding drives are provided in Fig. 3. Each drive took approximately 3 min to complete, depending on driver speed. The order of completing scenarios was counterbalanced across participants, such that all 24 possible orders of driving scenario were completed at least once for each condition.

3.1.3. Driving simulator

The study took place in NITES 2, a medium-fidelity simulator also based at the University of Nottingham. It consists of a steel rig that contains the basic car components, such as a pedal set, gearbox, instrument cluster, adjustable car seat and a rear view mirror. This is situated in front of a hemi-cylindrical projection screen with a diameter of 5 m. Images are projected onto this screen using three projectors mounted onto a gantry, producing 180° of field of view. The rear view mirror image is displayed on a 37″ HD TV placed behind the rig. Audio is played out during the drive using two speakers placed either side of the front of the rig. Eye tracking was recorded and tracked using FaceLab version 5.0, and two cameras placed at the front of the rig.

In all scenarios with low vehicle handling, participants started on a single-lane rural roads which were restricted to the UK national speed limit, which is 60mph. In scenarios with high vehicle handling, participants required to make a series of turns within a residential area with a maximum speed limit of 30mph. Pre-recorded audio instructions were programmed into the scenarios to inform the participant which direction they should be turning in. Scenarios with higher levels of visual complexity were programmed to include an increased number of cars and pedestrians.

3.1.4. Questionnaires

The SSQ and STAI were administered using the same methods as Study One. Mean trait anxiety scores were 37.39 (*sd* = 11.51) and prior to the instructional manipulation, mean state anxiety scores across groups were 30.27 (*sd* = 7.56).

3.1.5. Physiological recording

Skin conductance was recorded using two finger straps filled with isotonic gel (GEL101, BioPac Systems Inc, Goleta CA, USA) and attached to the index and ring fingers of the participant's right hand. These were linked to a BioPac GSR100C amplifier. This amplifier was linked to a BioPac MP150 amplifier that was linked a remote laptop recording physiological data using Acqknowledge version 4.1.

3.1.6. Procedure

Participants completed the STAI for the first time, and were taken into the simulator and given the opportunity to complete a practise drive which required the participant to complete a series of four turns. At this point the participant was allowed as much practise as they needed until they felt happy to continue with the study. Afterwards, they completed the SSQ before being taken out of the simulator and being given the instructional manipulation. Those in the experimental condition were given the instructions described in Section 3.1.2, whilst those in the control group were simply told that they would be completing four drives. After this, the STAI-Y1 was completed a second time. Then, all participants were taken back into the simulator, where skin conductance recorders were attached to the participant's right hand and eye tracking calibration took place. After this each experimental drive was completed, according to the counterbalancing order assigned before commencing the study. After all four drives, physiological equipment was removed from the participant before they were

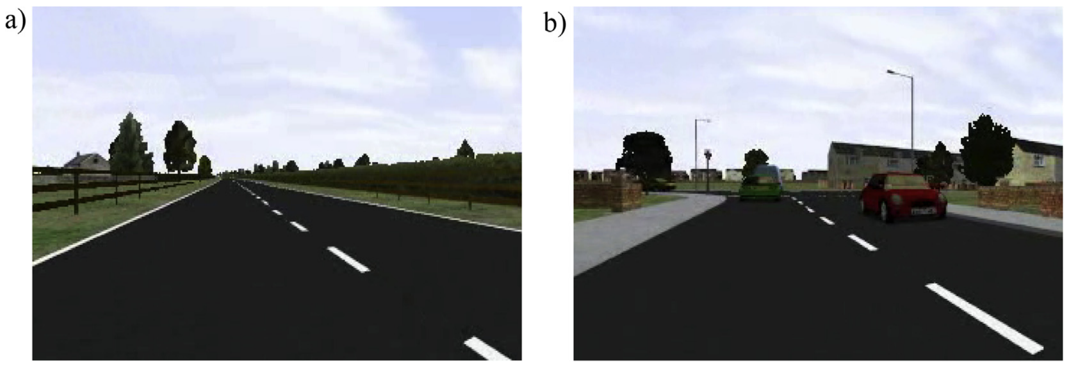

Fig. 3. Examples of drives with (a) low levels of visual complexity and low levels of vehicle handling, and (b) high levels of visual complexity and high levels of vehicle handling.

fully debriefed and given a mood repair task. On the basis that previous research into the topic of mood repairing has suggested using jokes or cartoons can be effective (Goeritz, 2007), a series of funny exam answers were shown to participants.

3.2. Results

Driving behaviour and eye movement data were extracted from XPI ADS using the IOS Data Extraction Tool. MATLABR2012A was then used to parse the data, and the chosen dependent variables were averaged and placed into separate arrays according to their respective driving conditions. To account for the fact that participant initially had to start the car moving, data were analysed from the first point at which the participant reached a speed of 20mph.

Skin conductance data were recorded in an Excel file by the researcher. Due to issues with recording, eye movement data were analysed for 29 participants.

3.2.1. State anxiety manipulation

In order to assess the effectiveness of the state anxiety manipulation used, a 2×2 ANOVA (instruction group $\times$ time of questionnaire administration) was conducted. This found no between subjects effect of condition ($F(1,42) = .011$, $p = .917$, $\eta_p^2 < .001$), and no interaction between condition and time ($F(1,42) = .121$, $p = .73$, $\eta_p^2 = .003$). There was a marginal main effect of time [$F(1,42) = 3.97$, $p = .053$, $\eta_p^2 = .086$] which suggested that state scores were marginally higher at time two ($m = 32.25$) than at time one ($m = 30.27$) (see Fig. 4).

Overall, this suggested that the ego-threatening instructions used were not successful in increasing levels of anxiety. However, as one aim of the study was to assess the effects of increased state anxiety on driving, the scores from the second state questionnaire were then subtracted from the first questionnaire score to obtain of measure of anxiety change levels from time one to time two. This is a method that has been used in previous driving research to assess effects of anxiety changes on heart rate (Briggs et al., 2011). This anxiety change score was then used as a covariate in 2×2 ANCOVAs for the remaining analyses, with levels of visual and behavioural demand as within-subjects factors.

3.2.2. Driving behaviour

For speed variability, no main effects of visual complexity, vehicle handling or state anxiety change were found. However, there was a significant interaction between visual complexity and vehicle handling ($F(1,42) = 4.39$, $p = .042$, $\eta_p^2 = .095$). This suggested that when drivers were not required to make any turns, speed variability would decrease with increasing visual demand. When participants were required to make turns however, speed variability increased with increasing levels of demand.

For SDLP, significant main effects of visual complexity ($F(1,42) = 47.24$, $p < .001$, $\eta_p^2 = .53$) and vehicle handling were found ($F(1,42) = 50.13$, $p < .001$, $\eta_p^2 = .54$). SDLP was significantly higher when visual complexity was high ($m = 0.67$) than when visual complexity was low ($m = .056$), and SDLP was higher when vehicle handling levels were high ($m = 0.69$) than when vehicle handling levels were low ($m = 0.54$). There was also a significant interaction between levels of visual and behavioural demand ($F(1,42) = 7.49$, $p = <.001$, $\eta_p^2 = .29$). This suggested that SDLP did not change with increasing levels of visual complexity when levels of vehicle handling were low. However, when a participant was required to make turns, increases in visual demand were associated with increases in SDLP.

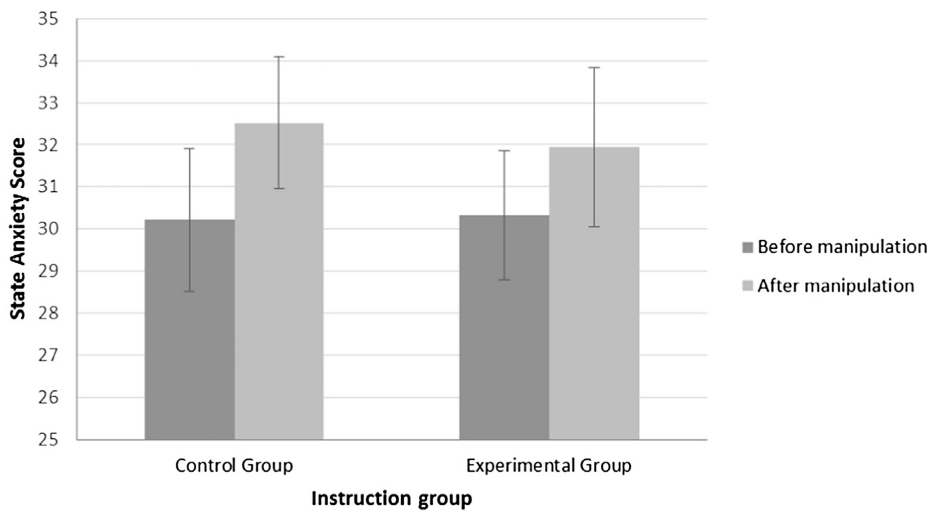

Fig. 4. State anxiety scores before and after instructions, according to experimental group.

Whilst there were no main effects of state anxiety changes on SDLP, there was a significant interaction between state anxiety changes and levels of visual complexity ($F(1,42) = 7.49$, $p = .009$, $\eta_p^2 = .15$). This suggested that with low levels of visual complexity, an increase in state anxiety was associated with decreases in SDLP. However, when visual complexity was higher, increases in state anxiety were associated with increases in SDLP (See Fig. 5).

3.2.3. Eye movements

Analysis of the eye movement data found no significant main effects of visual complexity, vehicle handling, or state anxiety changes. However, there was a significant interaction between levels of visual complexity and vehicle handling for spread of search ($F(1,27) = 8.9$, $p = .006$, $\eta_p^2 = .25$). The interaction suggested that when participants were not required to make any turns, spread decreased with increasing levels of visual complexity. However, when participants were required to make turns, spread of search increased with increasing levels of visual complexity.

3.2.4. Skin conductance

Analysis of the skin conductance data found no significant main effects of visual complexity or state anxiety changes (all *p*s > .05). However, there was a significant main effect of vehicle handling on skin conductance levels ($F(1,42) = 21.32$, $p < .001$, $\eta_p^2 = .34$), which was significantly higher when vehicle handling levels were high (*m* skin conductance = 8.5 μS) than when vehicle handling levels were low (*m* skin conductance = 7.29 μS).

A significant three-way interaction was also found between visual complexity, vehicle handling, and state anxiety changes, with regards to skin conductance levels ($F(1,42) = 15.04$, $p < .001$, $\eta_p^2 = .26$). This interaction suggested that when both visual and vehicle handling demands were low, there was not a relationship between state anxiety changes and skin conductance. When either visual or vehicle handling demand was high, an increase in state anxiety was associated with an increase in skin conductance levels. However, when both visual and vehicle handling demands were high, an increase in state anxiety was associated with decreases in skin conductance (see Fig. 6).

4. General discussion

The aim of this paper was to investigate the use of instructional sets on increasing levels of state anxiety, and assess any subsequent changes in driving behaviour as a result of state anxiety increases. It was hypothesised that not only would instructions successfully increase state anxiety levels, but that this would lead to changes in driving behaviour that could be interpreted as dangerous. The findings from Study One suggested that whilst safety-related instructions are successful in increasing state anxiety, they did not result in changes in driving behaviours during simple motorway tasks. Study Two, on the other hand, found that ego-threatening instructions were not successful in increasing state anxiety levels; however, when taking changes in anxiety levels into consideration, this was associated with changes in both driving behaviours and autonomic activity. Thus, over the two studies, partial support was found for the initial hypotheses.

Study Two used an ego-threatening instructional set, which was more consistent with the methods used in the previous literature. However, these did not significantly increase levels of state anxiety, which is surprising given the clear effects found in previous studies. It could be argued that the decrease in simulator fidelities from Study One to Study Two resulted in a less immersive experience for the participant (Kaptein, Theeuwes, & van der Horst, 1996). The simulator used in Study

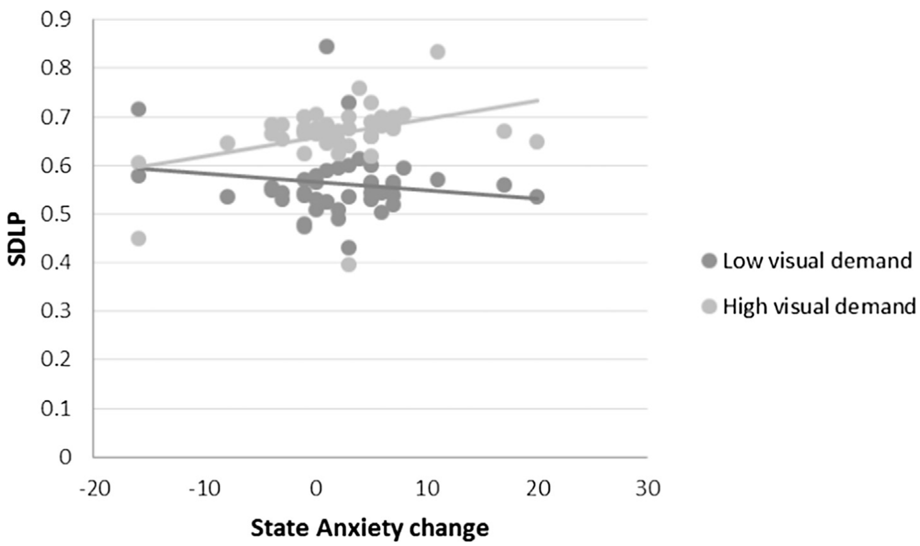

Fig. 5. The relationship between state anxiety changes and SDLP, according to differences in visual demand.

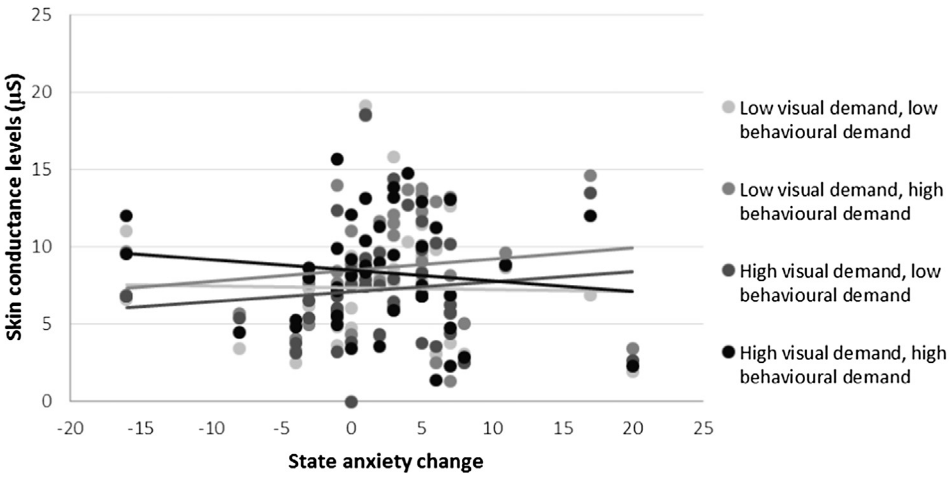

Fig. 6. The relationship between state anxiety changes and skin conductance levels, according to differences in visual and behavioural demand.

One is a high-fidelity simulator based on a motion platform. Due to its technological complexities, the participants may have perceived the instructions given as a representation of a real threat to their safety, making the anxiety manipulation used effective. The change in simulator in Study Two, therefore, could have made instructional set less effective, due to the perceived lack of immediate relevance to safety or ego. However, it should be noted that the simulators used within previous research have been of a similar or lower fidelity, which perhaps provides less support for this argument (Murray & Janelle, 2003; Wilson et al., 2006).

This suggests that there may be alternative explanations for the inconsistency in the effects of instruction, such as the nature of the instructional sets themselves, or the nature of the sample. However, it does pose two interesting questions for future research into anxiety and driving behaviour within simulated environments. Do instructions need to be relevant to driving, or to ego-threat, to induce anxiety, and does simulator fidelity have any impact on this relationship? These questions could be investigated by comparing different types of instructional sets in different types of simulator. An additional question that could be asked, and has not necessarily been covered in this research, is the degree of importance of ego and driving threats. Previous research has often used ego-threatening instructions that have focused specifically on driver behaviour. As we know of previous instructional sets that have not focused on driving to induce anxiety (Morton & White, 2013), this allows us to question the degree of relevance to the task that is necessary to induce anxiety. In other words, is it necessary to provide task-relevant threatening instructions to increase anxiety?

One methodological issue that was not considered was the additional use of motivational instructions. In the previous literature, ego-threatening instructions have also included an incentive for behaving in a competitive manner, such as a cash or material prize for the best performance across participants (Allsop & Gray, 2014; Murray & Janelle, 2003; Wilson et al., 2006). The lack of such instructions across both studies may help us understand the findings. For example, in Study One, safety-related instructions in a high-fidelity simulator were sufficient to increase state anxiety levels, but not sufficient to alter behaviours due to a lack of incentive. In Study Two, on the other hand, motivational instructions may have been necessary to both increase state anxiety and alter driving behaviours. Future research may wish to compare instructions with and without such incentives.

However, it is also noted that the state anxiety scores across both studies were rather low. In Study One, mean state anxiety scores across groups and conditions ranged from 32 to 36, whereas in Study Two, mean state anxiety scores across groups and conditions ranged from 30 to 32. In both cases, these are below the state anxiety scores reported in Spielberger's STAI (Spielberger, 1983), which for college students were 36.47 and 38.76 for males and females respectively. It is possible that this could be due to the sample of predominantly female students recruited across studies, who were already participating in exchange for course credit, or an inconvenience allowance. This highlights the possibility that future research may wish to recruit a more representative sample of drivers, in terms of age, gender and employment status.

Nonetheless, there were a series of significant findings in Study Two both in terms of driving behaviour and autonomic activity. Without any effects of state anxiety, there were significant interactions between visual complexity and vehicle handling levels on speed variability, SDLP and horizontal spread of search. These results may reflect the different attentional patterns required during each driving situation, as well as necessary compensatory changes in behaviour. For example, in driving situations with low levels of vehicle handling, an increase in visual complexity resulted in reductions of both speed variability and spread of search. Whilst previous literature would suggest that a more optimal search strategy would involve greater levels of horizontal scanning (Mourant & Rockwell, 1972), recent research into the effects of perceptual load on driving suggests that scanning behaviours may be determined by the value of a given region (Marciano & Yeshurun, 2015). When driving along a single-lane carriageway, the central region of the scene may contain the most value to the driver. Information in this region can be used to constantly monitor the speed of the car ahead, and in turn maintain a consistent speed in order to keep a safe distance away from the car in front.

In driving situations with high vehicle handling, on the other hand, increases in visual complexity resulted in increases in speed variability, spread of search and SDLP. In more visually and behaviourally demanding environments, drivers must attend and respond to potential hazards in both central and peripheral areas of the road (Edquist et al., 2012), hence increases in speed variability and SDLP are more likely to reflect behavioural changes in response to potential dangers in the environment. This also extends suggestions that situations with high levels of vehicle handling require the driver to attend to hazards moving in multiple lanes and directions (Chang et al., 2008) by suggesting this effect is exacerbated when an environment becomes more visually complex.

Changes in state anxiety also significantly interacted with levels of visual complexity to affect levels of SDLP. In environments with higher levels of visual complexity, a higher increase in state anxiety levels was associated with an increase in SDLP, indicating a poorer ability to maintain lane position. The fact that interaction was independent of vehicle handling levels may indicate that increased state anxiety leads to a reduction in top-down attentional control in driving. According to Processing Efficiency Theory (Eysenck & Calvo, 1992) and Attentional Control Theory (Eysenck, Derakshan, Santos, & Calvo, 2007), higher levels of anxiety are associated with an increase in worrisome thoughts, which in turn leave fewer processing resources available for completing primary tasks. In this case, stimulus-salient characteristics, which in this case would include an increased amount of traffic, are more influential than top-down, thought related processes. Whilst the original theories emphasised the theory's relevance in regards to trait anxiety, the driving and state anxiety literature has attributed state anxiety changes to poorer levels of processing efficiency. The current findings extend previous research by making implications for poorer processing efficiency on a behavioural, rather than primarily attentional, basis.

A significant three-way interaction was also found in relation to skin conductance levels. When both visual complexity and vehicle handling levels were low, there was no association between state anxiety and skin conductance. When only visual complexity or vehicle handling was high, there was a positive association between state anxiety increases and skin conductance. However, when both types of demand were high, there was a negative association between state anxiety increase and skin conductance. If skin conductance is a sympathetic measure of mental effort in response to increased task demands (Helander, 1978), then it is possible that those who show increases in anxiety are able to invest more mental effort into driving when demands increase, but when demands are too high, they are less able to invest the same levels of mental effort. Whilst it does not imply a direct relationship, it does seem to reflect an inverted U-shaped relationship between levels of driving demand and physiological reactivity in those who show increases in state anxiety (Hebb, 1955). This pattern of physiological reactivity may need to be explored in future research, and skin conductance patterns may need to be compared to autonomic measures that are more reflective of parasympathetic activity, such as heart rate.

The current findings provide practical implications regarding the use of relaxation or acclimatisation therapies, as well as the types of behaviours that may need to be monitored during training. Previous state anxiety research has already suggested that professional bodies may wish to consider the use of relaxation techniques for those experiencing high levels of anxiety whilst driving (Fairclough et al., 2006). The cumulative findings of behavioural changes with increased visual complexity highlight the potential for dangerous driving behaviour as a function of increased anxiety, and changes in skin conductance suggest that increased levels of state anxiety may decrease the levels of invested mental effort into the task when demands are too high. Therefore, this provides further evidence that supports previous recommendations. If professional bodies were to consider using relaxation therapies, then these may also wish to include sessions that train behaviours associated with attentional control, such as lane positioning. For example, the Driver Behaviour Survey (Clapp et al., 2011) includes a subscale of behaviours known as anxiety-based performance deficits; the authors argue that these behaviours, such as lane drifting and forgetting to make appropriate speed adjustments, may be due to a lack of adequate attentional control.

It should also be recommended that future research considers the impacts of both trait anxiety and driver-specific anxiety within this domain. Whilst the evidence for trait anxiety is small and primarily limited to self-report data, it does suggest that those with higher levels of trait anxiety are more likely to commit ordinary violations, errors, and lapses on the road (Pourabdian & Azmoon, 2013; Shahar, 2009). Additionally, those with higher levels of driving anxiety and those with a clinical diagnosis of driving phobia show differences in self-report, behavioural, and physiological measures (Alpers, Wilhelm, & Roth, 2005; Taylor, Deane, & Podd, 2007). In the current study additional measures of both trait and driving anxiety were not considered, as there was a general interest in the impact of heightened anxiety on behaviour. However, as there is a limited breadth of research in these domains, particularly for trait anxiety, their contributions to dangerous on-road behaviour could significantly increase our understanding of the effects of anxiety on driving, and should therefore be considered in future studies.

Additionally, driving anxiety can be influenced by a previous history of road accidents. In the current study, around a quarter of the sample in Study 2 reported previous involvement in some form of collision. It is worth highlighting the collisions do have an impact on feelings of anxiety and subsequent decisions regarding driving. For example, the Driving and Riding Avoidance Scale (Stewart & St. Peter, 2004) is a self-report questionnaire aimed to measure the degree of driving avoidance following a motor vehicle collision (MVC), and those who frequently avoid driving following an MVC may develop more specific forms of anxiety such as PTSD. This leads on to two points. Firstly, those who had reported previous collision involvement could have had increased levels of accident-related driving anxiety, which was not measured in the current study. Secondly, the development of a specific anxiety disorder as a function of MVCs could lead to the requirement for different types of therapy as effective treatments. In a recent study of those who had developed MVA-related PTSD, findings suggested that those who had undergone written exposure therapy saw changes in both general PTSD symptoms and changes in behavioural responses as a function of anxiety-related events on the road (Baker, Litwack, Clapp, Beck, & Sloan, 2014). Thus, it may be particularly important that future studies aim to distinguish those with generally high anxiety to those who have developed anxiety as a function of MVCs for practical as well as theoretical purposes.

Whilst the current findings have some interesting implications with regards to state anxiety's effects, there are some additional methodological issues to consider. Firstly, it is possible that the use of a police car in Study One could have some unintended effects on behaviour. A police car was chosen within the following task as it has distinguishing features which a participant would be able to readily identify and follow. However, a police car could also be interpreted as an authority figure, and as a result could have led to unintentionally adapted behaviours such as an increased compliance with road safety laws. However, based on the lack of literature looking at the effects of emergency vehicles on driving behaviours, this issue is based on speculation and would require future research.

Secondly, it is acknowledged that the driving periods within the current research may not have been long enough. Whilst participants were given an unlimited amount of time to practise driving in each simulator, the amount of time taken in each experimental condition was shorter compared to previous research on the topic. Previous simulator research has recorded journey lengths of between eight (Morton & White, 2013) to 10 (Briggs et al., 2011) minutes, whilst on-road studies have reported journey lengths of between 45 (Fairclough et al., 2006) and 50 (Mesken et al., 2007) minutes. Shorter journey lengths were chosen in the current research to minimise the risks of simulator sickness or any distress associated with it. Due to the degree of sensory conflict that can be induced in a driving simulator (Reason & Brand, 1975), recommendations were followed to take preventative actions such as minimising the total amount of 90° turns and the total time in the simulator (Stoner, Fisher, & Mollenhauer, 2011). Nonetheless, it is possible that the resulting shorter driving times may have accounted for variability in the results, and time spent driving should be considered in future studies.

The current research aimed to assess the effects of state anxiety on driver behaviours using instructional sets, and as a result has provided methodological, theoretical and practical implications. Whilst instructional sets were effective in Study One, they were ineffective in Study Two; this leads to implications that instructional sets do not have to be ego-threatening in order to increase state anxiety levels, and that motivational incentives may play an important role in subsequently influencing behaviours. However, state anxiety increases did interact with levels of sympathetic activity according to levels of demand, and with changes in SDLP. The fact that this latter finding was only as a result of increased visual complexity suggests that increases in state anxiety led to a reduction of top-down attentional control due to an increase in environmental stimuli. This leads to implications that increases in state anxiety may not result in more dangerous driving behaviours, but these behaviours may be specific to those associated with poor attentional control. As a consequence the research presented supports previous suggestions of introducing relaxation therapies to driver training, and emphasises a specific subset of behaviours that may need particular attention when considering high levels of state anxiety.

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