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Emotionally involving telephone conversations lead to driver error and visual tunnelling

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A B S T R A C T

It is now well established that driving performance deteriorates during a mobile phone conversation, but the precise conditions under which interference occurs warrant further research. The present study examined the effects of varying the participants' level of emotional involvement in the conversation, while keeping the conversation similar in content for all participants. Twenty-six participants, half of whom were spider-phobics, completed a simulated driving task, either while undistracted or while conversing on the subject of spiders. The individuals who were spider-phobic, and hence more emotionally involved in the conversation, demonstrated significantly higher cognitive workload (as indexed by heart rate), made more driving errors, and demonstrated a significant decline in the range of their visual fixations, showing a pattern of visual tunnelling. The *type* of conversation engaged in has a significant effect on driver performance: the more emotionally involving the conversation, the greater its potential for distraction.
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1. Introduction

Previous research has identified that using a mobile phone whilst driving can lead to decreased driving performance. Dual tasking drivers may demonstrate impairments at the strategic, tactial and operational levels of driving performance. They show increased reaction times for critical events in the driving scene (Horrey & Wickens, 2004; Strayer & Drews, 2007), and poor decision-making abilities (Brown, Tickner, & Simmonds, 1969). They may fail to detect other road users and road signs (Galpin, Underwood, & Crundall, 2009; Langham, Hole, Edwards, & O'Neil, 2002; Strayer & Johnston, 2001); Their lane discipline is poor (Alm & Nilsson, 1994, 1995; Redelmeier & Tibshirani, 1997; Reed & Robbins, 2008); they show alterations in speed choice (Reed & Robbins, 2008); and they make questionable headway and gap judgements (McKnight & McKnight, 1993; Stevens & Minton, 2001; see Collet, Guillot, & Petit, 2010, for a review of research in this area).

On a theoretical level, the majority of this research supports the assumption that individual task demands increase the driver's cognitive workload (CWL). According to multiple resource theory (MRT), if this increase is minimal, or if the tasks use different attentional resources, competent dual tasking may be possible (Horrey & Wickens, 2004; Norman & Shallice, 1980; Wickens, 1984, 2002). However, if CWL exceeds a manageable level, performance on one or both tasks may deteriorate (Cooper & Zheng, 2002; Hendricks, Fell, & Freedman, 1999; Matthews, Legg, & Charlton, 2003), resulting in potentially dangerous situations (Redelmeier & Tibshirani, 1997; Violanti & Marshall, 1996).

More contemporary theoretical models suggest that rather than being passively distracted, drivers can impose some level of active control over the allocation of their attentional resources. Building on Michon's (1985) *operational – tactical – strategic*

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model of driving, Regan, Lee, and Young (2009) propose that when faced with challenges whilst driving, individuals can apply three different types of control in order to maintain their performance. *Feedback* control is based on the difference between a 'goal' state and the current state of resource allocation, and can aid a driver by enabling them to alter their behaviour based on past outcomes. *Feedforward* control is anticipatory in nature, enabling the driver to alter their behaviour in anticipation of upcoming events or challenges *Adaptive* control works by reducing the difference between the 'goal' state and the actual state of the system, by redefining the 'goal' state (i.e. altering expectations of task performance based on resource capacity at any given time; see Regan et al., 2009, for a detailed model and description). However, disruption at any one level of control can lead to errors at other levels which can, in turn, result in a breakdown of the whole system (termed as 'cascade effects').

Thus, a driver who answers a telephone, may reduce demands at the operational level by reducing gear changes (feedback control); at the tactical level by slowing down and remaining in the same lane (adaptive control); and at the strategic level by selecting a quieter route, thus avoiding a busy intersection (feedforward control). This control applied by the driver is dependent on the *timing* of each task and the amount of attentional resources available at that time. In some instances such strategies may enable dual tasking whereas in others task demands may exceed attentional capabilities, leading to the whole system of attentional resources breaking down (termed as 'saturation effects'). Sheridan (2004) argues that this is because distraction-related failures in driving are due to both incoming interference from a secondary task and the driver's inability to control their attention, and subsequent behaviour, in the face of these added challenges.

Research has demonstrated that drivers engaging in a mobile telephone conversation are around four times more likely to be involved in an accident than undistracted drivers (Redelmeier & Tibshirani, 1997). Furthermore, the distracting effects of dual tasking have been shown to persist for up to 5 min after the conversation has ended, suggesting that the distraction experienced has its roots in attention allocation and CWL (Redelmeier & Tibshirani, 1997). A driver who has finished a phone call may continue to think about the conversation they have just had and therefore continue to draw upon cognitive resources which may otherwise have been directed towards the primary task of driving (see also a description of queuing theory in Regan et al. (2009) for an alternative explanation for the behavioural effects demonstrated). Whilst generalised increases in CWL have been shown to accompany deteriorations in dual tasking performance (Briem & Hedman, 1995; Brookhuis, de Vries, & de Waard, 1991), research has now progressed to attempt to identify the specific elements of the individual tasks which lead to such an increased drain on cognitive resources. Of particular interest are the elements of the secondary, conversation, task which may contribute to increased CWL. In addition to the *type* of conversation engaged in (whether it is a personal or a business call), the *content* of the conversation has also been the focus of investigation (see Matthews et al., 2003; Recarte & Nunes, 2002; Tsimhoni, Green, & Lai, 2001). Whilst some researchers contend that any conversation negatively affects driving performance when dual tasking (Strayer & Johnston, 2001), others suggest that differences in the topic of the conversation result in differential negative effects on driving performance (Wester, Böcker, Volkerts, Verster, & Kenemans, 2007).

Early research in this area investigated the different challenges faced by drivers engaging in either 'hard' or 'easy' conversations whilst 'driving' along simple or challenging routes (Alm & Nilsson, 1994; Brown et al., 1969), with results suggesting that the varying demands of both tasks produced increased arousal and greater CWL. More recently research has investigated different types of secondary task, including sending and receiving text messages (Reed & Robbins, 2008), sentence listening tasks (Just, Keller, & Cynkar, 2008), completing mental arithmetic tasks (Uno & Hiramatsu, 2000), problem solving tasks (Tsai, Viirre, Strychacz, Chase, & Jung, 2007), mental imagery tasks and tasks that require the participant to attend to other visual and auditory information (Engstrom, Johansson, & Ostlund, 2005; Maciej & Vollrath, 2009; Spence & Read, 2003). Findings have revealed that greater secondary task demands increase CWL and negatively affect driving performance. Nevertheless, few investigations have examined the topics covered in natural conversation and hence the precise nature of their demands on the driver. The question arises as to whether a more emotionally involving or anxiety-inducing conversation is more distracting to a driver than less involving or more mundane conversation topics.

Eysenck and Calvo's (1992) *Processing Efficiency theory* could provide an explanation for how a more emotionally involving telephone conversation could negatively affect driving. It suggests that when an individual experiences anxiety or stress they are less efficient in processing incoming sensory information and have to work harder to maintain performance levels. They claim that this is because anxiety leads to a depletion of *central executive* (CE) resources: these resources are used to cope with the increase in 'cognitive anxiety' that is experienced. As a result, the individual must share resources between tasks. Whilst the experience of anxiety could lead to the individual consciously applying more effort to the task in hand, and thus 'reinvesting' in controlled processing (as suggested by Masters et al.'s (1993) *conscious processing hypothesis*), it could also lead to greater distraction from the task as CE resources that are directed towards the task of driving are depleted by the presence of anxiety, making the individual more prone to distraction and thus resulting in poorer performance (Eysenck & Calvo, 1992). The effects of increased anxiety on task goals and performance have been investigated, with findings suggesting that increased anxiety introduces task-irrelevant goals which compete with task-relevant goals, depleting CE resources (Lavric, Rippon, & Gray, 2003). This increase in overall workload, in turn, contributes to failures in spatial working memory (Shackman et al., 2006) and decreased visual awareness (Wilson, Smith, Chattington, Ford, & Marple-Horvat, 2006; See also Matthews, Bryant, Webb, & Harbluk, 2001; Nunes & Recarte, 2002).

Easterbrook (1959) was amongst the first to propose that emotional arousal reduces the range of visual cues that are used by an individual when scanning a visual scene. He argued that in some cases this can be adaptive, as it would enable

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irrelevant visual information to be ignored. However in situations in which a range of visual cues are required for successful execution of the task, such as driving, this reduced scanning could have a detrimental effect on performance. Derryberry and Tucker's (1994) model took this further, suggesting that when an individual experiences high-arousal positive emotion, they process a more extensive array of visual information and have greater access to a range of memory constructs which may aid the individual in any given task. Conversely, they suggest, when an individual experiences high-arousal negative emotion, sensory processing is reduced and fewer cognitive resources are made available for task completion (see Friedman and Förster (2010) for a review of research in this area). Janelle, Singer, and Williams (1999) support this view with findings from their simulator study. They found that high anxiety 'drivers' demonstrated visual tunnelling (a narrowing of their visual attention, measured by tracking eye movements) but paradoxically also showed a greater tendency to be distracted by irrelevant cues in peripheral vision than did non-anxious participants. Anxious participants tended to focus on the central field (showing attentional narrowing). As a result, when any event occurred in the periphery, regardless of its level of relevance, they had to shift their gaze entirely to the peripheral field in order to process the information. Non-anxious participants did not demonstrate such a shift in gaze pattern. Janelle et al. (1999) claim that this shows that the experience of anxiety brings about *hyperdistractibility*.

Murray and Janelle (2003) confirmed these effects of anxiety on visual attention. Although overall 'driving' performance was similar between those who were high or low in anxiety, high anxiety drivers recorded much slower reaction times to a secondary task than did those who were low in anxiety. In support of Regan et al.'s (2009) model, Murray and Janelle (2003) suggest that their high-anxiety participants attempted to compensate for the increased demands made upon their attentional resources by consciously allocating more resources to the 'driving' task and fewer to the secondary task, thus preserving their 'driving' performance at the expense of the secondary task.

Thus, evidence suggests that when anxious or emotionally aroused, dual tasking individuals demonstrate decreased task performance in one or both tasks. This is brought about by a combination of increased CWL, depleted CE control, decreased visual attention and the application of inefficient visual search strategies (Janelle, 2002; see also Martens & Fox, 2007). Whilst it has been established that dual tasking has such negative consequences, and that varying types of secondary task affect driving performance when dual tasking, it has not yet been established if the anxiety effects summarised above can be elicited by a task involving naturalistic conversation. Put simply, can an emotionally involving conversation have similar effects on driving to those demonstrated in anxious, dual tasking, individuals?

Much of the research into dual tasking when driving has relied upon rather artificial conversation tasks to examine the individual effects of different tasks on driving. This procedure has experimental rigour, but lacks ecological validity. A driver may at least on some occasions engage in emotionally involving conversations behind the wheel, the effects of which may be qualitatively different from those produced by more routine topics of conversation. The present experiment explores this possibility. Specifically, it proposes that an individual who engages in an emotionally involving, personally relevant, conversation when driving will demonstrate increased CWL, visual and cognitive tunnelling and will show decreased driving competency. The technique used in this experiment is unique in that not only is a naturalistic conversation method employed, but the content of this conversation is constant across conditions: only the *significance* of the conversation will vary between groups. Thus, a balance is struck between ecological validity and methodological rigour.

2. Method

2.1. Participants

Twenty-six participants (10 male, 16 female) from the University of Sussex were recruited via posters and e-mails. Half had a phobia of spiders and the other half were non-phobic. Participants were naive to the purposes of the study, but were aware that discussion of spiders would be involved. They received course credits for participating. Participants ranged in age from 19 to 55 years (M = 27.68 years, SD = 10.72 years). All held a valid UK driving licence, had an average of 8.9 years driving experience and claimed to have normal vision. None of the participants reported any heart-related medical problems.

2.2. Design

This study used a mixed experimental design. There were two independent variables: type of simulated driving task (a repeated measures variable, with two levels: *distracted* by conversation or *undistracted*) and phobic state (an independent measures variable with two levels: *spider-phobic* or *non-phobic*). Each participant completed two sessions in a driving simulator. In the undistracted condition, they drove in silence, while in the distracted condition, they drove while conversing about spiders.

The dependent variables were driving performance (measured by number of lane deviations and number of speed deviations (from the instructed 50 mph)), CWL (as indexed by heart rate), and eye movements (number of fixations, and variance in vertical and horizontal fixation patterns). The 'driving' error dependent variables were chosen as an alternative to the commonly used method of obtaining reaction time data in response to staged events or hazards. This was because the focus of the current study was on 'normal' driving while engaged in a naturalistic secondary task. This experiment aimed to identify the level of control 'drivers' had over their speed and lane choices whilst they were distracted.

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Fig. 1. An example screen shot from the simulation (left) and the simulator equipment (right).

2.3. Apparatus

2.3.1. Questionnaires

The Spider Phobia Questionnaire (SPQ, Watts & Sharrock, 1984): this is a 43-item questionnaire, requiring yes/no responses, designed to measure the individual's cognitive and behavioural beliefs about spiders. Shown to be proficient in discriminating between phobics and non-phobics, this questionnaire has been found to be both reliable and valid (Anthony, Orsillo, & Roemer, 2002).

The State-Trait Anxiety Inventory – form Y1 (STAI, Spielberger, 1983): this is a 20-item questionnaire, using a 4 point likert scale, designed to measure the individual's current psychological state. This measure has also been validated and found to be reliable (test–retest reliability = .86, Spielberger, 1983). The questionnaire was given both before and after completion of the driving tasks to ascertain any changes in anxiety levels following the conversation task.

2.3.2. Driving task

A fixed base driving simulator was used, consisting of height adjustable seat, steering column and Logitech force feedback steering wheel. The display included both rear-view and wing mirrors and a speedometer for the 'driver' to monitor throughout the task. The simulator was positioned in front of a 3 m $\times$ 2 m screen, onto which a driving scene was projected using a Philips Hopper XG20 Impact data projector. The simulation was run using an Acer PC running Windows XP Professional, connected to the projector. All participants sat at a distance of 2 m from the screen.

The driving simulation used was 3D Driving School (Besier, 2004), used in its 'beginner, free drive' mode. It followed a route along a dual carriageway, containing no intersections, or other requirements for the 'driver' to stop. Participants 'drove' through both urban and rural surroundings (although they remained on a dual carriageway throughout). There were other vehicles present in the simulation, which followed or overtook the participant's 'vehicle', but they did not turn or stop. No other distractions, such as billboards at the side of the road were present. In each session, participants drove for 10 min and were instructed to maintain a constant speed of 50 mph, and follow the 'normal' rules of the road (as set out by the Highway Code) (see Fig. 1).

2.3.3. Heart rate monitoring

All participants had their heart rate (HR) monitored as a measure of CWL. A Polar S610i HR monitor was used for this, consisting of a band placed around the body and a wristwatch receiver. HR was recorded when the participants were resting (as a baseline for comparison) and then measures were also taken whilst they were 'driving'. At each point, the average and maximum HR were recorded for the period tested and the difference between these scores was taken. Thus, *HR change* was used for analysis as this removed the potentially confounding effect of outliers with extremely high resting HR.

2.3.4. Eye tracking equipment

All participants had their eye movements tracked using a video based head mounted ASL 5000 eye tracker (developed by Mike Land at the University of Sussex). The head mounted camera recorded what participants saw from their own viewpoint and the eye movements of participants were sampled, from the right eye, at a rate of 50 Hz. Fixation points were then superimposed onto the output of the head mounted camera. The temporal resolution of the eye movement equipment was 25 Hz, and the spatial accuracy was 1°. For the purposes of analysis, the variance of the horizontal and vertical range of fixations was recorded, plus the number of fixations made within a 30 s period during each 'driving' task.

2.4. Procedure

Each participant completed the experiment individually, in a 30-min session. Participants first completed the STAI, in order to assess their current anxiety state. They then completed the SPQ. An experimenter then marked the SPQ and assigned

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participants to either the *spider-phobic* or *non-phobic* condition. At the same time, a second experimenter measured the participant's resting heart rate. The driving simulator was then explained to the participant, and they were given a brief period to become accustomed to the controls. Participants were then fitted with the eye tracking equipment (calibrated individually for each participant). Participants were informed that they would shortly be asked to drive along a dual carriageway, once whilst simultaneously holding a conversation about spiders and once without distraction (order of sessions was counterbalanced across participants). Each driving session lasted for 10 min, and was followed immediately by the second session. Participant heart rate and eye movements were monitored throughout the experimental period. On completion of the driving tasks, participants again completed the STAI.

3. Results

Of the 26 participants tested, 23 provided data appropriate for analysis. Three participants (two non-phobic and one phobic) were eliminated from the study due to extremely high HR and anxiety measures prior to exposure to the driving task.

3.1. Analysis of overall number of driving errors

'Driving errors' were defined as behaviours that deviate from the normal rules of the road, as described in the Highway Code (e.g. failing to indicate when changing lanes, exceeding the specified speed limit, failing to maintain lane discipline, etc.). Recordings of each participant's performance were shown to 5 independent assessors, each with a minimum of 10 years driving experience. The assessors scored the films for the number of errors made within the driving trial (only unanimous decisions were recorded). The raters were unaware of the experimental design and procedure and did not know which participants were classed as phobic. The films were coded so that the raters were also unaware that the participants completed the driving task twice (once whilst distracted and once without distraction). A score was awarded for the number of errors made and these data were then used for analysis.

A 2 ('driving' session: undistracted or dual tasking) $\times$ 2 (phobic condition: phobic or non-phobic) mixed ANOVA revealed a highly significant difference in the number of driving errors made between 'driving' sessions ($F\,(1, 21) = 89.52$, $p < .001$, $\eta_p^2 = .81$). Furthermore, there was a significant main effect of phobic condition ($F\,(1, 21) = 4.23$, $p < .05$, $\eta_p^2 = .17$) and a highly significant interaction between driving session and phobic condition ($F\,(1, 21) = 21.03$, $p < .001$, $\eta_p^2 = .50$).

As can be seen from Fig. 2, spider-phobic and non-phobic participants made a similar number of driving errors when driving without distraction. When asked to drive while holding a conversation, both groups made significantly more driving errors. However, this effect was more marked for the spider-phobic group, showing that they were more distracted than the non-phobics.

3.1.1. Analyses of speed and lane deviations

Two separate 2 $\times$ 2 mixed ANOVAs were conducted on the type of 'driving' errors made; speed deviations (either exceeding or slowing down from the 50 mph target that participants were instructed to maintain), and lane deviations (failing to remain within the boundaries of the driving lane). For the purposes of these analyses, absolute values of the number of errors made in each category (speed deviation or lane deviation) were used. The direction of speed deviation (i.e. exceeding or failing to maintain the 50 mph target set) was not recorded. These errors were scored by the independent assessors previously described.

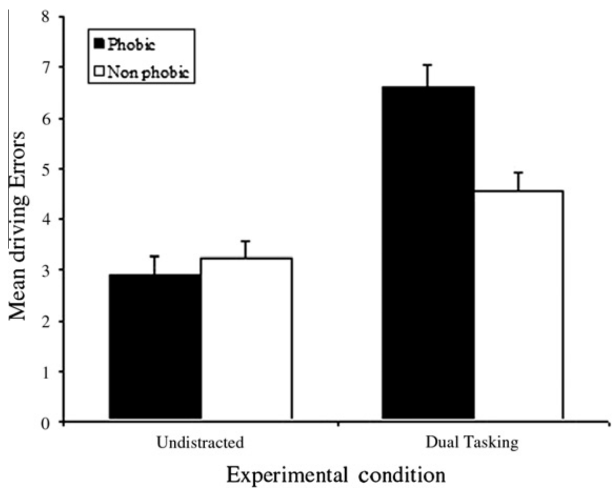

Fig. 2. Mean number of driving errors made dependent on experimental and phobic condition (error bars show standard error).

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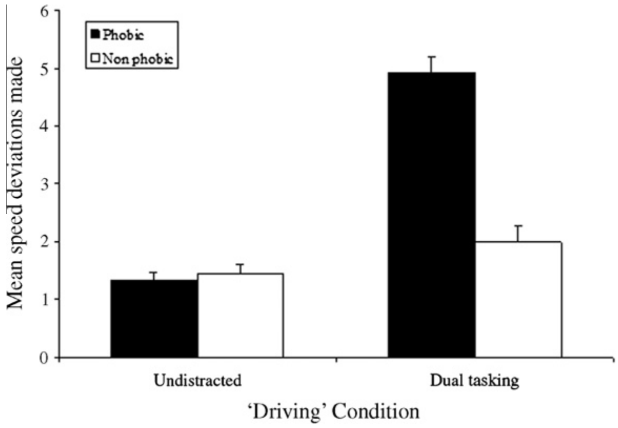

Fig. 3. Mean number of speed deviations made dependent on experimental and phobic condition (error bars show standard error).

Results showed a significant difference in the number of speed deviations made between 'driving' conditions (F $(1, 21) = 131.33$, $p < .001$, $\eta_p^2 = .86$) as well as a significant difference between phobic condition ($F\ (1, 21) = 28.56$, $p < .001$, $\eta_p^2 = .57$); and a significant interaction between the two ($F\ (1, 21) = 71.09$, $p < .001$, $\eta_p^2 = .77$).

As can be seen from Fig. 3, phobic participants showed a greater tendency than non-phobic participants to alter their speed when dual tasking.

Results from the number of lane deviations revealed a significant difference between 'driving' conditions ($F\ (1, 21) = 4.62$, $p < .05$, $\eta_p^2 = .18$) but no significant difference in performance between phobic and non-phobic participants ($F\ (1, 21) = 2.96$, ns) and no interaction between the two ($F\ (1, 21) = 2.92$, ns).

Taken together these results suggest that when dual tasking, phobic participants altered their driving speed, but were still able to maintain good lateral control. Although non-phobic 'drivers' also demonstrated changes in their speed, they did not show the phobic, dual tasking participants' pattern of marked increase in speed deviations. This suggests that the secondary, conversation, task affected phobic and non-phobic participants in a qualitatively different way.

3.2. Analysis of heart rate data and contribution of anxiety

Each participant's HR change was calculated by taking the difference between their average and maximum heart rates (see Section 2.3.3). This was done three times: while resting (i.e. not 'driving'); during the undistracted driving session; and during the distracted 'driving' session.

A 2×3 mixed ANCOVA (two levels of phobic condition $\times$ 3 levels of session: resting, undistracted and distracted 'driving'), with anxiety score (the difference between the scores from the first and second STAI questionnaires) as a covariate was carried out on the data. There were significant differences in HR change between the three sessions ($F\ (2, 38) = 4.46$, $p < .05$, $\eta_p^2 = .19$). A significant main effect of phobic condition was also found ($F\ (1, 19) = 4.76$, $p < .05$, $\eta_p^2 = .20$; phobic). There was also a significant interaction between session and the covariate of anxiety score ($F\ (2, 38) = 3.44$, $p < .05$, $\eta_p^2 = .15$), and a significant 3-way interaction between session, phobic condition and anxiety score ($F\ (2, 38) = 3.64$, $p < .05$, $\eta_p^2 = .16$). Contrast tests revealed no significant difference in HR change between resting and undistracted 'driving' ($p = .50$) but there were significant differences between resting and distracted 'driving' ($p = .02$) and between distracted and undistracted 'driving' ($p = .02$).

Taken together these findings suggest that participant HR was affected not only by the 'driving' task (i.e. no 'driving', undistracted 'driving' or distracted 'driving') but also by anxiety levels as well as the participant's phobic state. Phobic participants appeared to be more affected by the conversation than non-phobics, as demonstrated by their higher HR change between 'driving' conditions, and their higher average HR across the three 'driving' conditions. Furthermore, this suggests that the phobic sample became more anxious than the non-phobics, and displayed increased CWL, which may be attributed to their greater involvement in the conversation.

3.3. Anxiety data

A 2×2 mixed ANOVA was carried out on the anxiety data with repeated measures on the scores from the STAI (before and after 'driving') and independent measures on phobic condition (phobic or non-phobic). It was found that there was a significant difference in anxiety scores before and after completion of the 'driving' sessions ($F\ (1, 21) = 8.65$, $p < .01$, $\eta_p^2 = .29$) but there was no significant difference between phobic and non-phobic participants ($F\ (1, 21) = 1.93$, $p > .05$, $\eta_p^2 = .08$) nor an interaction between the two ($F\ (1, 21) = 2.47$, $p > .05$, $\eta_p^2 = .10$). However, paired sample t-tests revealed that, when split by condition, phobic participants showed a significant increase in anxiety following 'driving' (t $(11) = -2.60$, $p < .05$, $r = -.31$) whereas non-phobic participants did not ($t\ (10) = -1.56$, $p > .05$, $r = -.16$). Thus, phobic

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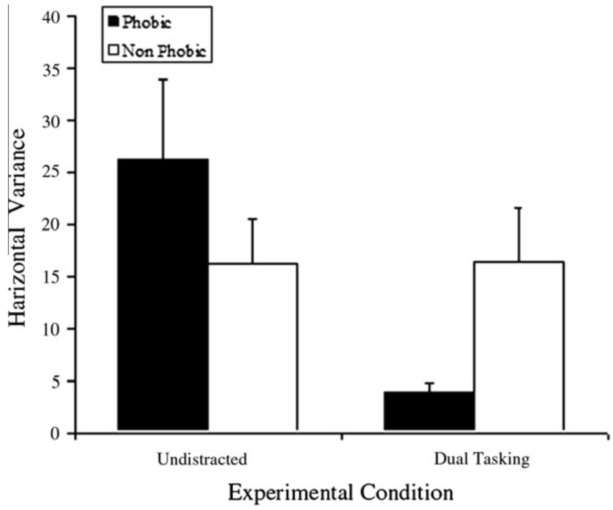

Fig. 4. Mean variance in horizontal fixations dependent on experimental and phobic condition (error bars show standard error).

participants showed an increase in anxiety scores after participation in the 'driving' task, whereas the anxiety levels of non-phobic 'drivers' remained relatively stable, suggesting that the conversation task had different effects on phobics and non-phobics.

3.4. Eye tracking data

In both the undistracted and distracted 'driving' conditions, a 30 s segment of each participant's driving was taken, 2 min from the start of the session. This time window was selected as it was at a point where participants had settled into the driving task and were accustomed to the controls. A $32 \times 40°$ grid was then superimposed over the recording of the eye tracking data. The film was then played frame-by-frame to enable recording of the positioning of the eye fixations.

3.4.1. Number of fixations

A 2×2 mixed ANOVA, with repeated measures on the 'driving' session (undistracted or distracted) and independent measures on phobic condition (phobic or non-phobic) revealed a highly significant difference in the number of fixations made in the two 'driving' sessions ($F(1, 21) = 8.99$, $p < .01$, $\eta_p^2 = .30$), with participants making significantly more fixations in the undistracted 'driving' session ($M = 170.22$, $SD = 60.90$) than in the distracted 'driving' session ($M = 127.30$, $SD = 51.04$). No significant main effect of phobic condition was found ($F(1, 21) = 2.74$, $p > .05$, $\eta_p^2 = .12$) nor was there an interaction between 'driving' session and phobic condition ($F(1, 21) = .28$, $p > .05$, $\eta_p^2 = .13$).

3.4.2. Differences in scan patterns: horizontal and vertical fixations

The variance in the number and positioning of fixations was used as a measure of each participant's scanning behaviour. The variance was chosen for analysis as it is a more representative measure of eye movements made than the mean or range alone and is less affected by individual idiosyncrasies in scanning behaviours.

3.4.2.1. Horizontal fixations. A 2×2 mixed ANOVA revealed a significant difference between horizontal fixations in the two 'driving' sessions ($F(1, 21) = 5.00$, $p < .05$, $\eta_p^2 = .19$). Although there was no significant main effect of phobic condition ($F(1, 21) = .06$, $p > .05$, $\eta_p^2 = .003$) there was a significant interaction between 'driving' session and phobic condition ($F(1, 21) = 5.12$, $p < .05$, $\eta_p^2 = .19$). However, when the data were split by phobic condition, it emerges that the phobic participants demonstrated a significant decrease in horizontal fixations ($t(11) = 3.08$, $p < .05$, $r = .50$) whereas the non-phobics did not ($t(10) = 0.02$, $p > .05$, $r = .003$).

As demonstrated in Fig. 4, phobic participants showed a significantly reduced variance in their horizontal fixations, compared to the non-phobics. Interestingly, in the undistracted driving session, phobics demonstrated a greater variance in fixations than the non-phobics. However, whilst the non-phobics retained a relatively even balance between the two driving sessions, the phobic participants showed a dramatic decrease in fixation variance, demonstrating visual tunnelling.

3.4.2.2. Vertical fixations. A further 2x2 mixed ANOVA revealed a marginally significant difference in vertical fixations between driving sessions ($F(1, 21) = 3.72$, $p = .06$, $\eta_p^2 = .15$). When the data were split by phobic condition, the phobics again showed a significant decrease in fixations across driving sessions ($t(11) = 2.76$, $p < .05$, $r = .44$) whereas the non-phobics did not ($t(10) = 0.78$, $p > .05$, $r = .17$).

Fig. 5 again shows that the phobic participants showed less variance in their vertical fixations than the non-phobics. Whilst the non-phobics demonstrated a slight reduction in vertical fixation variance between the driving sessions, the phobics showed a marked difference, again suggesting visual tunnelling.

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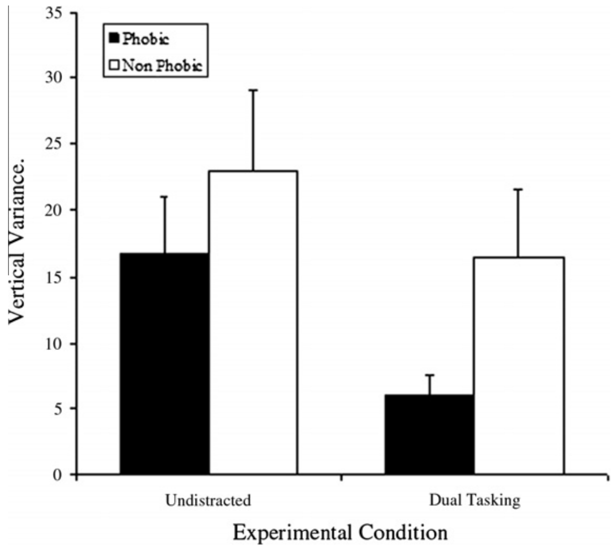

Fig. 5. Mean variance in vertical fixations dependent on experimental and phobic condition (error bars show standard error).

4. General discussion

Results suggest that the emotional aspects of a conversation may affect a driver's ability to control their attention. An increased level of overall CWL may contribute to inefficient visual scanning patterns, leading to cognitive and visual tunnelling. These visual scanning differences may lead to decreased visual awareness which could in turn contribute to decreased vehicle control, as demonstrated by differences in the number of driving errors made between phobic and non-phobic participants. For this reason, it appears that when the phobic participants were engaged in an emotionally relevant and involving conversation they were less vigilant and showed greater CWL than non-phobic participants, resulting in overall poorer primary task performance. The dual tasking phobic participants' tendency to deviate from the set target speed may possibly represent their attempt to control the demands on their cognitive resources, by limiting the primary, driving, task requirements (supporting Regan et al.'s (2009) suggestion of feedforward control). Whilst all participants demonstrated some degree of visual tunnelling when dual tasking, as compared to when they drove without distraction, the phobic participants showed a dramatic reduction in the breadth of their horizontal fixations. Supported by differences in measures of anxiety and driving performance, these findings suggest that the personal relevance of a conversation to a driver may have a significant effect on their ability to dual task.

These findings support the majority of previous investigations as those participants who were high in anxiety performed worse overall than those who were less anxious or undistracted. Specifically, Eysenck and Calvo's (1992) processing efficiency theory provides a clear explanation for these results: those individuals who were more affected by the conversation task appeared to allocate more of their attentional resources to the secondary task and suffered a depletion of CE control, to the detriment of their driving performance (as suggested by Lavric et al. (2003)). Shackman et al.'s (2006) research provides a possible explanation for the difference between dual tasking phobics and non-phobics in the number of driving errors made, by proposing that increased anxiety disrupts spatial WM abilities. As the task of 'driving' the simulator necessarily involved the use of all aspects of WM, any depletion to either CE control or overload of the slave systems, or both, could only serve to affect attentional resources further. This could explain Murray and Janelle's (2003) finding that anxious individuals are more prone to distraction than non-anxious individuals as well as the results of the current investigation. Masters (1992) provides further insight as to why anxious individuals are more prone to distraction by suggesting that the introduction of anxiety causes a shift in attention away from environmental cues to internal monitoring of feelings. Maxwell, Masters, and Eves (2000) argue that when attention is directed towards monitoring feelings, performance in self-paced tasks decreases. This would explain why the performance of phobic participants deteriorated above and beyond the decrease in performance shown by dual tasking non-phobic participants.

Derryberry and Tucker's (1994) suggestion that the experience of high-arousal negative emotion limits sensory processing is also supported by the current investigation. This is demonstrated in the pattern of visual and cognitive tunnelling shown by phobic, dual tasking participants, who were found to be more affected by the conversation task than non-phobic individuals. Such results are consistent with the findings of Nunes and Recarte (2002) and Harbluk and Noy (2002) who both found that with increased CWL came a decrease in the number and range of visual fixations made, with a tendency to focus attention on the central visual field rather than the peripheral fields. In contrast to Janelle et al. (1999) this investigation did not find scan patterns consistent with the notion that, in the face of a distractor, highly anxious individuals shift their attention entirely to the peripheral fields to take in information. In contrast, participants' scan patterns suggest that a small area in the central field was selected for most visual processing. This finding is consistent with Wilson et al.'s (2006) results showing

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that highly anxious individuals' scan patterns were altered with the introduction of an anxiety inducing task but were not altered when a task did not elicit anxiety. Taken together, the current investigation's findings suggest that increased anxiety leads to inefficient processing strategies (Eysenck & Calvo, 1992), an increase in CWL and a decrease in the number of visual cues which are processed (Easterbrook, 1959; Murray & Janelle, 2003) all of which lead to the need for greater CE control. If capacity of WM is exceeded, alternative attention allocation strategies may be implemented which could result in decreased 'driving' performance.

The results of this investigation support Regan et al.'s (2009) theoretical model. Specifically, these findings add weight to the suggestion that the varying levels of control are selectively interfered with by the introduction of a secondary, attention demanding, task. Feedback control was impaired because the conversation task delayed the updating of information in the attentional system, meaning the difference between the current state and the goal state of attentional resources was not clear. Regan et al.'s (2009) suggestion that feedforward control is limited when dual tasking is also supported: in order to anticipate potential attention allocation issues, the individual must have a clear internal model of the future state of the system. The introduction of a secondary, unexpected, task may limit the capacity for creating a clear, internal model, meaning attentional resources are not available to cope with the dual task demands. Finally, it could be argued that dual tasking phobic participants used adaptive control to moderate the task demands in the current experiment, by deviating from the speed limit which they were instructed to maintain. Due to the nature of the conversation task, which consistently demanded the 'driver's' attention, this adaptive control was ineffective, as demonstrated by their increased number of driving errors. This is in line with Regan et al.'s (2009) suggestion that if a secondary task cannot be delayed, adaptive control may not aid performance.

Collectively, these failures of control at various points in the experimental task support the assumption that the timing of tasks and the control of resources are crucial to competent dual tasking. Furthermore, given that phobic dual tasking participants were more prone to driving errors, appeared to show attempts to reduce task demands (e.g. speed deviations), and demonstrated visual tunnelling to a greater extent than their non-phobic counterparts, it could be argued that emotional involvement in a conversation exacerbates the negative effects of dual tasking. Thus, rather that offering a generalised explanation of decreased CE control, failures at all three levels of control (and subsequent cascade and saturation effects) proposed by Regan et al. (2009) can explain the deteriorated 'driving' performance in this experiment.

4.1. Methodological limitations

This investigation was novel in that one conversation task was used for all participants yet its significance to the participants varied. However, despite the apparent success of this study in identifying that the relevance of the conversation to a dual tasking driver could differentially affect visual scanning patterns, overall driving performance and CWL, it is equally apparent that improvements to the design could be made. One failing of this investigation was the lack of measurement of performance in the secondary task. Although the task was designed to elicit emotional involvement in a conversation in one group of participants and not in another group, the procedure used merely assumed that all participants were fully engaged in the conversation. Whilst this may well be a valid assumption, based on participant feedback following the experiment, a direct measure of involvement could easily have been achieved. Recording the number and rate of utterances made by a participant would have provided a measure of their involvement in the conversation which could then have been correlated with their anxiety score. This would then allow for greater certainty in the assumption that all participants were fully engaged in the conversation whilst they were 'driving'.

A further potential criticism of this investigation could be that due to the content of the secondary task, phobic participants were not solely distracted by the act of conversing, but also by the memories and mental images which the conversation provoked. However, whilst these effects would have varied between participants, and was therefore uncontrollable, this was the initial intention of the experimental design. The use of a naturalistic conversation, as opposed to a stilted, artificial secondary verbal task, is in its very nature variable and therefore has greater ecological validity. Nevertheless, although naturalistic conversation has obvious benefits, the topic chosen for this investigation may have served to exaggerate the effects of anxiety on CWL and visual perception in turn. Although it was challenging to identify a single conversation topic that was emotionally involving for one group of participants but not for another, the decision to use a phobic sample and to discuss the subject of their phobia may be questionable. In real-world situations, drivers may choose not to become involved in a conversation which makes them feel unduly anxious or stressed. Further investigations in a similar vein, but perhaps with less extreme topics are needed to validate the current results.

Finally, the point at which participants had their resting heart rates recorded may have affected results. Given that resting measures were taken *after* participants had completed the spider phobia questionnaire, it is possible that phobic participants experienced some level of anxiety, brought about by completing the questionnaire, prior to exposure to the conversation task. Although the results clearly demonstrated that there were differences between phobic conditions in levels of anxiety and heart rate, across 'driving' conditions, it could be that the magnitude of effects reported are reduced due to this order of task completion.

4.2. Future investigations

Few researchers have considered the effect on performance of the *relevance* of the conversation to a dual tasking individual. The implications of the present findings are important for further research, since they demonstrate that the type of

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secondary task used in investigations qualitatively affects performance and CWL. For this reason, researchers in this field should carefully consider the type of secondary task they ask participants to complete – one which is designed purely to increase CWL may lack both ecological validity and the ability to isolate the specific aspects of the secondary task which affect driving performance. Furthermore, given that very few investigations use naturalistic conversation as a secondary task, factors such as the length of an involving conversation and the rate at which anxiety is increased (e.g. what are the effects of anxious material interspersed with other topics, resulting in a more gradual increase in anxiety?) also warrant investigation.

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