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Are happy drivers safer drivers? Evidence from hazard response times and eye tracking data

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Highlights

- When in a sad mood, drivers response to hazards is slowed.
- Visual search patterns were also negatively affected.
- Being in a happy mood, however, is not necessarily more safe.
- Hazard perception is influenced by mood and arousal.

Abstract

Previous research shows that negative emotions have a detrimental effect on cognitive processes in general and on driving safety in particular. However to date, there has been no empirical investigation of the impact that positive emotions might have on driving safety. This research examined the influence of mood on driving safety using hazard perception videos and an eye tracker. Participants' mood was manipulated (Sad, Neutral, Happy) after which they had to observe videos containing a number of potential hazards. Hazard response times and eye fixations were measured. The Sad mood affected drivers the most, with the longest response times and fixation durations. The effects of the Happy mood were less clear, suggesting that apart from emotional valence, emotional arousal should be considered. In addition, hazard response times differed as a function of hazard onset (i.e. unexpected or developing hazard) and type of hazard (i.e. human, car). The results are interpreted in terms of theories of positive emotions and psychological arousal.

Key terms: hazard perception, eye fixations, mood, driving safety

1 Introduction

Road accidents are still the most common cause of accidental death in developed countries, claiming over 40000 lives every year (Plainis, Murray and Pallikaris 2006). Research suggests that attention, or rather lack of it, is an underlying dynamic of road accidents (Klauer *et al.* 2006). Attention can vary as a function of experience whereby an experienced driver's ability to divide their attention between car controls and the environment in enhanced (Crundall *et al.* 2012; Underwood 2007; Underwood *et al.* 2003). Poor road conditions or visibility, as well as various distractors which require additional attention, can result in attentional overload and a failure to react safely and promptly (Konstantopoulos 2009; Plainis, Murray and Pallikaris 2006). Thus, numerous factors can influence driver attention, but one of the most neglected factors is related to a drivers' emotional state and the interaction between emotion and attention.

Stress, worry, anger and even excitement can have as much negative impact on attention as other factors, such as talking on a mobile phone or driving under the influence of alcohol or drugs (Dahlen *et al.* 2005; Underwood *et al.* 1999). For example, Underwood *et al.* (1999) found that drivers who reported anger while driving, also reported near accidents in the same journeys. Deffenbacher *et al.* (2001) found that drivers with high anger trait characteristics also showed greater situational anger and adopted more aggressive and risky driving styles.

Research investigating the emotion-attention interaction in the driving environment has mostly focused on drivers' trait characteristics - emotions caused by traffic and their effect on driver behaviour. For instance, Abdu, Shinar and Meiran (2012) report that angry drivers more often run yellow traffic lights, and Arnett, Offer and Fine (1997) found a direct relationship between trait anger and exceeding the speed limit. Although, to date, the vast majority of research has been devoted to the investigation of negative emotions on road safety, the effect that positive emotions may have on driving has also been studied. For example, De Looze, Kuijt-Evers and Van Dieën (2003) point out the importance of positive emotions gained from seating comfort in connection with driver's tiredness and loss of attention. Regarding drivers' mood, Cackowski and Nasar (2003) found that scenes with vegetation have more positive effect on mood compared to scenes with man-made structures. They also found that roadside vegetation can help to reduce stress and facilitate recovery from attentional fatigue.

Emotion is the primary source of psychological arousal (Thayer 1978). Therefore, it is logical to examine the influence of different emotional states on attentional abilities. Many researchers agree that positive mood has a positive effect on human attention and cognition (Isen 2001; Fredrickson 2001; Carver 2003). Fredrickson (2001) developed the Broaden-and-Build Theory proposing that positive emotions expand the perceptual and attentional scope along with mental representations and actions. Fredrickson and Branigan (2005) further built on this work differentiating between a low-activation state of contentment and a high activation state of amusement. They concluded that attentional scope was enhanced regardless of low or high activation state.

Carver (2003) also investigated the attention-emotion relationship and suggested the existence of a so-called ‘regulatory system’ which maintains a state without emotions. If negative emotions are experienced, the regulatory system puts in effort to return the emotions back to a neutral level. This action is costly as the regulatory system strives to achieve a result as soon as possible and consequently ignores activities that are not directly related to this particular action. Although the regulatory system prefers neither positive nor negative emotions and it treats any deviation from the neutral state as an ‘error’, Carver (2003) argues that positive is not as costly as negative affect. He suggests that this is because of the different ways in which positive and negative affect are arrived at. People do not put effort into arriving at a negative affect, as this is unnatural and unwanted. Therefore, under negative affect energy is required to fix the problem. In contrast, to reach positive affect, people dedicate some effort; when the goal is reached, there is no need for further effort and the available resources could be directed elsewhere. Carver (2003) called this phenomenon the ‘effect of coasting’. Consequently, the available energy and attention, since the system is in an idle state, can be used to look for new sources of danger. For example, in the driving context, extra attention could be used to identify imminent hazards in order to be able to deal with them safely and promptly.

One method of measuring attention is to assess how well hazards are spotted during driving. Vlakveld (2014) defines hazard perception as the awareness of dangerous situations in the road and traffic environment. Importantly, hazard perception refers to potential hazards that may or may not materialise. Hazard perception tests are widely used not only for assessment of novice drivers, but also in a broad range of psychological research, and have been found to be a reliable measure of safety behaviour (Mckenna and Horswill 1999; Grayson and Sexton 2002; Chapman, Underwood and Roberts 2002; Pradhan *et al.* 2009; Vlakveld 2014). Traditionally, hazard perception tests are recorded as short videos taken from the driver's perspective. Participants are required to watch these videos and imagine they are the driver of the car. Each video contains at least one potential hazard, which later develops into a critical situation requiring immediate action. The potential hazards vary and can include pedestrians stepping into the road, cars merging unexpectedly, cars braking suddenly or too rapidly, or road users violating traffic rules. As soon as a participant identifies a hazard, he/she has to press a button. Hazard perception skills are evaluated by computing the hazard response time (HRT) measured from the first indication of the hazard until the button is pressed (Chapman and Underwood 1998).

The perception of a hazard is reliant on the participant's gaze behaviour. Research employing the measurement of eye-movements generally agrees that viewers mostly fixate on the most informative parts of the scenes and these fixations are significantly longer compared to the less informative parts, such as the background (Chapman and Underwood 1998; Chapman, Underwood and Roberts 2002; Rayner 1998). Visual fixation is defined as keeping the visual gaze on a particular position while processing visual information (Velichkovsky *et al.* 2003). Fixation times also change as a function of increased visual scene complexity (i.e. more cars, road signs, road furniture) in terms of shorter fixation durations and increased number of saccades (Chapman and Underwood 1998; Robinson *et al.* 1972). With regards to emotion, research is mostly consistent: content with an emotional connotation attracts visual focus leaving little or no attention left for peripheral stimulus processing (Kensinger 2009). However, Wadlinger and Isaacowitz (2006) found that positive priming results in more fixations on peripheral stimuli, therefore widening the visual field. Moreover, Kaspar *et al.* (2013) examined not only the impact of the emotional content on viewing behaviours, but also the effect of participants' particular emotional state. Longer fixations and shorter saccades were observed when primed with negative images. Priming with the positive images resulted in shorter saccades, but no longer fixations. Thus, eye movement data can help not only understand general observational patterns and the effect of emotion, but also gives deeper insight into the processes behind it and the resulting behaviours.

Previous research shows that fixation durations are directly related to driving safety. For example, Underwood (2007) states that when a hazard occurs it captures the drivers' attention. This increased focusing is characterised by longer eye fixations at the time of hazard detection. This attentional capture is natural and appropriate, as the driver needs time to assess the situation and decide if there is potential for a collision. The problem here is appropriate timing, as too long an attentional focus can result in missing secondary hazards, due to rapid changes in a traffic situation. On the other hand, shorter attentional capture was related to better attentional refocusing towards possible additional hazards. This evidence was derived by comparing search patterns of learner and experienced drivers. Experienced drivers were less vulnerable to the effect of attentional capture; long fixations, instead, were associated with less experience and, therefore, higher likelihood of involvement in an accident (Chapman and Underwood 1998; Huestegge *et al.* 2010; Konstantopoulos 2009). Moreover Konstantopoulos (2009) examined drivers' scene processing time in low visibility conditions. They found that driving at night and in rain resulted in longer fixation durations as compared to day time driving. They concluded that driving in poor visibility conditions is more difficult and more dangerous partly due to longer processing times.

To summarise, previous research has focussed mainly on the impact of negative emotion on driver safety and no empirical manipulations of positive emotion have been reported. Given that the preferred state of humans is to remain in a mildly positive state, and the current marketing by vehicle manufacturers to associate driving with enjoyment, we aimed to identify possible differences in attentional abilities and performance under both positive and negative emotions in the driving environment. In the present experiment, the mood of the participants was manipulated to be positive, neutral or sad. The aim was to discover if mood differentially affected participant's ability to detect and respond to hazards. Based on previous findings regarding the interaction between mood and attention (Carver 2003), it was hypothesised that a linear relationship would be found with the sad condition resulting in the longest response times and fixation durations, whilst the happy condition would result in the shortest response times and fixation durations.

2 Method

2.1 Participants

Twenty participants were recruited for the study (9 females and 11 males, age range 27-52 years). The inclusion criteria were driving experience of more than five years, more than 5000 miles driven each year, and normal or corrected to normal vision.

2.2 Material/Apparatus

All music was recorded in MP3 format and played using HP laptop with Beats audio. The music was played through Beats by Dr. Dre Executive Over-Ear Headphones (MH6W2ZM-A). The videos were developed using an in-car camera (1080P full HD, high-definition, light source frequency 50Hz/60Hz) with the visual angle of the recording 130 degrees. The videos and the pictures were presented on a 32" TV screen. Eye tracking data were recorded using SMI eye tracking glasses ; 30 Hz binocular resolution, and 60 degrees horizontal and 46 degrees vertical field of view

2.3 Mood induction and assessment

A meta-analysis by Westermann *et al.* (1996) showed that combined mood induction methods were more effective than using single mood induction techniques. Therefore in the present study music was used in combination with corresponding pictures. To induce a happy mood, Bach's Brandenberg Concerto No. 3, Allegro (played by Hubert Laws) was used; for the neutral mood Chopin's Waltz No. 11 in G flat and Chopin's Waltz No. 12 in F minor played by Alexander Brailowsky were used, and for the sad mood induction Prokofiev's Alexander Nevsky: Russia under the Mongolian Yoke, played by London Symphony Orchestra, was used. Bach and Prokofiev's music has been used in previous research (Rowe, Hirsh and Anderson 2007) showing significant differences in the mood valence rating scores. However, Rowe and colleagues played Prokofiev's music at half speed. In the present study it was decided not to do so, because music tempo can significantly affect drivers' performance (Brodsky 2001). The neutral mood was induced by playing Chopin Waltzes No. 12 in F minor and No. 11 in G flat, as used in previous studies (Green *et al.* 2003; Wood, Saltzberg and Goldsamt 1990). The happy music was combined with coloured pictures containing images of weddings, running horses, smiling children and puppies. The neutral music was combined with images of peaceful nature, and the sad music was combined with images of natural disasters (Westermann *et al.* 1996).

It should be noted that the present study does not distinguish between mood and emotion. Mood is usually a more prolonged psychological state compared to emotion. Emotion instead is a short, easily affected and rapidly changeable state of mind (Fredrickson 2001). Previous research states that the effect of emotional induction lasts for approximately 5-15 minutes (Bouhuys, Bloem and Groothuis 1995; Västfjäll 2002; Green *et al.* 2003). This feature has been taken into account in the present study, as a repeated measures design was employed. The length of each condition was approximately 15 minutes, which included: 5-6 minutes video clips, 5 minutes answering a questionnaire and 3-4 minutes eye tracker readjustment. This time was enough for previous emotions to fade and made it easier to change the participant's emotional state in a short period of time, to measure and compare the reaction times in different emotional states.

The presentation of the three musical fragments for the different mood induction (neutral, happy, and sad) was counterbalanced. Before the experiment started and after listening to each fragment, participants were asked to rate their mood using the Brief Mood Introspection Scale (BMIS). The BMIS contains 16 mood adjectives and a 10-point subscale for overall mood assessment (Mayer and Gaschke 1988). In previous research, the BMIS has discriminated reliably between mood conditions (Mead *et al.* 2011; Larsen and Ketelaar 1991). In the present study, a Pleasant-Unpleasant subscale of the BMIS was used

(Muraven, Tice and Baumeister 1998; Larsen and Ketelaar 1991), as the intention was to assess only the mood valence without a detailed assessment of every adjective. Participants then proceeded to view the hazard perception videos. The music was not played during the viewing for two reasons; first, the aim of the present study was not to investigate the effects that music per se might have on driving safety, and second, to increase the power of the mood induction, it was decided to use mood corresponding pictures and it would have been difficult to achieve this whilst participants were viewing the hazard perception videos.

2.4 Hazard perception videos

The recording camera was fixed on the inside of the windscreen of the vehicle to record the forward view. The videos were recorded during one month in all weather conditions and on all types of roads, except motorways. All videos were screened for potential hazards, and very busy and empty roads were excluded. Twenty seconds videos were then created and divided into those with and those without hazards. All the initial screenings were carried out by a professional driving instructor. The videos were evaluated against the following criteria for inclusion: 1) the image was of acceptable quality, 2) the hazard was not in temporal proximity to other potential traffic hazards (i.e. before and after each hazardous situation there was a conflict-free driving), 3) there was evidence of action taken by the ‘camera car’ to avoid a collision.

Three driving instructors then rated the hazards regarding the amount of danger they could pose via a three-point scale: very dangerous, dangerous, and not very dangerous. This assessment was guided by the UK driving instructor training programme. The videos containing the most dangerous situations were selected for the experiment, with minimal repetition of hazards. The videos that did not include hazards were randomly selected from those available. Ten videos with hazards and 15 baseline videos with no hazards were thus produced. The same videos were used for all conditions, only the order of presentation was changed. The no-hazard videos were different in all conditions. Each hazard had a starting point of development. These starting points were defined using Be-gaze software frame-by-frame technique from the moment when hazard started to develop. Two videos were excluded from the analysis (see section 3.2). Table 1 describes the remaining eight videos.

Table 1 Description of hazards and Hazard Onset Time (HOT)

Hazard	Description
1	A ball suddenly appears from the side of the road, and a child appears after the ball. The HOT is set from the time the ball appears.
2	A car has stopped on the left side of the road and then moves off in front of the participants' car. The HOT is set from the moment the car starts moving.
3	A motorbike suddenly appears from behind parked vehicles. The HOT is set from the moment of its appearance.
4	A car was moving in the right hand lane and then, after indicating, moves into the left lane. It then suddenly brakes and turns left into a side road. The HOT is set from the moment the car started moving into participant's lane.
5	The same situation as in video two, but a car was stopped on the right side. The HOT is set from the moment the car starts moving.
6	When travelling towards a green traffic light, a pedestrian steps out from the right and causes the participant to brake. The HOT is set from the moment the pedestrian lifts their leg.
7	On turning left at a green traffic light, a cyclist crosses the road on the red traffic lights without giving way. The HOT is set from the moment when the cyclist starts moving across the road.
8	A car ahead moves into the central refuge area from the right, stops to give way and then suddenly accelerates to cut in front of the participant's car. The HOT was set from the moment the merging car accelerates.

2.5 Procedure

After signing the consent form, participants were seated at a 70cm distance from the screen and asked to complete an initial mood assessment questionnaire (referred to as baseline mood) and given the opportunity to familiarise themselves with the hazard detection task. They were told to press the space bar on the keyboard in response to a hazard.

The eye tracker glasses were then calibrated using three point calibration. The calibration was checked after each condition, in total three times for each participant. The first mood induction music was then played, accompanied by the mood relevant pictures for a total of 7 minutes. Participants were asked to adjust the volume of the music using volume adjuster on the lap-top, so it was loud but not harmful or disturbing. Immediately following the end of the music and pictures, participants were required to watch 15 videos (10 with hazards and five without) and respond by pressing the space bar when they deemed a hazard to be present. As soon as they pressed the space bar (or the end of the video was reached) the next video automatically commenced. When the 15 videos had been played the participant was asked to complete a mood assessment questionnaire. After that, the same procedure was applied twice more for the remaining two mood induction conditions. The order of the three mood conditions was randomised across participants, and the whole experiment took approximately 40-45 minutes and participants were then debriefed and paid £5 for their time.

3 Results

Repeated measures analysis of variance were performed on the data, after checking for normality and homogeneity of variance. Where the assumption of sphericity was violated, the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity. Main and interaction effects are reported, along with post-hoc tests where appropriate. Bonferroni correction was used in all post-hoc tests.

3.1 Mood induction

Mean mood scores were calculated for each of the four conditions (three moods plus baseline). The data were normally distributed for the neutral (M=5.65, SD=2.23) and the baseline (M=5.8, SD=2.38) conditions. Data for the happy condition were left-skewed (M=6.55, SD=2.35) with one outlier scoring zero, and the data for the sad condition was right skewed (M=2.55, SD=2.37) with one outlier scoring 7. Multilevel analysis for repeated measures with four levels (baseline, happy, neutral and sad) was performed to accommodate the skewed data. The analysis showed that the type of music played in combination with pictures presented had a significant effect on the participants' mood F(3,57)=23.49, p<.001, η_p^2 = .41. Post hoc tests showed that the participants felt significantly more pleasant before the experiment (baseline) as well as in the happy and neutral conditions compared to the sad condition (p<.001). There were no significant differences between any other conditions (Figure 1).

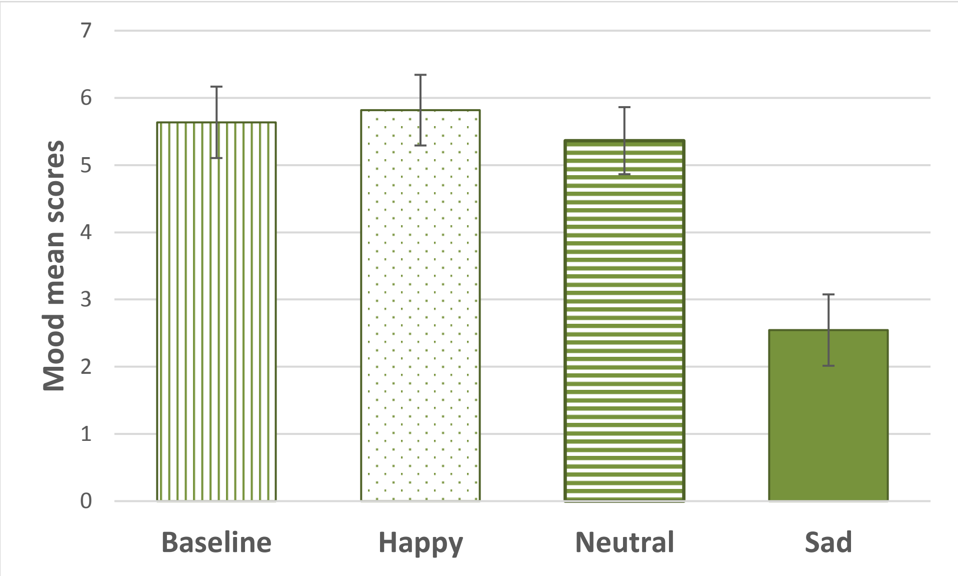

Figure 1 Mood mean scores from self-assessment questionnaire (error bars represent SE)

3.2 Hazard Response Times (HRT)

Two of the ten videos containing hazards were excluded from the analysis as more that 50% of the HRTs were either less than 200ms or exceeded 2000ms (Swensson 1972; Ratcliff 1993). Erroneous responses included late button presses and non-responses. The response times were calculated from the hazard onset time till the button press. A 3x8 repeated-measures ANOVA with three levels of Mood (neutral, happy and sad) and eight Videos was conducted. There was a significant main effect of Mood on HRT, F(2, 36) = 62.5, p < .01, η_p^2 = .78. Post hoc tests showed significant differences between all pairs (p < .05), with the sad condition producing the longest HRTs and the neutral condition the shortest, Figure 2.

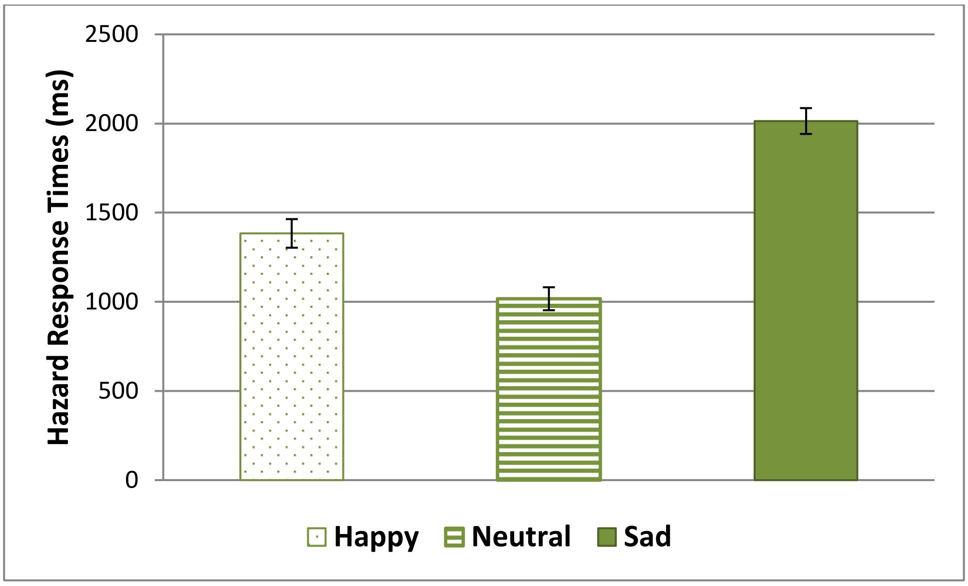

Figure 2 Hazard Response Times (ms) by Mood (error bars represent SE)

There also was a significant main effect of Video on HRTs, $F(4.27, 76.86) = 102.13$, $p < .01$, $\eta_p^2 = .85$ and post-hoc tests showed that the HRTs for videos 3, 5, 7 (means 824.23, 1063.96 and 1082ms) were significantly faster than the others (mean range 1342.41 – 3287.39ms, $p < .05$). Given that the mean HRT for video 4 was far in excess of 2 seconds (and thus considered as an erroneous response by Swensson (1972) and Ratcliff (1993)) further examination of those data were carried out. It was found that in this video the behaviour of the 'hazard vehicle' was ambiguous; however, as the response times were consistent across the participants, the video remained in the data analysis.

A significant Mood x Video interaction was also found, $F(6.86, 123.48) = 3.29$, $p < .01$, $\eta_p^2 = .15$. Pairwise comparisons showed that the sad condition affected the HRTs in all videos. Moreover, videos 1, 3, 6, 7 and 8 were differentially affected by all three moods. Closer analysis of these videos showed that these videos featured vulnerable road users; video 1 contains a ball emerging from the side, which could be followed by children, video 3 contains a motorbike rapidly moving from behind a parked van, video 6 contains pedestrians stepping into the road and video 7 contains cyclists crossing the road. Only video 8 contained a car - however, this scenario was filmed on a dual carriageway with a central refuge area, where the car stopped and then proceeded. This double movement (from the side road to the central reservation and then further into the main road) could have caused a decision delay (Green 2013). These five videos were processed significantly longer in the sad condition as compared to the other conditions, and significantly longer in the happy condition as compared to the neutral condition (p < .05) (Figure 3).

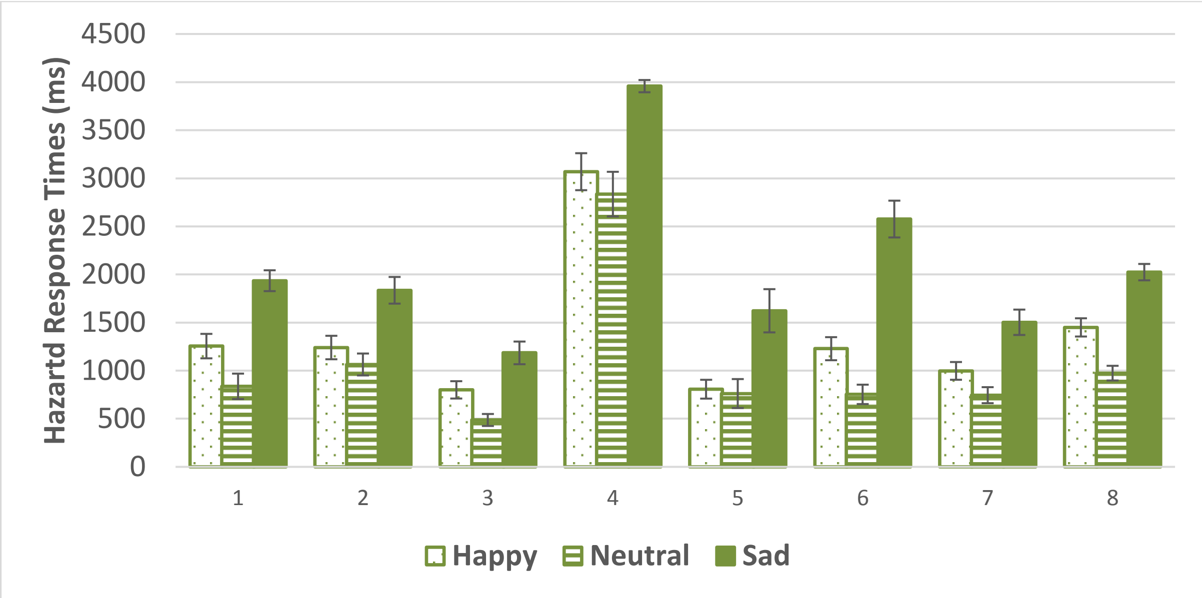

Figure 3 Mean HRTs (ms) in each video by mood (error bars represent SE)

3.3 Eye tracking data

The data from three participants were not recorded due to calibration difficulties. Fixation durations of eye movements were analysed using BeGaze software and data from videos that did not contain hazards were included in the analysis as a separate condition. For all eye tracker data analyses, factorial repeated measures design was used, with three levels of Mood (neutral, happy and sad), and two types of Video (with and without hazards).

There was a significant main effect of Mood on fixation duration, $F(1.26, 20.14) = 11.28$, $p < .05$, $\eta_p^2 = .41$. Within-subject contrasts showed that participants fixated longer in the sad condition compared to the happy $F(1, 16) = 12.73$, $p < .05$, $\eta_p^2 = .44$ and neutral conditions F(1, 16) = 11.54, $p < .05$, $\eta_p^2 = .41$. There was no significant difference between the happy and neutral conditions. A significant main effect of Video was found, F(1,16) = 14.36, $p < .05$, $\eta_p^2 = .47$ with significantly longer fixations in the videos not containing hazards. No significant Mood by Video interaction was found (Figure 4).

Figure 4 Fixation Duration (ms) by Mood and Video (with and without hazards) (error bars represent SE)

4 Discussion

The aim of the study was to investigate the relationship between mood and attention, via hazard perception. It was hypothesised that a happy mood would result in the shortest HRT and fixation durations, compared to the neutral and sad moods. Additionally, it was hypothesised that the sad mood would result in the longest HRT and fixation durations, as compared to the neutral and happy moods.

Carver (2003) proposed that individuals in a happy mood have additional attention resources available, which could be used to deal with problems or be attentive to sources of danger. The results of this study are partially in line with this model. Participants in the happy and neutral conditions reacted significantly faster to hazards as compared to the sad condition. This could be due to the different visual search patterns - according to Carver

(2003) being in a sad mood does not encourage exploration of the environment; instead attentional resources are devoted to diminishing the cause of the sadness by producing a type of 'tunnel vision'.

However, the responses to the hazards were significantly faster in the neutral condition as compared to the sad and happy conditions. Therefore, the responses did not increase in a linear manner, as hypothesised. Instead, the HRTs showed an inverted U shape. This does not fully support Carver's 'coasting' (gradual slowing caused by inertia, with no effort) prediction. Coasting would result in faster reactions in the happy condition as compared to the neutral condition. In addition, Carver proposed that 'the system' likes neither a sad nor happy state; instead, it prefers a neutral state. In this case, the neutral condition (as the preferred one) and the happy condition (as the coasting condition) should have an advantage over the sad condition, but no difference between themselves, as they both represent an energy saving positive affect. However, HRTs were significantly different between the neutral and happy conditions and it is still not clear if and how the two positive conditions can significantly differ with regards to hazard response times.

This leads to the conclusion that, apart from emotional valence, there is another aspect that could influence performance - emotional arousal. A happy mood is considered to be a high-arousal physiological state (Masmoudi, Dai and Naceur 2012; Jefferies *et al.* 2008; Gilet and Jallais 2011). The level of arousal is an important characteristic of performance, first explained by Yerkes and Dodson (1908). The Yerkes-Dodson law states that arousal improves performance, but only up to a certain level. When arousal exceeds this level, performance deteriorates, creating an inverted U - shaped function, with the lowest performance at the edges. The hazard response data supports this model, the sad condition has the lowest arousal and the happy the highest, which caused performance deterioration in these conditions.

The questionnaire data in this study supports this model. There was no significant difference between the baseline, happy and neutral moods. Moreover, the participants reported feeling more positive at the beginning (mean 5.8 on a 10-point scale) as compared to the Neutral condition (mean 5.65). Although these numbers did not differ significantly, they represent a tendency in predicted direction, indicating that people are generally in a positive mood, as proposed by Diener and Diener (1996), which suggests that, by default, we feel a little bit better than neutral for the vast majority of time. Therefore, the neutral and happy conditions might be both considered as positive conditions. However, it is still not clear how the two positive conditions can significantly differ with regards to hazard response times. According to the Broaden-and-Build theory (Fredrickson and Branigan 2005) low (i.e. contentment) and high (i.e. excitement) emotional states broaden attentional scope by inducing different urges. For example, joy creates an urge to play, and contentment integrates the present life circumstances into new attitudes and representations. These different emotions are products of different arousal and result in different thought-action tendencies. The present research shows that the Yerkes–Dodson law can be applied to the emotion-attention relationship in the driving environment. Consequently, these concepts allow us to refer to the neutral condition as a positive mood condition with low arousal and the happy condition as a positive mood condition with high arousal, although the present study did not find a significant difference between the happy and neutral conditions, which could be due to the questionnaire being not sensitive to arousal measurements. Therefore, when one conducts research investigating the impact of emotions on attention and performance, the level of arousal should also be taken into account.

Alternatively Kahneman (1973) suggests that attentional changes in high and low arousal depend on available cues. He states that in a low arousal condition there are many cues available to solve a problem. When arousal increases, the number of available cues diminishes. The more cues available, the longer the time required for processing and selecting the relevant ones, resulting in longer processing times in a low arousal state. However, a high arousal state implies more selectivity between relevant stimuli and concentration on fewer of them; this results in missing some of the important cues that could speed up the problem-solving process. Therefore, the most superior processing is observed in the midpoint of the arousal scale, resulting in an inverted U-shape. If access to the cues is restricted due to arousal, the limited available cues will slow down the processing times. In other words, positive affect with low arousal is the most optimal state of mind for driving. In this condition, drivers can spot hazards significantly earlier as compared to both negative affect and positive affect with high arousal. In other words, drivers' emotional involvement does not benefit drivers' attention and road safety, instead as less emotional involvement as possible encourages safe driving. This statement is also supported by Brodsky and Slor (2013) who found that elevated mood resulted in severely deficient driving behaviour.

The analysis also revealed that a number of videos were associated with significantly shorter HRTs. These videos contained 'unexpected hazards', which needed less time to be processed, compared to 'developing hazards'. Unexpected hazards are those that appear suddenly, for example, a motorcycle moving out from behind a parked van. On the other hand, developing hazards are potential hazards that can be seen for a while and could or could not develop into real hazards. For example, a car waiting to merge into the main road and giving way to oncoming traffic suddenly cuts in front of the participants car, see Figure 5. The reduced length of time required to process unexpected hazards implies a more automatic process as compared to developing hazards. The latter possibly required assessment and handling (Shiffrin and Schneider 1977). This leads to the conclusion that automatic and controlled processes are both affected by a participant's emotional state.

Figure 5: Examples of developing and unexpected hazards

A significant interaction between Mood and Videos was found, with some videos showing faster responses. There is no definitive explanation for these results; however it could be speculatively assumed that the shorter responses were due to the presence of vulnerable road users in the videos. Yet, it equally could be that the 'time frame' (time need for a hazard to develop into a critical event) was shorter for these videos. However, the sad mood resulted in longer response times to all the videos. This suggests that the introvert character of the sad mood prioritises dealing with personal emotions, therefore prolonging the reactions in this condition (Pêcher, Lemercier and Cellier 2009). As for the eye tracking data, the findings are in line with previous research with the longest fixations in the sad condition (Kaspar *et al.* 2013). Driving safety research claims that fixation durations depend on driver experience with novice drivers fixating longer (Chapman and Underwood 1998), as well as road type with roads richer in road furniture generating shorter fixations (Chapman and Underwood 1998; Robinson *et al.* 1972) and driving conditions with low visibility resulting in longer fixations (Konstantopoulos 2009). These studies relate longer fixations to longer cognitive processing time and failure to refocus attention (Underwood *et al.* 2003). Furthermore, Huestegge *et al.* (2010) claim that these differences are due to faster processing among the experienced drivers. From the present study it can be concluded that the sad mood produces somehow similar outcomes. Sad drivers appear to need more time to switch their attention to different objects or they need more time for information processing.

Hazard response times, using computer-based tests, measuring the time from a hazard appearance till a button press, have been associated with road safety (Chou and Chuang 2013). Well skilled drivers, with good ability of predicting the road ahead, detected more hazards and were quicker in responding to hazard detection tasks. The current study presents both oculomotor data and the computer-based data collection, thus providing evidence that HRTs could be related to the longer processing times as indicated by the fixation durations. However, the present research did not find a significant difference between fixation durations in the happy and neutral conditions, but did find a significant difference in the response latencies.

Another aspect that has been related to longer fixations is a reduced ability to refocus attention. For example, Mack and Rock (1998) referred to 'inattentional blindness' as a failure to recognise unexpected stimuli due to attention being focused on other aspects of the visual field. The present research brings combined evidence for both of these statements; longer eye fixations are mirrored in the longer HRTs. Both these factors are caused by reduced ability to switch attentional focus (Konstantopoulos 2009). We found longer fixations in the sad condition accompanied by longer hazard response times, providing evidence that the reduced ability to refocus attention results in response delay. We also found longer fixations in videos without hazards, which simply could be due to the fact that the videos with hazards were interrupted by a button press after a hazard was detected. Videos without hazards, instead, required higher efforts to search for detect hazards and, as a consequence, longer fixation durations. Nevertheless, positive conditions did not show the same effect. The reason for this is not clear- it could be that there was not enough power to pinpoint the differences in eye fixations, or that positive affect can influence only response latencies but not fixation durations. However, to be able to conclude with confidence which factor is the most influential, (attentional refocusing or prolonged processing time) one would need to manipulate attentional refocusing explicitly. For now it can be only taken as a preliminary result and a suggestion for further research.

4.1 Conclusions and further research

The fact that the sad condition had a significantly stronger influence on response times leads to the conclusion that negative emotions have potentially greater power over human reactions as compared to positive emotions or a neutral state of mind. These findings are in line with the literature; Fredrickson (2001) comments that negative emotions are more important for human survival, and Carver (2003) states that the 'system' that deals with normalising negative affect is highly costly for other functions as it puts all the effort and attention to solve the particular problem, and there is little spare capacity for anything else. However, not all positive emotions lead to 'coasting' and minor 'system' involvement in regulatory processes. Simply dividing emotions and mood into positive and negative affect is not sufficient. Emotional arousal can act in a similar way to negative emotions, forcing the system to make an effort towards emotional normalisation.

The longer HRTs in the sad condition are also mirrored in the longer eye fixation times. Both these indicators are considered to be signs of more extensive processing resulting in a higher likelihood of accidents and near misses. In driving safety research, the time taken to identify hazards and manually respond to them corresponds to a safety margin available to a driver (Chapman and Underwood 1998; Miltenburg and Kuiken 1990). Thus, it can be concluded that longer fixations and longer HRTs resemble a reduced safety margin, and as a consequence higher accident involvement probability.

This leads to the conclusion that neither a sad mood nor high arousal benefits driving safety. Instead, the best state of mind is a positive mood without high arousal. However, it is still not clear whether driving safety is affected by different levels of arousal under negative mood conditions. To clarify this, there is a need to manipulate negative mood experimentally, differentiating between high and low arousals. This study presents a step towards identifying the contribution of emotional valence to driving safety. Further research needs to identify the possible role of emotional arousal and its interaction with emotional valence as factors contributing to hazard perception in driving safety.

The current findings contribute to the understanding of emotional involvement in driving safety. This knowledge can be used in the development of compensatory mechanisms of in-car intelligent technologies responsible for maintenance of inattentiveness caused by certain states of driver's mood.

5 References

Abdu, R., D. Shinar and N. Meiran. 2012. Situational (state) anger and driving. *Transportation research part F: traffic psychology and behaviour,* **15**(5), pp.575-580.

Arnett, J. J., D. Offer and M. A. Fine. 1997. Reckless driving in adolescence:'State'and 'trait'factors. *Accident Analysis & Prevention,* **29**(1), pp.57-63.

Bouhuys, A. L., G. M. Bloem and T. G. Groothuis. 1995. Induction of depressed and elated mood by music influences the perception of facial emotional expressions in healthy subjects. *Journal of affective disorders,* **33**(4), pp.215-226.

Brodsky, W. 2001. The effects of music tempo on simulated driving performance and vehicular control. *Transportation Research Part F: Traffic Psychology and Behaviour,* **4**(4), pp.219-241.

Cackowski, J. M. and J. L. Nasar. 2003. The restorative effects of roadside vegetation implications for automobile driver anger and frustration. *Environment and Behavior,* **35**(6), pp.736-751.

Carver, C. 2003. Pleasure as a sign you can attend to something else: Placing positive feelings within a general model of affect. *Cognition & Emotion,* **17**(2), pp.241-261.

Chapman, P., G. Underwood and K. Roberts. 2002. Visual search patterns in trained and untrained novice drivers. *Transportation Research Part F: Traffic Psychology and Behaviour,* **5**(2), pp.157-167.

Chapman, P. R. and G. Underwood. 1998. Visual search of driving situations: Danger and experience. *PERCEPTION-LONDON-,* **27**, pp.951-964.

Chou, W.-S. and P.-C. Chuang. 2013. Design of Drivers' Hazard Perception Context Test. *In: Proceedings of the Eastern Asia Society for Transportation Studies*.

Crundall, D., P. Chapman, S. Trawley, L. Collins, E. Van Loon, B. Andrews and G. Underwood. 2012. Some hazards are more attractive than others: Drivers of varying experience respond differently to different types of hazard. *Accident Analysis & Prevention,* **45**(0), pp.600-609.

Dahlen, E. R., R. C. Martin, K. Ragan and M. M. Kuhlman. 2005. Driving anger, sensation seeking, impulsiveness, and boredom proneness in the prediction of unsafe driving. *Accident Analysis & Prevention,* **37**(2), pp.341-348.

De Looze, M. P., L. F. Kuijt-Evers and J. Van Dieën. 2003. Sitting comfort and discomfort and the relationships with objective measures. *Ergonomics,* **46**(10), pp.985-997.

Deffenbacher, J. L., R. S. Lynch, E. R. Oetting and D. A. Yingling. 2001. Driving anger: correlates and a test of state-trait theory. *Personality and Individual Differences,* **31**(8), pp.1321-1331.

Diener, E. and C. Diener. 1996. Most people are happy. *Psychological science,* **7**(3), pp.181-185.

Fredrickson, B. L. 2001. The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions. *American psychologist,* **56**(3), p218.

Fredrickson, B. L. and C. Branigan. 2005. Positive emotions broaden the scope of attention and thought-action repertoires. *Cognition & emotion,* **19**(3), pp.313-332.

Gilet, A.-L. and C. Jallais. 2011. Valence, arousal and word associations. *Cognition and Emotion,* **25**(4), pp.740-746.

Grayson, G. and B. Sexton. 2002. The development of hazard perception testing. *TRL REPORT 558*.

Green, J. D., C. Sedikides, J. A. Saltzberg, J. V. Wood and L. a. B. Forzano. 2003. Happy mood decreases self-focused attention. *British Journal of Social Psychology,* **42**(1), pp.147-157.

Green, M. 2013. *Visual Expert* [online]. [Accessed 16/06/2015]. Available from: http://www.visualexpert.com/Resources/reactiontime.html

Huestegge, L., E.-M. Skottke, S. Anders, J. Müsseler and G. Debus. 2010. The development of hazard perception: Dissociation of visual orientation and hazard processing. *Transportation research part F: traffic psychology and behaviour,* **13**(1), pp.1-8.

Isen, A. M. 2001. An influence of positive affect on decision making in complex situations: Theoretical issues with practical implications. *Journal of consumer psychology,* **11**(2), pp.75-85.

Jefferies, L. N., D. Smilek, E. Eich and J. T. Enns. 2008. Emotional valence and arousal interact in attentional control. *Psychological Science,* **19**(3), pp.290-295.

Kahneman, D. 1973. *Attention and effort.* Citeseer.

Kaspar, K., T.-M. Hloucal, J. Kriz, S. Canzler, R. R. Gameiro, V. Krapp and P. König. 2013. Emotions' impact on viewing behavior under natural conditions. *PloS one,* **8**(1), pe52737.

Kensinger, E. A. 2009. Remembering the details: Effects of emotion. *Emotion review,* **1**(2), pp.99-113.

Klauer, S. G., T. A. Dingus, V. L. Neale, J. D. Sudweeks and D. J. Ramsey. 2006. *The impact of driver inattention on near-crash/crash risk: An analysis using the 100-car naturalistic driving study data*.

Konstantopoulos, P. 2009. *Investigating drivers' visual search strategies: Towards an efficient training intervention*. thesis, University of Nottingham.

Larsen, R. J. and T. Ketelaar. 1991. Personality and susceptibility to positive and negative emotional states. *Journal of personality and social psychology,* **61**(1), p132.

Mack, A. and I. Rock. 1998. *Inattentional blindness.* MIT press Cambridge, MA.

Masmoudi, S., D. Y. Dai and A. Naceur. 2012. *Attention, Representation, and Human Performance: Integration of Cognition, Emotion, and Motivation.* Psychology Press.

Mayer, J. D. and Y. N. Gaschke. 1988. The experience and meta-experience of mood. *Journal of personality and social psychology,* **55**(1), p102.

Mckenna, F. P. and M. Horswill. 1999. Hazard perception and its relevance for driver licensing. *IATSS research,* **23**(HS-042 879).

Mead, N. L., R. F. Baumeister, T. F. Stillman, C. D. Rawn and K. D. Vohs. 2011. Social exclusion causes people to spend and consume strategically in the service of affiliation. *Journal of Consumer Research,* **37**(5), pp.902-919.

Miltenburg, P. and M. J. Kuiken. 1990. *The effect of driving experience on visual search strategies: Results of a laboratory experiment.* Verkeerskundig Studiecentrum, Rijksuniversiteit Groningen.

Muraven, M., D. M. Tice and R. F. Baumeister. 1998. Self-control as a limited resource: Regulatory depletion patterns. *Journal of personality and social psychology,* **74**(3), p774.

Pêcher, C., C. Lemercier and J.-M. Cellier. 2009. Emotions drive attention: Effects on driver's behaviour. *Safety Science,* **47**(9), pp.1254-1259.

Plainis, S., I. Murray and I. Pallikaris. 2006. Road traffic casualties: understanding the night-time death toll. *Injury Prevention,* **12**(2), pp.125-138.

Pradhan, A. K., A. Pollatsek, M. Knodler and D. L. Fisher. 2009. Can younger drivers be trained to scan for information that will reduce their risk in roadway traffic scenarios that are hard to identify as hazardous? *Ergonomics,* **52**(6), pp.657-673.

Ratcliff, R. 1993. Methods for dealing with reaction time outliers. *Psychological bulletin,* **114**(3), p510.

Rayner, K. 1998. Eye movements in reading and information processing: 20 years of research. *Psychological bulletin,* **124**(3), p372.

Robinson, G. H., D. J. Erickson, G. L. Thurston and R. L. Clark. 1972. Visual search by automobile drivers. *Human Factors: The Journal of the Human Factors and Ergonomics Society,* **14**(4), pp.315-323.

Rowe, G., J. B. Hirsh and A. K. Anderson. 2007. Positive affect increases the breadth of attentional selection. *Proceedings of the National Academy of Sciences,* **104**(1), pp.383-388.

Shiffrin, R. M. and W. Schneider. 1977. Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory. *Psychological review,* **84**(2), p127.

Swensson, R. G. 1972. The elusive tradeoff: Speed vs accuracy in visual discrimination tasks. *Perception & Psychophysics,* **12**(1), pp.16 - 32.

Thayer, R. E. 1978. Toward a psychological theory of multidimensional activation (arousal). *Motivation and Emotion,* **2**(1), pp.1-34.

Underwood, G. 2007. Visual attention and the transition from novice to advanced driver. *Ergonomics,* **50**(8), pp.1235-1249.

Underwood, G., P. Chapman, Z. Berger and D. Crundall. 2003. Driving experience, attentional focusing, and the recall of recently inspected events. *Transportation Research Part F: Traffic Psychology and Behaviour,* **6**(4), pp.289-304.

Underwood, G., P. Chapman, S. Wright and D. Crundall. 1999. Anger while driving. *Transportation Research Part F: Traffic Psychology and Behaviour,* **2**(1), pp.55-68.

Västfjäll, D. 2002. Emotion induction through music: A review of the musical mood induction procedure. *Musicae Scientiae,* **5**(1 suppl), pp.173-211.

Velichkovsky, B. M., A. Rothert, D. Miniotas, S. M. Dornhofer, M. Joos and S. Pannasch. 2003. Visual fixations as a rapid indicator of hazard perception. *NATO SCIENCE SERIES SUB SERIES I LIFE AND BEHAVIOURAL SCIENCES,* **355**, pp.313-322.

Vlakveld, W. P. 2014. A comparative study of two desktop hazard perception tasks suitable for mass testing in which scores are not based on response latencies. *Transportation research part F: traffic psychology and behaviour,* **22**, pp.218-231.

Wadlinger, H. A. and D. M. Isaacowitz. 2006. Positive mood broadens visual attention to positive stimuli. *Motivation and Emotion,* **30**(1), pp.87-99.

Westermann, R., K. Spies, G. Stahl and F. W. Hesse. 1996. Westermann, R., Spies, K., Stahl, GK, & Hesse, FW (1996). Relative effective¬ ness and vali-dity of mood induction procedures: A meta-analysis. European Journal of Social Psychology, 26, 557-580. *European Journal of Social Psychology,* (26), pp.557-580.

Wood, J. V., J. A. Saltzberg and L. A. Goldsamt. 1990. Does affect induce self-focused attention? *Journal of personality and social psychology,* **58**(5), p899.

Yerkes, R. M. and J. D. Dodson. 1908. The relation of strength of stimulus to rapidity of habit-formation. *Journal of comparative neurology and psychology,* **18**(5), pp.459-482.