Adverse effects of anxiety on attentional control differ as a function of experience: A simulated driving study

Gisele C. Gotardi[a,b,*], Paula F. Polastri[b,c], Paulo Schor[a], Raôul R.D. Oudejans[d,e], John van der Kamp[d], Geert J.P. Savelsbergh[d,f], Martina Navarro[g], Sérgio T. Rodrigues[b,c]

[a] Health Informatics Postgraduate Program, Paulista School of Medicine, Federal University of São Paulo, São Paulo, São Paulo, Brazil
[b] Laboratory of Information, Vision and Action, Department of Physical Education, Faculty of Sciences, São Paulo State University, Bauru, São Paulo, Brazil
[c] Human Movement Science Postgraduate Program, Department of Physical Education, Faculty of Sciences, São Paulo State University, Bauru, Sao Paulo, Brazil
[d] Amsterdam Movement Sciences, Department of Human Movement Sciences, Vrije Universiteit Amsterdam, the Netherlands
[e] Faculty of Sports and Nutrition, Amsterdam University of Applied Sciences Amsterdam, the Netherlands
[f] Institute for Biomedical Research into Human Movement and Health, Manchester Metropolitan University, Manchester, UK
[g] Department of Sport and Exercise Science, Faculty of Science, University of Portsmouth, Portsmouth, England, UK

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ABSTRACT

This study tested whether adverse effects of state anxiety on attention and performance may be modulated by experience. Sixteen experienced and eleven inexperienced drivers drove in a simulator under low- and high-stress conditions. Anxiety was manipulated by competition, the presence of an evaluator, external video camera, and traffic noise. Most drivers showed greater anxiety scores and higher mean heart rates following manipulation. In both groups increased state anxiety decreased car speed control and caused more collisions, accompanied by fewer fixations of longer duration towards the driving lane across a horizontally narrower region. Inexperienced drivers increased the number of short fixations towards cars, while experienced drivers increased the number of short fixations on the speedometer. Although anxiety impairs processing efficiency and performance effectiveness for both groups, attentional changes differ as a function of experience. Inexperienced drivers tended to shift attention to threatening stimuli, while experienced drives were more likely to consciously monitor task goal.

1. Introduction

The often-detrimental effects of anxiety on performance have been investigated for a long time. However, recent advances in gaze-tracking technology *during* action has recently renewed interest in how attention modulates the performance decrements following an increase in anxiety in dynamic situations such as sports, policing and car driving (Allsop and Gray, 2014; Briggs et al., 2011a; Causer et al., 2011; Nibbeling et al., 2012; Vickers and Williams, 2007; Navarro et al., 2012; Williams et al., 2002; Nieuwenhuys and GJPOudejans, 2015; Pijpers et al., 2005; Navarro et al., 2013; Malhotra et al., 2014). Typically, anxiety can be understood as a (transitory) state or a personality trait. According to Eysenck, state anxiety is an aversive transitory emotional and motivational state evoked by threatening and/or stressful circumstances (Eysenck et al., 2007a), while trait anxiety is an individual's propensity towards anxiety. It has been shown that increased levels of state anxiety can disrupt performance by enhancing a performer's propensity for distraction (Allsop and Gray, 2014; Wilson et al., 2009a; Janelle et al., 1999), attentional narrowing (Briggs et al., 2011a; Janelle et al., 1999), and/or reduced processing efficiency (Nibbeling et al., 2012; Behan and Wilson, 2008; Causer et al., 2014; Wilson et al., 2009b).

Recently, Nieuwenhuys and Oudejans proposed an integrated model that encompasses anxiety and perceptual-motor performance for explaining the disparate behavioural responses observed under threatening and stressful circumstances (Nieuwenhuys and Oudejans, 2012, 2017). This model builds heavily on Attentional Control Theory (ACT) (Eysenck et al., 2007b) that is suitable for cognitive tasks, yet extends it to fit the specific characteristics of perceptual-motor performance, including the critical role of visual attention. According to the integrated model, and in line with ACT, increased anxiety provokes performance

decrements because it impairs attentional control; it intensifies the engagement of the stimulus-driven system at the expense of the involvement of goal-directed system. The goal-directed system regulates the conscious control of attention. This top-down system directs attention in accordance with a performer's expectations, knowledge and current task goals. The stimulus-driven system recruits attentional resources via automatic processing. This bottom-up system serves to detect maximally salient and/or threatening stimuli in the environment. In low stressful situations, the contributions of two attentional systems are optimally coordinated for achieving the task goal. However, with increased levels of anxiety, the systems' coordination is disrupted. Attentional control may shift more to the stimulus-driven system, increasing attention to conspicuous stimuli (Allsop and Gray, 2014; Briggs et al., 2011a; Nibbeling et al., 2012; Janelle et al., 1999; Eysenck et al., 2007b) and away from the goal-directed system. To counter this and with increased mental effort, one may manage to maintain goal-directed attention; in that case, performance is maintained but with decreased processing efficiency (Masters and Maxwell, 2008). On the other hand, if there is indeed a shift toward the stimulus-driven system under high anxiety then the time visually fixating irrelevant/threatening cues is increased (Allsop and Gray, 2014; Williams and Elliott, 1999) and the number of fixations towards relevant areas of the visual scene is reduced (Allsop and Gray, 2014), leading to hampered performance. In addition, it provokes a relatively narrow range of visual scanning (Briggs et al., 2011a). However, it is not particularly clear whether, and if so to what degree, the effects of increased anxiety differ as a function of the level of experience or expertise.

In car driving -the task under study here-the level of experience (or perhaps expertise) does influence perceptual and motor performance (Underwood, 2007; Crundall and Underwood, 1998). For example, inexperienced drivers have been shown to have a reduced visual exploration (e.g., less fixations with a relatively narrower distribution) compared to experienced drivers, in particularly when potential hazards are more likely to occur (e.g., driving in dual carriageway, night and rain visibility). The less developed capacity to acquire information (Crundall and Underwood, 1998; Mourant and Rockwell, 1972; Crundall et al., 1999; Konstantopoulos et al., 2010) goes together with an enhanced susceptibility for getting involved in traffic accidents in the first years after obtaining a driving license (Underwood, 2007; Clarke et al., 2005). Likely, less experienced drivers require stronger conscious monitoring and control of their driving skills, whereas the experienced drivers' skills proceed more automatically (Brown and Carr, 1989; Fitts and Posner, 1967). Less experienced drivers would thus require more processing resources to assure safe driving. Yet, there is a dearth of studies examining whether, and if so how, anxiety mediates these experience-related attentional differences.

From the perspective of the integrated model of Nieuwenhuys and Oudejans, 2012, 2017, we can predict increased processing demands and/or increased attention for conscious/threatening stimuli. Increased levels of anxiety can cause a reduction in processing efficiency, that is, more attentional resources are consumed to monitor and control the skill (which, for instance, may be reflected in more or longer fixation to task relevant information such as direction of heading, or speedometer). If auxiliary attentional resources are available to compensate anxiety decrements, performance effectiveness can be maintained under pressure, but at the cost of a reduced processing efficiency (Nibbeling et al., 2012; Eysenck et al., 2007b; Williams and Elliott, 1999). Among inexperienced drivers, for whom driving already is more effortful than for experienced ones, the attentional capacity limits may be more likely to be exceeded (Nibbeling et al., 2012), thus resulting in larger drops in performance effectiveness compared to more experienced drivers counterparts (Nibbeling et al., 2012; Williams and Elliott, 1999). Alternatively, novices drivers may be more easily distracted by conspicuous or threatening stimuli and thus at increased risk of unsafe driving performance (i.e., which, for instance, may be reflected in more or longer fixations for threatening stimuli such as toward other cars to avoid collision).

In the traffic, personal factors, such as, work-related stress or fatigue, hurry, adverse life events, and/or environmental factors such as a gridlock, an overload of auditory or visual noise can induce increased levels of anxiety and thus affect driver's performance. In this respect, it has been reported that increased anxiety causes deterioration in motor performance (Allsop and Gray, 2014; Briggs et al., 2011b) and is related to more frequent involvement in traffic accidents (Clapp et al., 2011; Roidl et al., 2014; Dula et al., 2010). A better understanding of how attentional control mediates the relation between anxiety and driving performance can be a first step in further improving safety of cars and the traffic environment to reduce the adverse effects of increased anxiety. For example, if anxious drivers would indeed be more easily distracted by conspicuous stimuli, then it is important to take this into account in the design of a car's dashboard or permitting advertisements (Fioravanti-Bastos et al., 2011).

The aim of this study was to investigate, whether, and if so how adverse effects of anxiety on perception and action in drivers are modulated by driving experience In line with previous findings (Allsop and Gray, 2014; Briggs et al., 2011a; Nibbeling et al., 2012; Eysenck et al., 2007b; Williams and Elliott, 1999; Murray and Janelle, 2003), it was hypothesized that high levels of state anxiety would shift drivers' attention from task-relevant stimuli toward threat-related and/or salient stimuli. We suspect that the particular shift in balance between the two attentional systems may depend on the available attention resources. Accordingly, because they need fewer resources for regular driving, experienced drivers may more likely maintain contribution of the goal-directed systems and thus attention for stimuli that inform about heading and speed (e.g., fixations toward the lane, speedometer). On the other hand, inexperienced drivers may be more easily distracted by conspicuous and/or threatening stimuli that inform about collisions (e.g., more fixations toward hard shoulder, other cars, rearview mirror) and would thus show a drop in performance effectiveness (e.g., less car speed control or more occurrences of collisions), due to non-automatized steering control which makes this group unable to allocate sufficient resources to minimize anxiety decrements.

2. Materials and method

2.1. Participants

Forty drivers (25 male, 15 female) voluntarily participated in this experiment and filled out the Driving Experience Questionnaire (DEQ), which was developed by the experimenters to quantify the drivers' experience, prior to participation. This questionnaire consisted of three items for gauging the frequency of driving in the city (*Q1- How long have you been driving a car weekly? Q2- How many days a week are you typically driving a car? Q3- How many kilometers are you typically driving per day?*), and two items about the frequency of driving on the highway (*Q4- Monthly, how often have you been driving a car on the* highway*?; Q5- How many kilometers are you typically driving during such a trip?*). To quantify the driving experience (DE) of the drivers, experience in the city was summed with the experience on the highway using the following equation:

$$DE = [((Q2 * 4) * 12 * Q1 * Q3) + (Q4 * Q5)]$$

Where *Q2* is the weekly driving rate in the city and was used to calculate the annual driving rate in the city [(*Q2**4) *12]. To estimate the total rate of driving in the city, the annual driving rate was multiplied by the number of years of the driving license (*Q1*), which was multiplied by the number of kilometers traveled per day (*Q3*). To estimate the total rate of driving on the highway, the monthly driving rate on the highway *(Q4)* was multiplied by the total number of kilometers in each trip (*Q5*).

Drivers were classified into an inexperienced group (n = 20), when

DE was less than 5000 km, and an experienced group (n = 20), when DE was above 30,000 km (Summala et al., 1996; Lehtonen et al., 2014). Both groups were asked to perform a simulated driving task in a low- and high-stress condition. Drivers' self-reported anxiety scores were compared prior and immediately after each condition (see below, section 2.2.3. for more details about the anxiety ratings) and used as inclusion criteria. Four experienced and nine novice drivers did not report increased anxiety in the high-stress condition compared to the low-stress condition. Because it was not particularly clear how these participants coped with the high-stress condition (i.e., they did not have lower trait anxiety scores), they were excluded from further analyses.

The remaining sixteen experienced drivers (26.38 ± 2.80 years old; 83.38 ± 17.89 kg; 177 ± 0.08 cm; 154228.44 ± 25190.37 km) and eleven inexperienced drivers (24.00 ± 2.66 years old; 66.09 ± 10.79 kg; 169 ± 0.09 cm; 1830.00 ± 694.05 km) were included for data analyses. To check whether experienced and inexperienced participants showed no difference in tendency to respond to stressful circumstances with a higher level of state anxiety, the Brazilian Portuguese version of the Trait scale of the short-form State-Trait Anxiety Inventory (STAI-T) (Fioravanti-Bastos et al., 2011) was also completed prior to participation. Student's t-test revealed that there was no significant difference between groups for the trait-anxiety score, t (df) = −1.831, p = .079 (experienced drivers = 10.44 ± 2.25 pts; inexperienced drivers = 12.09 ± 2.38 pts). To assess the visual acuity of the participants the *Snellen* test was conducted, which consists of reading letters from large to small with one eye at a time. One printed page with the test (A4 standard format) was placed at 6 m away from the individuals' eyes. The test was performed with visual acuity corrections (e.g., contact lenses or glasses) when necessary. As inclusion criteria were selected those who obtained visual scores were between 20/20 and 20/30. Ethical approval for the study was obtained from the Local Committee and participants signed informed consent before the start of the study.

2.2. Apparatus

2.2.1. Driving simulator

The simulated driving task was performed with *City Car Driving* simulator (Forward Development, version 1.5) that was configured to drive on a highway (multi-lane, 20% of traffic and daytime visibility) with a left-handed vehicle of a manual gearbox. The simulation was run using a PC (ASUS), running *Windows 7 Ultimate Edition Service Pack 1*, connected to a TV screen (LG, LED 46″). To approach a realistic condition, the TV screen was fixed in a cockpit (XT Premium V2 Racing Extreme) with the driver's seat positioned 100 cm away from the screen. In addition, driving accessories (steering wheel, pedals, and gearbox - Logitech, G27) were attached to the cockpit to control the vehicle during the driving task and configured with *Logitech Gaming Software* (version 5.10.127).

2.2.2. Gaze behavior

Drivers' eye movements were recorded using *Head-Mounted Eye Tracker* (model H6, Applied Science Laboratory, USA) at a sampling rate of 60 Hz. This video-based analysis system of eye movements contains two micro-cameras, one that films the eye and another one the scene, attached to a headgear that was anatomically adjusted to the participant's head. In the eye video, pupil and corneal reflection centroids were identified and the vector between both is used to determine horizontal and vertical coordinates of eye position on scene video.

2.2.3. Anxiety measures

Participants' anxiety was determined using psychological and physiological measures. The Brazilian Portuguese version of State scale of the short-form State-Trait Anxiety Inventory (STAI-S) (Fioravanti-Bastos et al., 2011) was used to measure state anxiety. The short-form STAI-S is a 6-item questionnaire about an individual's current

psychological state, which encompasses positive items (e.g., *"I feel calm", "I feel content"*) and negative items (e.g., *"I am tensed", "I am worried"*). Participants rated each item on a 4-point Likert scale from *"Not at all"* to *"Very much"*. Scores from positive items were inverted for their opposite value (e.g., score 1 is inverted in 4; score 2 is inverted in 3) and the scores from negative items were maintained at the original value (Marteau and Bekker, 1992). The scores from each item were summed to determine the level of anxiety, considering that higher scores represent a greater state anxiety. The short-form STAI-S was completed by all participants prior to and immediately after performing in the low- and high-stress conditions. Heart rate was measured using the *Polar* (RS800CX) Heart Rate (HR) monitor (Essner et al., 2013), which contains an electrode belt and transmitter (WIND). The transmitter recorded and processed the HR records as beats per minute (bpm) at a frequency of 100 Hz.

2.3. Procedure

Prior to the start of the test, participants had their rest HR measured. The electrode belt (Polar) was strapped around the participants' chest, with the transmitter placed ventrally to register the HR during the experiment. After that, participants were asked to take a seat in the cockpit and the gaze tracker's headgear was adjusted on their head. A nine-point calibration plan was projected on the TV screen, for which participants were asked to maintain their head as still as possible and to move their gaze from one point to another in ascending order. After calibration participants were informed that the simulated driving task consisted of uninterrupted driving during 3 min on a highway. Furthermore, participants were instructed to maintain car speed between 100 and 120 km/h and to avoid traffic violations (e.g., no turn signals in overtaking, collisions). The anxiety manipulation (see below) was provided a few minutes before the beginning of the high-stress condition. Participants had 3 min to familiarize themselves with the simulator and equipment. Trial time started to be timed when drivers reached 100 km/h for the first time, and recordings of gaze fixations and HR were started synchronously.

2.4. Anxiety manipulation

The simulated driving task was performed in two experimental conditions: *i) low-stress*, driving task performed in a quiet environment; *ii) high-stress*, driving task performed in a competitive environment, ego-threatening instructions, performance evaluation, external video camera and traffic noises. The competition consisted of performing the simulated driving task by making as few errors as possible and less than other competitors. Driving errors were defined as the time that drivers achieved speeds outside the speed bandwidth (i.e., < 100 km/h or > 120 km/h), the absence of the turn signals when overtaking, and/or collisions. For the competition, these errors were scored as one, one, and three errors, respectively. An evaluator positioned behind the cockpit during the high-stress condition determined the errors instantly. First, participants were informed about the competition rules and the presence of the evaluator and, subsequently, that the winner of the competition would win a *Tablet* (Galaxy SMMM-T113NU, Samsung). Second, the ego-threating instructions were that the performance during simulated driving task would represent their real driving abilities, and thus, at the end of the study a performance ranking would be disclosed among participants. Third, an external video camera (Sony, DCR SR68) was placed in front of participants in order to register their arms movements in steering wheel control. They were informed that, in the case of a tie in the competition, the analyses of their arm movements would be used to indicate who the best driver was. Finally, a computer laptop (Lenovo, G450) running *Windows Media Player* (Windows 10) and connected to an amplifier box (Meteoro, 50 W) was used to reproduce traffic noises at a volume between 70 and 80 dB. Performance feedback to the participants was only provided

Table 1

Means (SDs) for the manipulation check during simulated driving task in low- and high-stress conditions.

	Experienced drivers		Inexperienced drivers	
	Low-stress	High-stress	Low-stress	High-stress
STAI-S score (Navarro et al., 2012; Williams et al., 2002; Nieuwenhuys and GJPOudejans, 2015; Pijpers et al., 2005; Navarro et al., 2013; Malhotra et al., 2014; Eysenck et al., 2007a; Wilson et al., 2009a; Janelle et al., 1999; Behan and Wilson, 2008; Causer et al., 2014; Wilson et al., 2009b; Nieuwenhuys and Oudejans, 2012; Nieuwenhuys and Oudejans, 2017; Eysenck et al., 2007b)	9.75 (1.98)	13.69 (2.82)	9.00 (3.25)	13.36 (2.58)
Heart rate (bpm)	79.34 (10.16)	92.92 (14.31)	79.52 (10.81)	89.90 (11.92)

after the test was completed. This revealed which errors they had committed under high-anxiety and, after summing all errors, their respective position in the performance ranking. The choice for these four manipulations was based on previous research, in which they have proven successful in increasing participants' experience of (transitory) anxiety and are associated with decrements in performance efficiency and/or outcome (Behan and Wilson, 2008; Murray and Janelle, 2003; Baumeister and Showers, 1986).

2.5. Data analysis

In order to verify the anxiety manipulation, a total score of the short-form STAI-S before and immediately after each experimental condition was calculated. Heart rate data (bpm) was transmitted at the end of each recording to a PC computer (ASUS) via a bidirectional infrared interface using the Polar® software (Protrainer 5).

Driving performance was assessed via frame-by-frame video analysis to calculate the percentage of the trial time driving outside of the speed zone and the frequency of collisions in each trial. The percentage of trial time driving outside of speed zone was defined as the duration (s) at which the car speed was below or above the specified speed zone divided by total trial time and multiplied by 100. Finally, the total number of collisions throughout driving performance was counted for each participant in both conditions.

Gaze recordings were transferred to a PC (ASUS) running *ASL Results Plus* software (version 1.8.2.18, Applied Science Laboratory, USA) for further analysis with Areas of Interest (AOIs). AOIs are two-dimensional (2-D) regions defined in the viewing plane (e.g., scene video from Eye Tracker) that allow the calculation of the gaze behavior (number and duration of fixations) in relevant parts of the visual scene. Four AOIs were considered as sources that contain potentially relevant and/or threatening information to performing the task: *i) lane*, which provides the essential visual information to steering control; *ii) other cars,* which need to be avoided and iii) *speedometer*, task-relevant information for successful task performance; *iv) rearview mirrors*, task-relevant information for deciding overtakes. Total number (unit) and mean duration (ms) of fixations to each AOI were calculated. Fixation detection criteria were a minimal duration of 100 ms and the spatial limit of 1° (Land, 2006).

Furthermore, the horizontal and vertical variance of fixation locations (cm) was calculated to express the range of visual scanning strategy employed by drivers in the conditions (Crundall et al., 1999, Crundall and Underwood, 2011). Horizontal and vertical of fixations position were exported as text files in a matrix of two columns (horizontal and vertical eye position, respectively) by the number of rows equivalent to the number of fixations in each trial. Then, the square root of standard deviations of the fixations position in both axes was calculated using *Matlab* (Mathworks, 7.10.0.499).

2.6. Statistical analysis

To investigate the effects of experience and anxiety on gaze behavior and performance of drivers, group (experienced, inexperienced) by condition (low-stress, high-stress) ANOVAs with repeated measures on

the last factor were performed on the following dependent variables: *anxiety - i* and *ii) total score STAI-S and mean Heart Rate (HR); performance - iii* and *iv) % time driving outside of the speed zone and number of collisions; gaze behavior - v* and *vi) total number and mean duration of fixations on lane; vii* and *viii) total number and mean duration of fixations on cars; ix* and *x) total number and mean duration of fixations on speedometer; xi* and *xii) total number and mean duration of fixations on rearview mirrors; xiii* and *xiv) horizontal and vertical variance of fixations;* Statistical analyses were run using *SPSS Statistics* (17.0.1). Tukey Honestly Significant Difference tests, Greenhouse-Geisser degrees of freedom adjustments, and Bonferroni multiple-comparison probability adjustments were conducted in all statistical analyses as necessary. The value *alpha* was .05. Effect sizes were calculated using Partial Eta Squared with 0.02 or less, 0.13, and 0.26 or more, representing small, medium and large effect sizes, respectively (Cohen, 1988).

3. Results

3.1. Manipulation check for anxiety

A complete overview of means and SDs of the anxiety measures is provided in Table 1. For the STAI-S and HR the ANOVAs revealed a main effect for condition, $F(1,25) = 80.590, p < .001, \eta_p^2 = 0.763$ and $F(1,25) = 35.917, p < .001, \eta_p^2 = 0.763$ respectively, indicating that drivers self-reported more anxiety during the high-stress than the low-stress condition, and that they had higher HRs during the high-stress than the low-stress condition. For both STAI-S and HR there were neither differences between groups, $F(1,25) = 0.334, p = .568, \eta_p^2 = 0.013$ and $F(1,25) = 0.111, p = .742, \eta_p^2 = 0.004$, nor any interactions, $F(1,25) = 0.212, p = .649, \eta_p^2 = 0.008$ and $F(1,25) = 0.640, p = .431, \eta_p^2 = 0.025$, respectively.

3.2. Performance

For the % time driving outside of the speed zone (Fig. 1a) and the number of collisions (Fig. 1b) the ANOVAs revealed a main effect for condition, $F(1,25) = 15.115, p = .001, \eta_p^2 = 0.377$ and $F(1,25) = 14.224, p = .001, \eta_p^2 = 0.363$, respectively, showing that in the high-stress condition drivers increased both the time driving outside the speed zone and were involved in more collisions compared to the low-stress condition. For both the time driving outside of the speed zone and the number of collisions there were no differences between groups, $F(1,25) = 2.980, p = .097, \eta_p^2 = 0.106$ and $F(1,25) = 0.042, p = .839, \eta_p^2 = 0.002$, or interactions, $F(1,25) = 2.289, p = .143, \eta_p^2 = 0.084$ and $F(1,25) = 0.355, p = .557, \eta_p^2 = 0.014$, respectively..

3.3. Gaze behavior

Means and SDs of the gaze behavior are provided in Table 2.

3.3.1. Areas of interest analyses

For the total number and mean duration of fixations on the lane the ANOVA revealed a main effect for condition, $F(1,25) = 16.855$,
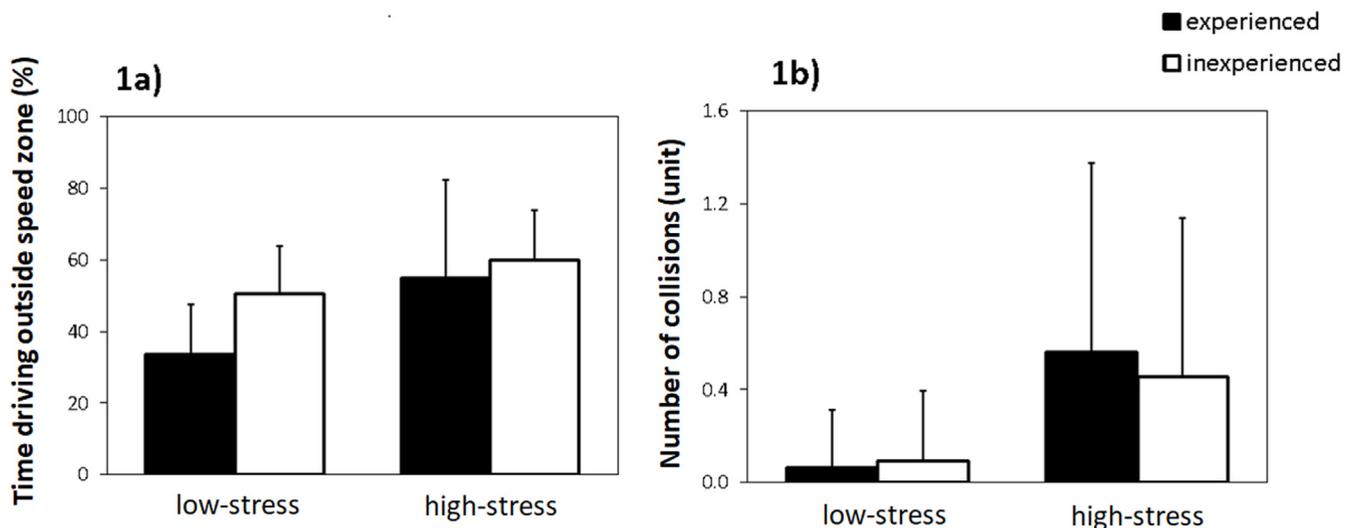
Fig. 1. Percentage of the trial time driving outside of speed zone (a) and the number of collisions (b) as a function of experience and stress.

$p = .000$, $\eta_p^2 = 0.403$ and F $(1,25) = 3.904$, $p = .053$, $\eta_p^2 = 0.135$, respectively. Drivers performed fewer fixations, yet of longer duration on lane in the high-stress than in the low-stress condition. There were no significant differences for group, F $(1,25) = 2.434$, $p = .131$, $\eta_p^2 = 0.089$ and F $(1,25) = 0.066$, $p = .800$, $\eta_p^2 = 0.003$, or interaction between group and condition, F $(1,25) = 1.319$, $p = .262$, $\eta_p^2 = 0.050$ and F $(1,25) = 0.443$, $p = .512$, $\eta_p^2 = 0.017$, respectively.

For the total number of fixations on rearview mirrors the ANOVA revealed a main effect for condition, F $(1,25) = 7.790$, $p = .010$, $\eta_p^2 = 0.238$, but no differences for group, F $(1,25) = 2.200$, $p = .150$, $\eta_p^2 = 0.081$, or the interaction, F $(1,25) = 0.138$, $p = .714$, $\eta_p^2 = 0.005$. In the high-stress condition, the drivers decreased the total number of fixations on the mirror compared to the low-stress condition. For the mean duration of fixations on rearview mirror there were no significant differences for condition, F $(1,25) = 1.524$, $p = .228$, $\eta_p^2 = 0.057$, group, F $(1,25) = 0.934$, $p = .343$, $\eta_p^2 = 0.036$, or their interaction, F $(1,25) = 1.023$, $p = .322$, $\eta_p^2 = 0.039$.

For the total number and mean duration of fixations on cars the ANOVAs revealed main effects for condition, F $(1,25) = 7.953$, $p = .009$, $\eta_p^2 = 0.241$ and F $(1,25) = 12.507$, $p = .002$, $\eta_p^2 = 0.333$, respectively, but no main effects for group, F $(1,25) = 4.024$, $p = .066$, $\eta_p^2 = 0.109$. Yet, the main effects for condition were superseded by interactions with group, F $(1,25) = 6.789$, $p = .015$, $\eta_p^2 = 0.214$ and F $(1,25) = 14.211$, $p = .001$, $\eta_p^2 = 0.362$, respectively. *Post-hoc* pair-

wise comparisons indicated that only inexperienced drivers increased the total number of fixations on cars, which were of shorter duration, during the high-stress condition compared to the low-stress condition. The experienced drivers showed no significant differences in gaze behavior toward other cars as function of anxiety.

The total number of fixations on the speedometer the ANOVA revealed a main effect for group, F $(1,25) = 4.284$, $p = .049$, $\eta_p^2 = 0.146$, as well as and interaction between group and condition, F $(1,25) = 12.834$, $p = .001$, $\eta_p^2 = 0.339$. Also, for the mean duration of fixations on the speedometer a main effect for condition, F $(1,25) = 36.437$, $p = .000$, $\eta_p^2 = 0.593$, for group, F $(1,25) = 9.293$, $p = .005$, $\eta_p^2 = 0.271$, and an interaction between both factors, F $(1,25) = 5.050$, $p = .034$, $\eta_p^2 = 0.168$, were revealed. Post-hoc tests indicated that in the high-stress condition only experienced drivers increased the number of fixations to the speedometer, yet these were of shorter duration compared to the low-stress condition. The inexperienced drivers showed no such differences.

3.3.2. Variance of fixation location

For the horizontal variance, the ANOVA revealed a main effect for condition, F $(1,25) = 11.534$, $p = .002$, $\eta_p^2 = 0.316$, but no significant difference for group, F $(1,25) = 0.254$, $p = .618$, $\eta_p^2 = 0.010$, or the interaction between group and condition, F $(1,25) = 0.200$, $p = .659$, $\eta_p^2 = 0.008$. The main effect showed that drivers reduced the

Table 2

Means (SDs) for the gaze behavior of each group during simulated driving task in low- and high-stress conditions.

	Experienced drivers		Inexperienced drivers	
	Low-stress	High-stress	Low-stress	High-stress
Lane				
Total number of fixations	139.81 (41.68)	113.00 (39.88)	125.27 (63.58)	77.64 (44.48)
Mean fixations duration (ms)	471.75 (72.00)	495.06 (103.29)	469.00 (108.65)	516.00 (125.22)
Cars				
Total number of fixations	138.37 (29.59)	139.69 (24.58)	143.55 (34.57)	176.73 (37.56)
Mean fixations duration (ms)	480.56 (85.26)	483.75 (83.65)	583.27 (103.70)	483.45 (79.15)
Speedometer				
Total number of fixations	64.50 (30.74)	86.12 (48.75)	51.36 (23.92)	44.45 (25.98)
Mean fixations duration (ms)	367.88 (73.20)	312.63 (53.57)	288.18 (44.10)	262.91 (42.96)
Rearview mirrors				
Total number of fixations	39.25 (18.81)	24.88 (14.73)	46.73 (22.83)	35.73 (23.22)
Mean fixations duration (ms)	545.31 (176.54)	460.25 (206.32)	565.18 (171.15)	556.73 (158.02)
Variance of fixations location				
Horizontal (cm)	132.50 (60.94)	94.19 (58.56)	148.26 (77.96)	98.34 (37.34)
Vertical (cm)	72.64 (23.58)	71.80 (30.26)	91.82 (44.59)	81.37 (37.15)

horizontal variance of fixations under high-stress condition compared to low-stress condition. For the vertical variance of fixations, the ANOVA showed neither effects for condition, F (1,25) = 0.486, p = .492, η_p^2 = 0.019, nor for group, F (1,25) = 1.957, p = .174, η_p^2 = 0.073, and the interaction between the two factors, F (1,25) = 0.352, p = .558, η_p^2 = 0.014.

4. Discussion

The aim of this study was to investigate the effects of anxiety on gaze behavior and performance of car drivers and how this is mediated by experience. Inexperienced and experienced drivers were invited to drive in a simulator within a certain speed zone and without making collisions. Competition with ego-threatening instructions and the presence of an evaluator were used to increase anxiety (Allsop and Gray, 2014; Briggs et al., 2011a; Behan and Wilson, 2008). Increases in STAI-S scores and mean heart rate in the high-stress condition compared to low-stress condition in both skill groups confirmed that the manipulations were successful (i.e., participants who did not show increased anxiety were excluded from analyses). The increased anxiety evoked significant disruptions in driving performance for both groups of drivers. In comparison to low-stress condition, drivers with increased anxiety spent more time driving outside the speed zone (100–120 km/h) and showed an increased collision rate. As this was true for both groups, apparently despite their experience and more automatic behavior, even experienced drivers did not, contrary to the expectations, have sufficient resources to maintain attentional control and thus performance.

We were especially interested to find out to what degree these performance decrements could be associated with deterioration in attentional control (as measured by shifting patterns of gaze) as would be predicted on the basis of the integrated model of anxiety and perceptual motor performance (Nieuwenhuys and Oudejans, 2012, 2017). In particular, we addressed whether, and if so how, increased anxiety would affect attentional control differently as a function of a driver's experience. The shifts in attention control following increased anxiety showed not only similarities but also differences between the two groups, despite the performance decrements being of similar kind. Specifically, the experienced drivers showed an increased number of shorter fixations towards the speedometer with increased anxiety, while the inexperienced group showed an increased number of shorter fixations towards other cars. Other shifts in visual attention due to increased anxiety were similar across groups: participants showed fewer fixations toward the lane and rearview mirrors. Although these fixations tended to be longer, overall fixation duration decreased.

In line with the Integrated Model (Allsop and Gray, 2014; Briggs et al., 2011a; Nibbeling et al., 2012; Janelle et al., 1999), the attentional shifting towards threat-related stimuli (other cars – potential collisions) among inexperienced drivers may be interpreted as a consequence of a larger role of the stimulus-driven attentional system and reduction of the goal-directed system (i.e. shift of attention from more task-relevant to more threatening stimuli). This result partly confirms our hypothesis that inexperienced drivers would be more affected by anxiety manipulation than their experienced counterparts. Nibbeling, Oudejans and Daanen (Nibbeling et al., 2012) observed that in a dart throwing task both dart players (experts) and undergraduate students (inexperienced group) showed reduced final fixation durations on bulls-eye under high-stress conditions (i.e., high on a climbing wall) compared to the low-stress conditions (i.e., low on the climbing wall); however, only the students showed a decrease in performance accuracy as their the final fixation duration dropped from over a second to below 650 ms, which was apparently no longer sufficient to maintain performance. Thus, novice performers were less capable to allocate sufficient attentional resources to minimize anxiety decrements on performance. Furthermore, Williams and Elliot (Williams and Elliott, 1999) showed that expert and novice karate practitioners, in response to videotaped offensive sequences under low-stress (i.e., in a neutral performance

instructions) and high-stress (i.e., in competition and ego stressors instructions) conditions, had a better performance accuracy with increased anxiety; however, only novices increased the number of fixations towards opponents' hands and legs (i.e., sources of potential threat) while the expert group maintained their attentional allocation to the central area of the opponent (Williams and Elliott, 1999).

According to the integrated model of anxiety and perceptual motor performance (Nieuwenhuys and Oudejans, 2012, 2017) (see also ACT; 1,2,19,30), increased anxiety requires extra processing resources required to inhibit attention shifts toward threat/distractors. Accordingly, the performance decrements along with a shift towards fixation cars (i.e., potential threat) among the less experienced performers' appear a consequence of insufficient mental resources to resist interference from threatening distractors (Allsop and Gray, 2014; Janelle et al., 1999; Eysenck et al., 2007b). There is ample evidence to show that direction of gaze determines the direction of heading in the environment (Land, 2006; Land and Hayhoe, 2001). Accordingly, increased looking at other cars likely results in a stronger inclination to steer toward other cars. By contrast, the performance decrement following the increase in anxiety among experienced drivers was associated by increased monitoring of the speedometer to adhere to speed instructions, rather than attention shift toward threatening stimuli. It seems that with increased anxiety, experienced drivers' attention was shifted toward task relevant information, arguably in an attempt to (more) consciously monitor speed. This may reflect a stronger contribution of the goal-directed system with increased anxiety. Apparently, neither the changes in attention of the experienced drivers, nor those of the inexperienced drivers were fully effective in preventing the negative effects of anxiety as performance of both groups decreased with anxiety. (Nieuwenhuys and Oudejans, 2012, 2017) argue that skill-focused attention (i.e., explicitly monitoring own performances) may be a specific form of distraction for expert performers, as they no longer need this kind of attention (i.e., skilled performance is typically automatized). The increased number fixations toward the speedometer (i.e., to monitor speed) may reflect such (debilitative) skill-focused distraction. The short duration of these fixations might underline the inefficiency of this shift in goal-directed attention. Paradoxically, the enhanced monitoring of performance may have resulted in reduced performance because of an increased effort occurs for maintain performance level (Englert and Oudejans, 2014).

5. Limitations of the research

Four experienced and nine novice drivers were excluded from data analyses because they did not show increased anxiety score. It is not particularly clear why the stress manipulation did not inflict an increase in experienced anxiety in these participants. They did not report higher trait anxiety. Perhaps they were more familiarized with competitive environments and driving simulations (e.g., by playing racing video games in a competitive mode) and/or they were less compelled to perform well in the competition. Because it remained uncertain how these participants coped with the high-stress condition, it is inappropriate to use them as a control group, and hence, they were excluded from further analyses. However, this does raise the issue of the representativeness of the stress manipulations. Possibly, rather than introducing a competitive element, stress manipulations such as tailgating, speeding and aggressive driving in the simulation may result in more systematic increases in state anxiety. Such may also represent a clearer, unequivocal definition of threat-related information (and distinction from target-related information), allowing stronger tests of the nature of the attentional shifts predicted by the integrated model and ACT. Nonetheless, it is important to realize for future research that determination and interpretation of areas of interest for gaze will need to be task- and stressor-specific.

6. Conclusion

In sum, increased anxiety led to drops in performance for both inexperienced and experienced drivers. Yet, the underlying attentional mechanisms showed important differences, along with similarities. With anxiety inexperienced drivers showed an attentional shift from task-relevant to threat-related information (i.e., other cars), while experienced drivers shifted their attention more to task-relevant information (i.e., the speedometer), possibly in an attempt to increase conscious monitoring of performance. Thus, we may conclude that effects of anxiety on attentional control and performance are mediated by the level of expertise.

Conflicts of interest

None.

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