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A cross-cultural comparison of where drivers choose to look when viewing driving scenes

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ABSTRACT

A substantial proportion of road accidents occur as a result of drivers having poor or insufficient visual search strategies. However, the majority of research into drivers visual search comes from high income Western countries where roads are relatively safe, with less being known about the visual search of drivers from non-western, low and middle income countries with much higher crash rates. This is despite the fact that cross-cultural studies have shown differences in visual search outside of driving between Western and Eastern individuals. The current study aimed to see whether these differences were present in driving by asking UK and Malaysian drivers to select where they would look when viewing images of roads from the perspective of a driver. Results showed that all drivers selected a similar number of focal objects, however there was a difference in the type of background information drivers chose to attend to, with Malaysian drivers selecting more task irrelevant information at the expense of task relevant information. Results suggest that there are cultural differences in what drivers choose to attend to which may contribute to the increased crash rate amongst drivers from low and middle income countries.

1. Introduction

Understanding where drivers look when driving is essential for road safety as a large proportion of all collisions are caused by drivers not looking in the right place at the right time (Lee, 2008). As such, a great deal of research has been conducted to investigate where drivers look. As one might expect, research into drivers' visual search has shown that typically drivers look at the road straight ahead (the focus of expansion; FOE) and to the right and left of this point (Chapman & Underwood, 1998; Crundall & Underwood, 1998; Mourant & Rockwell, 1972) as well as looking at task relevant objects (Luoma, 1988).

Drivers' visual search has been found to vary as a function of driving experience. Individuals with more driving experience tend to increase their spread of search on more complex roadways in order to take in information at a wider angle away from the focus of expansion, whereas novice drivers tend to mostly fixate on the road straight ahead (Alberti et al., 2014; Konstantopoulos et al., 2010; Robbins & Chapman, 2019; Underwood et al., 2002). This is despite the fact that scanning a wider angle of the roadway can be seen as essential for safe driving as hazardous events do not always occur in the centre of the visual field (Mills, 2005). Less experienced drivers also often fail to fixate on relevant areas of the roadway where hazardous events may occur (Borowsky et al., 2010; Pradhan et al., 2005) and may fixate on currently occurring hazards for too long at the expense of scanning the roadway for new emerging hazards (Chapman & Underwood, 1998). These insufficient visual search strategies of novice drivers may explain their overrepresentation in

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crash statistics (McCartt et al., 2009).

An explanation for these differences in visual search between experienced and novice drivers is that both groups hold different mental models and have different levels of knowledge about where to look as a result of their experience (Underwood et al., 2002). As driving experience increases, so does knowledge about where to look when driving. For example, when gaining experience of driving along complex dual carriageways, a driver will start to learn that they need to not only look at the road ahead, but also to the left and right of this point in order to take in all relevant information. As this knowledge increases drivers begin to improve their visual search.

Differences in visual search as a result of experience have also been observed when drivers are asked to select which regions of the roadway they would attend to, with novice drivers consistently failing to prioritise key regions such as rear-view mirrors and side roads (Konstantopoulos & Crundall, 2008). This suggests that experience can impact visual search not just in an automated manner in which a learnt mental model implicitly impacts visual search, but also under active control when drivers are engaging in decision making. As such, choosing where to look whilst driving can be influenced by both automated processes, as well as active controlled evaluation of a visual scene and decision making (Maldonado et al., 2020; Trick & Enns, 2009).

Whilst these findings are useful in describing the differences in visual search across driver groups, and in providing a potential explanation for the increased crash risk amongst novice drivers, most existing studies of drivers' search have been conducted with participants from high-income, western countries where crash rates are relatively low. Yet the majority of road deaths occur in in low (13%) and middle (80%) income countries, with only 7% occurring in high-income countries (World Health Organization, 2018). The narrow focus of research on western (high-income country) participants is particularly problematic because attempts to generalise these findings are based on the assumption that visual search processes are universal across all cultural and ethnic backgrounds. However, cross-cultural comparisons have shown that when viewing a visual scene Westerners typically attend to individual salient focal objects, whereas Eastern viewers attend more to background and contextual objects and view a visual scene in a more global manner (Nisbett & Masuda, 2003). These differences have been observed in object recognition tasks (Masuda & Nisbett, 2001), eye tracking studies (Chua et al., 2005; Goh et al., 2009), and change blindness tasks (Masuda & Nisbett, 2006). If these characteristic cross-cultural differences in visual search extend to driving scenarios, they could have important implications for what is processed within the visual scene and, consequently, road safety.

As previously discussed in the context of driving, a wider spread of search is often associated with greater safety on the road. This is because the driver is attending to a greater amount of driving relevant information. However, if a driver has a more global visual search which also involves fixating on background features (as seen amongst Eastern participants in previous studies), this could lead to attention being allocated to task irrelevant objects, which can be detrimental in driving situations. On the other hand, whilst fixating on focal objects (as seen by Western participants in cross-cultural studies) has benefits when driving, focusing too much on focal objects may lead to a narrowing of attention which could lead to drivers failing to attend to task relevant information which is occurring away from the salient focal object.

Visual search, including spread of search, has previously been found to differ between drivers from different countries. Research by Di Stasi et al. (2020) compared visual search between drivers from four European countries. They found differences in gaze entropy between Spanish and Italian drivers when viewing hazard perception images, with Italian drivers having a wider dispersion of fixations. The authors suggested that this difference in visual search was due to different driving styles in the countries, and the national traffic climate, further suggesting that experience and exposure to a driving environment can lead to changes in visual search.

Despite past cultural comparisons between European drivers, relatively little research has compared visual attention in driving situations between drivers from Western and Eastern countries. A study which compared British and Malaysian drivers on a hazard perception test found that fixation durations were significantly shorter when viewing hazard perception clips of Malaysian roads than British roads, particularly amongst Malaysian drivers (Lim, Sheppard, & Crundall, 2013). This might suggest that highly hazardous road environments require drivers to allocate their attention across the whole scene with a series of brief fixations, and that Malaysians in particular may have visual search strategies adapted to these scenarios. However, this study did not analyse which particular aspects of the scene drivers attended to, so it remains unclear whether the Malaysians attended more to background features. Work by Shinohara et al. (2017) compared fixations to focal and background objects between US and Japanese drivers during a driving simulator study, and found no cultural differences. However, there were many background elements in this study which were much more salient than focal objects. Therefore findings may not be an accurate representation the way these groups typically attend to focal and background objects.

The current study was a preliminary investigation into whether the cross-cultural differences in visual search observed in non-driving contexts also occur within driving contexts. Data was collected online (due to restrictions on in-person testing at the time of data collection) with the aim of exploring whether drivers from one Eastern country (Malaysia) and one Western country (the UK) would choose to look at different areas of the roadway when driving. Drivers were presented with images of roadways taken from the UK and Malaysia and were tasked with selecting where they would look if they were driving along those roads.

It was predicted that Malaysians would have wider horizontal and vertical distributions of visual search (reflected by clicks on regions further from the FOE) than UK participants. In relation to road type, it was predicted that both horizontal and vertical spread of search would be greater for Malaysian than UK roads due to higher levels of visual clutter in Asian scenes (Miyamoto et al., 2006). It was also hypothesised that Malaysian drivers would select more background regions of the roadway than UK drivers, who would select more focal regions. As background regions could be either relevant or irrelevant to the driving task, in order to understand possible safety implications of differing search strategies, comparisons were made between the groups for task relevant and task irrelevant non-focal regions.

2. Method

2.1. Design

The study utilised a mixed design where the between groups variable was the nationality of drivers (UK or Malaysian). Within groups, all participants were exposed to the same 20 images from a variety of road types across two countries (UK and Malaysia). The dependent variables were the locations participants selected in each image, these were later used to calculate the distribution of clicks in the horizontal and vertical axes and the proportion of clicks on focal or contextual objects and background regions.

2.2. Participants

Participants were recruited through online advertisements within the University of Nottingham UK and Malaysia campuses, as well as advertisements on social media. Initially, 281 drivers started the study, however 94 participants were removed from the final sample. The reasons for these removals were; exiting the study before starting the main experimental trials (n = 70), completing less than 50% of the experimental trials (n = 13), failure to complete the task correctly (all clicks in one area in quick succession) (n = 2), and not being British or Malaysian, or having lived outside of their home country for over half of their lifetime (n = 9). The final sample consisted of 187 drivers, 92 from the UK (21 male, 71 female), and 95 from Malaysia (33 male, 62 female). inferential statistics can be found in Table 1.

This research received full ethical approval from the University of Nottingham School of Psychology (ref: S1261).

2.3. Stimuli

Stimuli were created by extracting still images from videos filmed across a series of roads in the East Midlands in the UK, and the Klang Valley in Malaysia, from the perspective of the driver (see Fig. 1 for examples). Based on the available stimuli, images from five different road types were used to ensure that the stimulus set reflected some of the natural variability in driving scenarios within the two countries. These were motorways, rural roads, suburban housing areas, city centre, and outer city roads. Images were taken at points where the video was not blurry, and no major obstructions were present in the frame.

2.4. Procedure

Before starting the experimental task, participants were presented with a short questionnaire covering general demographics, driving experience, and time spent living and driving in other countries.

For the experimental task, participants were presented with an image of a road and were instructed to "Select six locations that you would choose to look at if you were driving along this road." These locations were selected by a mouse click which then generated a small blue circle on the image (see Fig. 2). In cases where participants could not identify six locations, they were informed that they should select the same region more than once. The software enabled participants to change their choices if they wished.

There was no time limit and participants could spend as long as they needed selecting their six locations. In total there were 20 trials with participants seeing two images from each of the five road types in both countries. The order of the trials was randomised.

Prior to starting the task, participants were also given a practice image which was not included in the main stimuli set, in order to become familiar with the procedure of clicking on the appropriate regions. The experiment was completed by participants on their own devices through Qualtrics, and took approximately 20 min on average to complete.

Table 1
Demographic data.

Nationality	UK (n = 92)		Malaysian (n = 95)		*t*-test		
	Range	*M* (SD)	*Range*	*M* (SD)	*t*	*p*	*d*
Age	18–65	26.52 (10.15)	18–43	23.11 (4.39)	2.94	0.004	0.44
Driving experience (years)	0.67–44.83	7.35 (8.66)	0.92–20	5.16 (4.31)	2.13	0.035	0.33
Annual mileage*	30–40000	5631.69 (6079.16)	1.24–31068.50	4872.13 (5883.26)	0.84	0.403	0.13
Hours driven per week	0–30	4.79 (4.57)	0–35	6.82 (5.16)	2.79	0.006	0.41

*Malaysian participants reported their annual distance driven in KM which was then converted to miles.

Fig. 1. Examples of images used for suburban housing areas in the UK (left) and Malaysia (right).

Fig. 2. Example of participant making response to an image of a UK motorway. Blue circles represent the location of each individual click. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2.5. Analysis

To explore the distribution of the regions selected across the horizontal and vertical axes, the standard deviation of the horizontal (x) and vertical (y) locations in pixels were calculated for the six clicks in each individual image. These were then averaged across each country, and for the total 20 images.

In order to compare the locations participants selected in the images, focal and background regions were defined. While focal regions were always relevant to the driving context, background regions could be either relevant or irrelevant to the task of driving; therefore the background regions were further subdivided into context relevant and irrelevant regions. Focal referred to any region or object within the driver's lane (the lane where the road was filmed from). This included lead vehicles, road markings, and the roadway itself. Context relevant referred to regions or objects outside of the current lane which were still applicable to the driving task. This included other vehicles, the roadway and road markings, signage, traffic lights, and pedestrians. Finally, context irrelevant referred to any other regions or objects which were not relevant to the driving task. These included task irrelevant objects, buildings, trees, and general background space. For analysis purposes, the proportion of clicks in each of these regions was calculated. All data were analysed using SPSS version 27. Data used for these analyses are available at doi.org/10.17639/nott.7133.

3. Results

Independent samples t-tests found differences between UK and Malaysian participants in terms of their age, driving experience, and weekly driving hours (see Table 1). As such, bivariate correlations were used to see if these variables correlated with outcome variables. There were significant correlations between age and vertical distribution of search ($r = -0.24$, $p = .001$) and the proportion of focal regions selected ($r = -0.24$, $p = .001$) as well as correlations between experience and vertical distribution of search ($r = -0.21$, $p = .004$) and the proportion of focal regions selected ($r = -0.22$, $p = .002$). There were no significant correlations between weekly driving hours and any outcome variables.

As there was a highly significant correlation between age and driving experience ($r = 0.92$, $p < .001$), and both correlated with the same outcome variables, experience (but not age) was controlled for as a covariate in all analyses.

For both UK and Malaysian participants, there was an almost equal number of participants who completed the task on a computer or a mobile phone. The average screen size (in number of pixels) did not differ between UK and Malaysian participants ($t(185) = 0.68$, $p = .51$, $d = 0.01$). There were correlations between screen size and the proportion of context relevant regions selected ($r = 0.42$, $p < .001$), the proportion of context irrelevant regions selected ($r = -0.33$, $p < .001$), and the distribution of clicks in the vertical axis ($r = -0.26$, $p < .001$). However these were similar across both nationalities therefore screen size was not controlled for in the remaining analyses.

3.1. Response time

The average response time across all trials was 16.60 s (SD = 8.48). A univariate analysis found that this was higher for Malaysian participants (M = 18.59, SD = 9.56) than UK participants (M = 14.62, SD = 6.83) ($F(1, 177) = 12.71$, MSE = 68.03, $p < .001$, $\eta_p^2 = 0.07$). This was underpinned by Malaysian participants taking longer between their first and final clicks (M = 13.37, SD = 8.51) than UK participants (M = 9.78 SD = 7.15) ($F(1, 177) = 13.53$, MSE = 58.46, $p < .001$, $\eta_p^2 = 0.07$). There were no differences between participant groups in the time between being first presented with the image and making their first selection ($F(1, 177) = 2.88$, MSE = 16.66, $p = .09$, $\eta_p^2 = 0.02$).

3.2. Distribution of regions selected

Heatmaps showed that the manner in which participants distributed their clicks across the images was similar to the distribution of visual search during driving in the real world (Crundall & Underwood, 1998), with the majority of clicks at the focus of expansion and spread across the horizontal axis, with additional clicks on specific objects (see Fig. 3 for an example).

Both the horizontal and vertical distribution of clicks were analysed using 2 (nationality) × 2 (road country) mixed ANCOVAs. For the horizontal distribution, there was no effect of nationality ($F(1, 179) = 1.09$, MSE = 7798.26, $p = .30$, $\eta_p^2 = 0.01$). However there was a main effect of road country ($F(1, 179) = 415.11$, MSE = 798.13, $p < .001$, $\eta_p^2 = 0.70$) such that distribution of clicks was wider in images of Malaysian roads (M = 320.96, SD = 61.98) than UK roads (M = 238.66, SD = 68.61). No significant interaction between nationality and road country was found ($F(1, 179) = 0.12$, MSE = 798.13, $p = .73$, $\eta_p^2 = 0.001$).

In the vertical axis there was a main effect of nationality ($F(1, 179) = 10.82$, MSE = 1698.06, $p = .001$, $\eta_p^2 = 0.06$) with Malaysian drivers showing a wider distribution (M = 96.16, SD = 37.01) than UK drivers (M = 80.05, SD = 27.28). There was also a main effect of road country ($F(1, 179) = 71.15$, MSE = 466.92, $p < .001$, $\eta_p^2 = 0.28$) such that distribution of clicks was wider on Malaysian roads (M = 100.81, SD = 34.03) than UK roads (M = 76.10, SD = 34.39).

Finally, there was a significant interaction between nationality and road country ($F(1, 179) = 6.06$, MSE = 466.92, $p = 0.02$, $\eta_p^2 = 0.03$). Post hoc univariate analyses comparing participants groups across the two road countries revealed that on UK roads, Malaysian participants had a wider distribution of clicks compared to UK participants ($F(1, 179) = 16.85$, MSE = 1057.29, $p < .001$, $\eta_p^2 = 0.09$). Whilst there was no difference between participant groups when viewing images of Malaysian roads ($F(1, 179) = 3.06$, MSE = 1107.69, $p = .08$, $\eta_p^2 = 0.02$) (see Fig. 4).

3.3. Focal and contextual regions

For participants who did not change any of their click locations, it was possible to determine the location of their first region selected. 49.39% of first clicks were on focal regions, whilst 50.61% were on background regions. When considering the task relevance of background regions, 36.25% of first clicks were in context relevant regions, and 14.37% in context irrelevant regions. Univariate analyses revealed no differences between UK and Malaysian drivers on the proportion of first clicks in focal regions ($F(1, 172) = 3.12$, MSE = 592.86, $p = .08$, $\eta_p^2 = 0.02$), context relevant regions ($F(1, 172) = 2.77$, MSE = 396.89, $p = .10$, $\eta_p^2 = 0.02$), or context irrelevant regions ($F(1, 172) = 0.48$, MSE = 199.65, $p = .49$, η_p^2 less than 0.00).

For all regions selected, a univariate analysis revealed that participants collectively selected more background regions (M = 71.61%, SD = 10.35) than focal regions (M = 28.39%, SD = 10.35) ($F(1, 180) = 368.84$, MSE = 204.47, $p < .001$, $\eta_p^2 = 0.67$). The same was also true for participants from each nationality individually. For UK participants, 72.95% (SD = 9.78) of clicks were in background regions and 27.05% (SD = 9.78) were in focal regions ($F(1, 85) = 240.11$, MSE = 179.30, $p < .001$, $\eta_p^2 = 0.74$). For Malaysian participants 70.39% (SD = 10.74) of clicks were in background regions and 29.61% (SD = 10.74) were in focal regions ($F(1, 93) = 116.48$, MSE = 228.50, $p < .001$, $\eta_p^2 = 0.56$).

In order to further examine attention to background/contextual aspects of the scenes, a 2 (nationality) × 2 (context relevance)

Fig. 3. Distribution of clicks across all participants on a Malaysian city centre road.

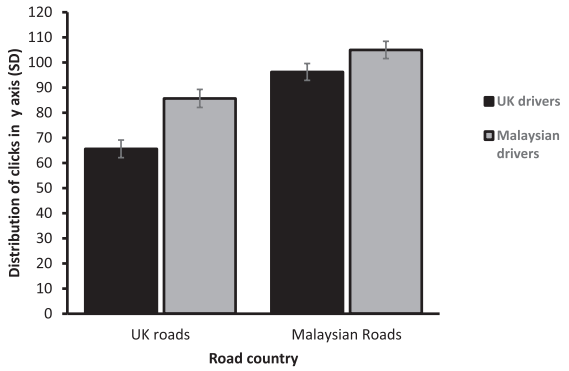

Fig. 4. Distribution of clicks in the y axis as a function of nationality and road country. Error bars represent SEM.

mixed ANOVA was conducted to explore distribution of attention to contextual regions. Results showed a significant effect of region type ($F(1, 179) = 97.41$, $MSE = 264.20$, $p < .001$, $\eta_p^2 = 0.35$) such that participants made an overall higher proportion of clicks on context relevant regions ($M = 46.68\%$, $SD = 10.79$) than context irrelevant regions ($M = 24.97\%$, $SD = 14.36$).

There was no main effect of nationality ($F(1, 179) = 1.51$, $MSE = 50.97$, $p = .22$, $\eta_p^2 = 0.01$) but there was a two way interaction between nationality and region type ($F(1, 179) = 8.10$, $MSE = 263.20$, $p = .01$, $\eta_p^2 = 0.04$). As can be seen in Fig. 5 (context relevant and context irrelevant), UK participants selected more context relevant regions than Malaysian participants $F(1, 179) = 7.87$, $MSE = 108.88$, $p < .001$, $\eta_p^2 = 0.07$) and Malaysian participants selected marginally more context irrelevant regions than UK participants ($F(1, 179) = 3.41$, $MSE = 206.30$, $p = .07$, $\eta_p^2 = 0.02$). Univariate analyses comparing the proportion of clicks in context relevant vs context irrelevant regions for UK and Malaysian participants also revealed significant differences for both groups (with a higher proportion of clicks on relevant areas for both nationalities), but with a much larger effect size amongst UK participants ($F(1, 85) = 82.45$, $MSE = 248.23$, $p < .001$, $\eta_p^2 = 0.49$) than Malaysian participants ($F(1, 93) = 18.88$, $MSE = 280.55$, $p < .001$, $\eta_p^2 = 0.17$).

In order to further our understanding of which aspects of the scene differed for the UK and Malaysian participants, the percentage of clicks falling onto different kinds of objects in each region was calculated. Fig. 6 shows a breakdown of the objects contained within each region. As previously described (in section 2.5), focal regions consisted of the drivers' current lane and any vehicles within this lane, context relevant regions contained any objects relevant to the driving task including the roadway itself, and context irrelevant regions contained non-driving related background objects.

Although there is a trend to suggest differences in several regions, univariate analyses found an effect of nationality on the proportion of other vehicles selected ($F(1, 179) = 11.96$, $MSE = 63.29$, $p = .001$, $\eta_p^2 = 0.06$) (UK > Malaysians), and a marginally significant difference in the proportion of general background space selected (background areas not containing a specific object) ($F(1, 179) = 6.81$, $MSE = 81.42$, $p = .01$, $\eta_p^2 = 0.04$) (Malaysians > UK) (adjusted $\alpha = 0.008$ when corrected for multiple comparisons).

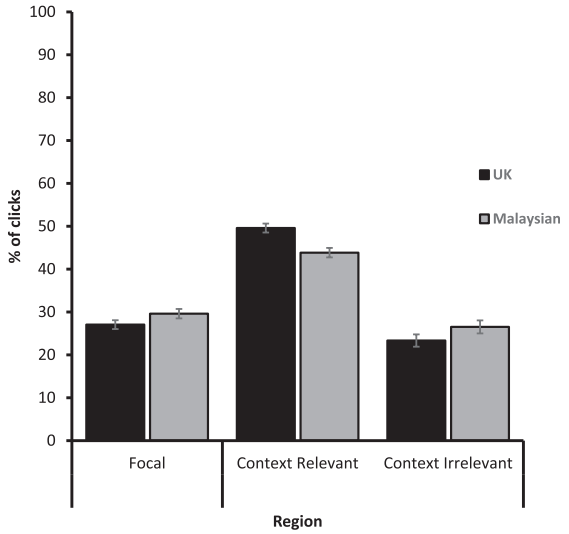

Fig. 5. The average proportion of clicks made by participants from both countries in each of the three regions. Error bars represent SEM.

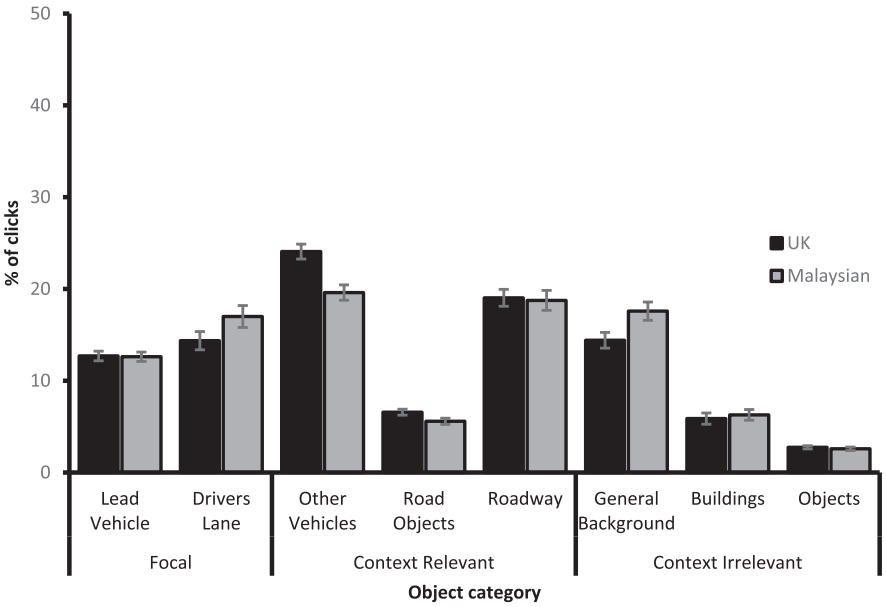

Fig. 6. The average proportion of clicks made by participants from both countries across the different object categories. Error bars represent SEM.

4. Discussion

This study aimed to investigate whether drivers from Malaysia (an Eastern, middle income country with a high road crash death rate) would choose to look at different areas of the roadway compared to drivers from the UK (a Western, high income country with a much lower crash rate). It found differences in how drivers from the two countries choose to look at non-focal objects.

4.1. Distribution of regions selected

The distribution of the regions selected was higher in both the horizontal and vertical axes when viewing Malaysian roads. Along the vertical axis, there was also a cross cultural difference with Malaysians having a wider distribution of search.

The increased distribution of clicks in both axes for Malaysian roads could suggest that these roads contained more information and required drivers to consider points further away from the centre of the image (the FOE). This would be expected as Malaysian roads contained much more visual clutter than UK roads, and a lot more objects to be attended to. However, it should be noted that differences in the vertical axis may also partly be due to incidental differences in the images themselves as the camera position for some UK images was lower, meaning that the FOE was at a lower point on the vertical axis, and a narrower distribution of search was sufficient to select relevant regions. Therefore, caution is required when interpreting any differences between Malaysian and UK images.

The lack of a difference between UK and Malaysian drivers in their search of the horizontal axis does not support our hypotheses. This might suggest that drivers from the two countries search the roadway similarly when driving; however, this could also be explained by the fact that participants were required to select six regions in each image, which may have artificially increased their spread by forcing them to consider regions that they would not have chosen if they could make fewer than 6 selections. Additionally, the manner in which stimuli were presented could have contributed to the lack of cultural differences. Many previous studies have shown experiential differences in spread of search using more immersive methods such as multiple screens, driving simulators, and real world driving (see Robbins & Chapman, 2019 for review), and attention is often measured using eye tracking (experience differences have also been found across less immersive methodologies when using eye tracking (Robbins & Chapman, 2019 for review)). In the current study, stimuli were static images covering a small visual angle compared to that of real world driving; therefore all information was presented in front of participants. It should be noted that previous cross cultural studies, outside of the domain of driving, have utilised images as stimuli (i.e. Masuda & Nisbett, 2001: Chua et al., 2005) but these studies did not investigate spread of search across the horizontal or vertical axes. However, the cross-cultural comparison from Di Stasi et al. (2020) found cultural differences between Italian and Spanish drivers in their dispersion of visual search when tasked with viewing static images in a hazard perception task. This further suggests that exposure to a particular environment or road environment can lead to differences in drivers' spread of search.

Within the vertical axis, Malaysians had a wider spread of search than UK participants, and spread of search was wider for Malaysian than UK stimuli. This might be consistent with the notion that Malaysian scenes have more information in the vertical axis - and that Malaysian participants have a spread of search that is adapted to this type of environment. However, a wider spread of search could actually be indicative of a poorer visual search strategy which involves looking at context irrelevant information. The wider search amongst Malaysian drivers suggests that they were selecting regions which may not be relevant such as higher points in the sky

or on buildings. Within driving, Mourant and Rockwell (1972) and Crundall et al. (2003) have suggested that scanning a wider angle in the vertical axis is not a suitable type of visual search, and has been observed amongst less experienced drivers (albeit only in Western participants).

Finally, in relation to the interaction between nationality and road country there were no cultural differences in spread of search when viewing images of Malaysian roads. However, when viewing UK roads Malaysian drivers showed a wider spread of search than UK drivers. With drivers from both countries showing a wide spread of search when viewing Malaysian roads (with no cultural differences) it may be the case that the stimuli led participants to select regions further from the FOE due to the higher visual complexity of Malaysian roads, the increased number of objects to attend to, and the novelty of these objects compared to those present on UK roads. When viewing the UK roads, which may not require a wide spread of search, UK drivers had a narrower spread of search, whereas Malaysian drivers still maintained a wide spread of search. This could suggest that exposure to a Malaysian driving environment has led to Malaysian drivers naturally having a wider spread of search, even when this may not be necessary on less complex roads. However, this interaction may also be underpinned by the different positions of the focus of expansion between UK and Malaysian images as previously discussed.

4.2. Focal and contextual regions

Contrary to our hypotheses, there was no difference in the proportion of focal regions selected between UK and Malaysian drivers. This finding is seemingly inconsistent with some cross-cultural studies (e.g. Masuda & Nisbett, 2001; Chua et al., 2005) which have shown that Westerners are more likely to attend to focal objects than Eastern participants, although in these cross-cultural studies all participants allocate at least some attention to the focal object. This might suggest that when driving, task-specific attentional requirements may overcome natural tendencies in visual search. When driving it is necessary to focus on the roadway ahead in order to maintain safe driving, and consistent with this, the majority of fixations are typically at the road straight ahead, towards the focus of expansion (Mourant & Rockwell, 1972). Therefore, it is perhaps unsurprising that a similar proportion of fixations to focal objects occurred across cultures.

Similarly, the majority of first clicks across both UK and Malaysians participants were on focal objects compared to context relevant or irrelevant background objects. Again this is likely due to the fact that all drivers initially have to fixate on focal objects before then spreading their search to other areas of the visual scene. This is similar to past cross-cultural studies in which Western and Eastern observers initially attend to focal objects, before cultural differences emerge after initially fixating on salient focal objects (Chua et al., 2005).

The fact that all drivers selected a larger number of background regions than focal regions also appears contradictory to our hypothesis, however this is explained by the fact that there were simply less focal objects to select (and participants were required to select six regions in total). As such non-focal regions were categorised as either context (driving task) relevant and context (driving task) irrelevant. Overall participants from both countries selected more context relevant regions that context irrelevant regions in the images. However, UK drivers selected more context relevant information than Malaysians. Additionally, there was a trend to suggest that Malaysians selected more context irrelevant regions than UK participants. This could suggest that Malaysian drivers attend slightly more to context irrelevant information at the expense of attending to context relevant information, which could lead to instances in which safety critical information is missed, subsequently leading to a collision on the road.

This difference is likely the result of the increased complexity of Malaysian roads, and the more global perceptual style found amongst Eastern participants in cross-cultural studies. As with the effect of driving experience, exposure to a particular environment can influence ones perceptual style. This has been demonstrated in cross-cultural studies in which exposure to an Eastern environment has been found to lead to Western participants adopting a more global style of visual search (Miyamoto et al., 2006). Similarly, when comparing drivers from European countries, Di Stasi et al. (2020) suggest that differences in visual search arose as a result of exposure to different driving environments, and the different visual and cognitive demands associated with these.

In the case of this study, exposure to the visually complex environments found in Malaysia may have led to a more global style of visual perception as previous studies have shown. This global style may make the Malaysian participants more prone to attend to background and task irrelevant objects, an effect which may still be present in driving situations. Additionally, drivers may choose to allocate some of their attention to seemingly task irrelevant information in order to obtain a more accurate representation of what is happening around them. In other words, for Malaysians these items may not be context-irrelevant as they form part of their holistic, global perception of the scene. Whilst this may reduce the amount of strictly context relevant information which can be attended to, it may give the drivers a perceived greater sense of situational awareness when driving.

As this study involved self-report without time constraints, it may be the case that participants are making controlled rational choices about where they would choose to look if they were driving along these roads. In their two-dimension approach to understanding attentional selection during driving Trick and Enns (2009) describe how attention may be guided by internal or external cues, as well as controlled or automatic processes. In the current study, participants are likely engaging in a controlled process in which they evaluate the images and decide where they would look if they were driving along these roads. Although this can involve exploration of the visual scene, controlled attention can also be influenced by mental models, as a drivers past experience will influence where they choose to allocate attention. Similarly, the dual model of risky decision making (Maldonado et al., 2020) suggests that decisions in driving can be rationally controlled (as is likely in the current study), or may be a result of affective-experiential automation.

4.3. Implication of these findings

Combined, these findings suggest that there may be differences in where drivers from Western and Eastern countries choose to look whilst driving. This is further evidence that the way drivers search scenes whilst driving may not be the same across countries, and one of the first to explore this by comparing Western and Eastern drivers.

Previous studies which show that driving experience, in the form of years driving, impacts where drivers choose to look (Crundall & Underwood, 1998; Konstantopoulos et al., 2010; Pradhan et al., 2005) suggest that these differences are due to the development of a more suitable mental model over time in which drivers learn where to look. In the case of cross-cultural differences, it may be the case that a mental model is developed based on their exposure to a particular type of visual environment.

The environmental affordances theory which suggests that cultural differences in visual attention arise as a result of differences in the visual environment itself (Cramer et al., 2016; Miyamoto et al., 2006) would support this interpretation. Outside of driving, developing a visual strategy in which a large amount of focal and contextual information is taken in may prove beneficial in a visually complex environment, such as the roads in Malaysia, in which there is a large amount of visual clutter. Having such a global perceptual style may also prove useful in driving if it results in the appropriate information being attended to. However, when a global style of visual perception leads to an individual attending to more contextual information which is not relevant to the task of driving (subsequently allocating less attention to task relevant information), this perceptual style could lead to an increase in crash risk. A priority of future research would be to determine the effects of any differences in perceptual style on crash propensity.

Whilst the current study only focused on comparing Malaysian drivers to drivers from the UK, the findings might well apply to drivers from other countries or regions in which crash rates are higher. Previous findings from cross-cultural studies are not limited to comparisons between Western and Eastern individuals; perceptual differences have also been found amongst participants from other low and middle income countries such as those in Africa and South America (Duan et al., 2016; Janse van Rensburg, 2017; Kastanakis & Voyer, 2014; Köster et al., 2018) further suggesting that visual perception can be influenced by experience and environment. If this similar pattern of visual search is used by drivers in other low and middle income countries, it could explain some part of the increased crash risk.

Although the effects observed in the current study are small and need to be replicated using other methods, a case could be made for the importance of visual attention as part of driver training in these countries. Previous studies with UK drivers have found that visual attention training can improve novice drivers visual search by making drivers aware of their insufficient visual search (Chapman, Underwood, & Roberts, 2002; Pradhan et al., 2011). Additionally, cross-cultural studies have shown that culturally dependent visual search strategies are not rigid, but can adapt as a result of exposure to new environments (Miyamoto et al., 2006; Cramer et al., 2016). Therefore, it is possible that driver training can encourage drivers to look in the correct areas when driving in order to attend to appropriate task relevant information.

Such a training regime should focus on making drivers aware of potentially insufficient visual search strategies (such as attending to irrelevant information) and encourage drivers to re-direct their attention to task relevant information in order to be safer on the roads. This may be particularly important in middle income countries with rapidly developing transport infrastructure and an increase in vehicle ownership. An intervention of this nature will not be a singular fix to the higher proportion of road deaths in low and middle income countries (larger factors such as infrastructure and vehicle standards, as well as other driver related factors such as risk taking and attitudes towards safety also must be addressed) but it could help to contribute to safer roads in low and middle income countries.

4.4. Limitations

Whilst these findings have implications for better understanding driver behaviour in Malaysia, and potentially other non-western low and middle income countries, they should be considered within their limitations. The first limitation of this study is the use of static images as stimuli. Driving is a dynamic task where the visual environment is changing constantly, however stimuli within the current study were static and available to be viewed for an unlimited amount of time by the participant. Additionally, as images were presented to participants via their own single screen, it was less possible to explore attention to peripheral stimuli.

Another limitation of the current study was the self-report nature of the task. When asking participants to indicate where they would look if they were driving along each road, it is possible that their responses could have been different to their visual search if it was measured more objectively as the current study seems to reveal conscious decisions made by drivers about where they would look, as opposed to investigating more automated processes which would be present in a real driving situation. Participants could have responded in a socially desirable manner or may simply not know where they would actually look. The requirement to choose six regions may also have led them to include regions they would not typically look at (possibly explaining the wider spread noticed amongst novice drivers). It would be beneficial in future research to ask participants directly about their strategy when approaching the task. Nevertheless, this methodology was still able to reveal differences between participants from the two countries implying differing knowledge/beliefs about where to look when driving. Future research should use eye tracking as a more objective measure of visual search when driving.

5. Conclusions

In conclusion, this study has shown that there may be cultural differences in how drivers visually search their environment whilst driving, with these differences possibly leading to an increased crash risk amongst Malaysian drivers. Although the current study focused on drivers from the UK and Malaysia, the findings may also be applicable to drivers from other non-western countries.

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CRediT authorship contribution statement

Karl A. Miller: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft. **Peter Chapman:** Conceptualization, Methodology, Resources, Writing - original draft, Supervision. **Elizabeth Sheppard:** Conceptualization, Methodology, Resources, Writing - original draft, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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