Thesis title: A cross-cultural comparison of drivers' visual attention

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Abstract

Driving is a highly visual task and understanding where drivers look is of paramount importance to road safety. Previous research into drivers' visual attention has shown the typical scan path of drivers, as well as differences in visual search across different levels of experience and different road types. Whilst these findings are helpful in understanding some causes for different fatality rates between novice and experienced drivers, the research has been carried out in Western countries where driving is relatively safe. As such, little is known about visual attention amongst drivers in developing countries, where the majority of the worlds' road-related fatalities occur. However, cross-cultural research has demonstrated differences in visual search between Westerners and East Asians such that East Asians have a more global and holistic style of attention. This thesis explores whether these differences are also present in driving tasks by comparing visual attention between drivers from the UK and Malaysia. A series of studies were conducted using different measures of attention including self-reported looking choices, change blindness, and eye tracking. Overall, the results suggest that several aspects of visual attention are universal between drivers and are not affected by culture, however when the demands of the driving task are reduced, and participants are free to allocate their attention in a controlled manner cross-cultural differences begin to emerge. It is believed that these differences come about as a result of prolonged exposure to visually cluttered environments such as the Malaysian roadway. As well as expanding the literature in both transport and cross-cultural psychology, these findings have several potential implications which could lead to improvements in road safety.

Publications associated with this research

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Chapter 1: Introduction

This thesis explores the potential cross-cultural differences in visual attention between drivers from two countries, the UK and Malaysia. Understanding drivers' visual attention is an important topic within the field of traffic and transport psychology as a large proportion of collisions on the road are thought to occur due to a driver failing to look in the right place at the right time. On the road, attention must be allocated across the environment towards various spaces and objects. For example a driver should attend to other vehicles, road signs, road markings, emerging hazards, and have a general awareness of their surroundings when driving.

Studies investigating where drivers look have been beneficial in explaining accidents (particularly in explaining differences between novice and experienced driver crash rates) as well as allowing for the development of training to improve drivers' visual search. However, this research has mostly been conducted in Western countries where driving is relatively safe, under the assumption that visual search is universal and will be similar across drivers from all countries. This is despite the fact that cross-cultural studies have shown differences in visual attention in non-driving contexts between people from Western and Eastern countries. In brief, it has been found that Westerners have a local or analytical perceptual style in which they predominantly attend to salient focal objects. In contrast, East Asians are said to have a more global and holistic style of attention and perception in which they attend to the background and contextual information as well as focal objects. These differences in perceptual style may arise as a result of social differences between cultures such as the way people view themselves and others within a society, or instead may be due to exposure to a particular type of perceptual and physical environment.

Currently these cross-cultural findings have only been explored in scene perception more broadly. However it may be the case that these cross-cultural differences are also present in driving tasks where visual attention is more imperative. If this is the case, there may be implications for road safety in both countries as well as driver training, and potentially the design of future vehicles. In addition, gaining a further insight into differences in drivers' visual attention will be useful in better understanding the role of cultural and environmental factors on visual search.

The current research explored these cross-cultural differences by examining visual attention amongst drivers from two countries with vastly different road crash rates. The UK, a high-income Western country with a fairly low number of road crashes when compared to other countries, and Malaysia a middle-income South East Asian country with a significantly higher crash rate.

This thesis has three overarching research questions:

1. What are the cross-cultural differences in widely used measures of visual search in driving, between drivers from the UK and Malaysia?
2. Do Malaysian drivers attend more to background information on the roads?
3. If there are cross-cultural differences, are these a result of cultural social differences (self-construal) or exposure to a particular environment?

These questions are investigated across a series of studies using a variety of different research methodologies including focus groups, online data collection, driving simulation and eye tracking. The structure of the thesis is as follows. First, in Chapter 2 the key literature related to drivers' visual attention and cross-cultural differences in visual attention is discussed, bringing together theories and findings from two areas of psychology. Alongside this, the current literature on cross-cultural differences in driver behaviour is reviewed.

This is followed by a series of focus groups presented in Chapter 3, in which Malaysian drivers discussed their experiences of driving in Malaysia including the appearance of the roadway and behaviour of other road users, unwritten rules of the road, and their initial thoughts on how they allocate their attention on the road.

Chapters 4 and 5 present online studies which were conducted using two different methodologies. The study described in Chapter 4 used a self-report method in which participants were asked to select where they would look if they were driving along a series of roads. In Chapter 5, two change blindness experiments explored if drivers were better able to detect changes occurring in focal or background regions across driving and non-driving tasks.

The final two experimental chapters describe two driving simulator studies in which drivers' eye movements were recorded whilst driving through a series of simulated environments. The study in Chapter 6 provided some initial insights into how drivers distribute their attention across a driving environment and different road types similar to past research on visual search amongst drivers from Western countries. The study presented in Chapter 7 investigated which objects drivers attend to across a series of driving tasks when either driving continuously, or stopped at junctions.

Finally, Chapter 8 summarises the findings from each of the studies in the context of the previous literature. This chapter also discusses the overall contributions to the scientific literature and further avenues for future research related to this thesis.

Chapter 2: Literature review

2.1 Introduction

This literature review will first discuss what is currently known about drivers' visual attention such as where drivers look and the factors that influence this. Particular emphasis will be placed on the role of experience and exposure to driving environments which leads to changes in drivers' visual attention.

Second, the cultural differences in visual attention between Westerners and Easterners in non-driving situations will be discussed. There will also be a discussion of the underlying mechanisms leading to these differences in attention, which will also focus on the role of experience and exposure to a particular environment leading to distinct patterns of visual attention.

Finally, this review will cover the existing literature on the cross-cultural differences in driver behaviour and visual attention between drivers from Western and Eastern countries, with a particular focus on Malaysian drivers.

2.2 Drivers' visual attention

Understanding where drivers look is essential for road safety research. This is due to the fact that a large proportion of collisions are caused by drivers not looking in the right place and the right time (Lee, 2008).

In the UK data from the Department for Transport (2023) suggests that 34% of all road traffic collisions in 2022 were due to drivers or riders failing to look properly. This failure to look properly has also been found to be a contributory factor in 22% of fatal accidents, and 30% of accidents in which someone is seriously injured.

Similarly, data from the Institute for Advanced Motorists (2011) estimates that a failure to look properly was a contributory factor in 35% of all road accidents, 20.5% of fatal accidents, and 29.3% of serious accidents between 2005 – 2009. These data also showed that a failure to look properly was the most frequently reported cause for accidents amongst car drivers across three different age groups (below 25, 26-69 and 70+), as well as being the most frequently reported cause of accidents for both male and female drivers.

These data show that visual attention is essential in driving and a lack of suitable visual attention can contribute to serious road traffic accidents. However, it should be noted that the data reported by the Department for Transport (2023) and the Institute for Advanced Motorists (2011) are based on STATS19 police reports. These reports are created by police when visiting the site of a road traffic accident that resulted in personal injury, or when an accident of this nature is reported to the police. Determining the factors which contribute to these accidents is therefore dependent on the knowledge and experience of the police officer visiting the scene of a crash, and statements from witnesses or those who survive the accident. As such, it is possible that the estimates of the times a driver failed to look properly may be inaccurate. In fact, it is likely that the number of accidents in which a driver fails to look properly may be higher as this may not always be self-reported by a driver, and there will be a number of accidents in which personal injury is not sustained so a STATS19 report will not be generated, or near-misses which are not reported to the police.

2.2.1 Methods used to investigate visual attention

Given the importance of understanding drivers' visual attention, several different methods have been used to investigate this. At the more subjective level, several studies have used self-report to gain an understanding into what drivers look at on the road. For example, Hughes and Cole (1986) asked 25 drivers to report what attracted their attention when driving along a route in the real world. Results revealed that drivers attended to objects relevant to the driving task, but also roadside objects such as advertisements. Using a self-report method can provide useful information on what drivers believe they attend to on the road, or what aspects of the road environment attract their attention. Whilst this type of methodology is easy to implement, it will be subject to reporting biases. These could be in the form of drivers reporting attending to where they think they should look whilst driving as opposed to where they actually looked, or not being aware of what information they looked at whilst driving and therefore not being able to report this accurately.

Another way to investigate drivers' visual attention is through computer-based tasks in which a driver must respond to particular stimuli. For example, drivers' attention may be assessed using a hazard perception task (e.g. Borowsky et al., 2010; Horswill, 2016). In these tasks, a participant must watch a video from the perspective of a driver and make a response when they notice an emerging hazard on the road. Participants accuracy and response times when detecting these hazards can be seen as an indicator of whether they were attending to relevant areas of the roadway whilst completing the task.

As well as hazard perception, drivers' attention has been investigated using cognitive tasks present throughout the psychological literature. One example, which will be used later in this thesis, is change blindness (Rensink et al., 1997; Simons & Rensink, 2005). In a change blindness task participants are presented with two images separated by a blank screen. The images are identical apart from one change, and the task of the participant is to respond once they identify this change. Change blindness has been used to explore attention across various domains, but it is particularly useful in exploring drivers' attention as driving involves navigating through a complex and ever-changing environment. Results from studies using this method have shown that it is possible for drivers to miss changes occurring in the environment even if they are highly salient (this is particularly prominent when changes are not directly related to the driving task itself) (Beanland et al., 2017; Galpin et al., 2009; Lee et al., 2007; Mueller & Trick, 2013; Velichkovsky et al., 2002; Zhao et al., 2014).

Although these methods have their benefits, in most cases, drivers' visual attention is measured by recording eye movements via the use of eye trackers. The use of eye tracking provides a more direct measure of where drivers are looking, and can often be recorded in more naturalistic settings such as whilst driving in the real world or in a driving simulator.

Eye tracking has been used as a method to investigate drivers' visual attention for the last 50 years, starting with studies in the 1970's which measured drivers' eye movements whilst driving on real roads (Mourant & Rockwell, 1970; Mourant & Rockwell, 1972). These studies were fairly small, however the method has become much more widely used within the psychology of driving in since the early 2000s (see Taylor et al. (2013) for a review) and is currently used to understand a wide variety of driver behaviours.

Broadly speaking, eye movements consist of two distinct categories, fixations and saccades (Land, 2009; Salvucci & Goldberg, 2000). Fixations are points of relative stability in which the eye is focused on a singular location, it is during these fixations that the majority of information is taken in and later processed (Carrasco, 2011; Just & Carpenter, 1976). Typically a fixation will last approximately 200-300ms, however this is dependent on the task, with longer fixations being associated with higher processing demands (Rayner, 1998; Rayner & Pollatsek, 1989). In contrast to fixations, saccades are rapid eye movements between fixations in which visual information is not taken in.

Although eye tracking is a widely used method to investigate drivers' visual attention, it is worth mentioning that simply observing a fixation on an object does not mean that the object is actually attended to (Underwood & Everatt, 1992), in fact there are many cases where drivers appear to be looking at an object or oncoming vehicle as shown by fixations, but are not actually attending to them (Brown, 2002; Herslund & Jørgensen, 2003; Langham et al., 2002). In these cases, a fixation is often not long enough to fully process the item the driver is fixating on, therefore suggesting that a simple measure of whether there was a fixation or not is not sufficient to determine whether an object has been attended to. Instead, the presence of a fixation should be combined with the fixation duration as a more useful measure of visual attention.

2.2.2 Where do drivers look?

Eye tracking data has shown that when driving, people will typically spend a large proportion of time looking at the road straight ahead, towards the point where their vehicle will be in the next few seconds. On straight roads this point is often the focus of expansion (FOE) (the singular point from which the optic flow field expands) (although note that this is not the case when navigating curved roads, see Land and Horwood (1995)). Early research into drivers' visual search found that up to 94% of fixations occur at this point (Mourant & Rockwell, 1972).

As well as looking at the point in the road straight ahead, fixations are also scattered to the left and right of this point within a horizontal search window (Chapman & Underwood, 1998; Crundall & Underwood, 1998). This spread of search allows drivers to attend to other lanes and vehicles, pedestrians, side roads, and other relevant objects within the horizontal search window.

The degree to which we scan the road whilst driving can be affected by an interplay of bottom-up and top-down factors (discussed further below). For example, an on-road investigation by Crundall and Underwood (1998) found that as roads become more complex (such as moving from a quiet rural road to a dual carriageway) more experienced drivers increase their visual search in order to scan a wider angle of the roadway. This constant scanning by spreading visual search to the left and right of the FOE is essential for safe driving as hazardous events do not always occur in the centre of the visual field (Mills, 2005).

In terms of individual fixation locations, drivers allocate attention and make fixations on aspects of the driving scene which are relevant such as other vehicles (e.g. D. Crundall et al., 2008; Crundall et al., 2004; Smiley et al., 2004), road signs (e.g. Costa et al., 2018; Liu et al., 2022; Smiley et al., 2004), and road markings (e.g. Martens & Fox, 2007b; Pashkevich et al., 2018), whilst ignoring task irrelevant stimuli such as houses bordering roads (Luoma, 1988). However, drivers still allocate some attention to aspects of the driving scene which are not directly relevant to the driving task such as background scenery and roadside advertisements (Costa et al., 2019; Crundall et al., 2006; Green, 2002; Hughes & Cole, 1986; Land & Horwood, 1995; Young et al., 2009). This suggests that whilst drivers do attend to task relevant areas of a visual scene, they also have some extra capacity to attend to task irrelevant objects whilst still maintaining safe driving.

2.2.3 Factors that influence where drivers look

The literature described previously provides a brief example of the typical search pattern from a driver. However, understanding what a driver looks at requires an understanding that a combination of bottom-up and top-down factors are at play (Connor et al., 2004; Crundall, 2003, 2005; Egeth & Yantis, 1997). This section will discuss the influence of these factors, before considering a model which explains drivers' visual attention across two dimensions.

2.2.3.1 Bottom-up influences

Attention can be captured by bottom-up influences which are often stimuli driven. This is often an automated process in which attention is drawn to an aspect of the physical environment, also described as attentional capture (Yantis, 1993). Several aspects of a visual scene may attract attention in a bottom-up manner. Underwood et al. (2003) demonstrated how attention can be grabbed as a result of movement by presenting participants with videos of driving scenes whilst recording their eye movements. Results showed that participants were more likely to fixate on dynamic targets than static targets in the scene, particularly if these targets were not located in the centre of the video frame. Additionally, these dynamic target events received more fixations when they were hazardous compared to when they were non-hazardous. These results provide evidence that movement and sudden onset within a visual scene can attract attention in a bottom-up manner.

Similarly, attention can be captured in a visual scene by characteristics such as colour or luminance. For example, a case control study of motorcycles accidents conducted by Wells et al. (2004) found that motorcyclists wearing reflective or fluorescent clothing, or driving with their headlights on, had a lower risk of being involved in an accident than those not wearing reflective clothing. This suggests that the bright colour and increased luminance employed by these motorcyclists is better able to attract drivers' attention and make them more noticeable on the road.

In driving, these factors might lead to your attention being drawn to a vehicle suddenly entering your lane, a new emerging hazard, or the lights of an emergency service vehicle. Although this kind of attention is automated and will lead to a large amount of relevant information being attended to (such as sudden onsets of hazards), drivers can also fail to attend to bottom-up cues. For example, drivers may fail to attend to a change in an environment, even if this is highly salient, as a result of inattentional blindness (Beanland et al., 2017; Galpin et al., 2009). In addition, drivers may attend to and fixate on salient objects but fail to perceive them (known as the looked but failed to see error) (Brown, 2002; Langham et al., 2002).

It is also possible that bottom-up attentional cues can lead to distractions whilst driving such as attending to salient aspects of the environment which are not related to driving, such as roadside advertisements and electronic billboards. For example, an on-road investigation in Sweden found that drivers had significantly longer dwell times when looking at electronic billboards compared to traditional roadside advertisements, likely as a result of their increased luminance and motion (Dukic et al., 2013).

2.2.3.2 Top-down influences

Whilst bottom-up attention is mostly stimuli driven and automated, top-down influences on attention are more cognitive in nature. Top-down visual attention is more often goal orientated and comes about as a result of knowledge or expectations. It is based on schemas which develop as a result of exposure and experience. For example, when driving along a road which contains an obstructed pedestrian crossing, a driver unfamiliar with this road may fail to allocate their attention to this region, however with experience and knowledge a driver will know to look at this area to see if there is an emerging pedestrian (Pradhan et al., 2005). Section 2.2.4 discusses the influence of one particularly important top-down factors in drivers' visual attention, driving experience.

2.2.3.3 A two-dimensional model of attention

Although bottom-up and top-down factors play an important role in visual attention whilst driving (as well as visual attention in non-driving tasks as discussed later), attention can also vary on different dimensions. Lana Trick and colleagues (Trick & Enns, 2009; Trick et al., 2004) proposed a two-dimensional model of visual attention which considers the role of bottom-up and top-down influences, as well as the role of automatic and controlled modes of attention.

This model suggests that attention varies on two dimensions, giving four different modes of attentional selection (see Figure 2.1). These dimensions are automated – controlled, and exogenous – endogenous.

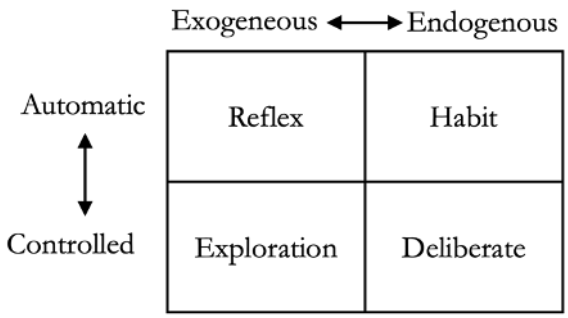

Figure 2.1: Four modes of attention as described by Trick et al. (2004)

On the first dimension, attention whilst driving can either be automatic, or more controlled. Automatic attention can be seen as unconscious, innate, rapid, and effortless, whereas controlled attention is more conscious and planned.

On the second dimension, attention can be controlled by exogenous, external cues (this can be seen as somewhat akin to bottom-up processing which is stimuli driven) or may be driven by endogenous, internal, person-specific cues and knowledge (somewhat similar to top-down processing). Across these two dimensions, four modes of attention are present.

The first mode, **reflex** (automatic exogeneous) refers to innate automated processes in which attention is drawn to something salient within the environment. Similar to bottom-up cues as described above, this may include highly salient objects, bright luminance, sudden onset or movement. For example, all drivers would automatically respond to the bright lights of an emergency vehicle, or the sudden onset of a hazard ahead. This mode of perception will always be present and will be similar across all drivers regardless of experience or exposure to the driving task. As such, this mode of attention is said to be rigid and unchangeable.

The second automatic process is **habit** (automatic endogenous). Whilst this mode of attention is automatic, it develops as a result of experience and exposure. As such, different habits can be formed or disappear across a lifetime of driving. When an action, or visual search, is repeated over multiple occasions it can become habitual and begin to occur automatically. This is most evident in the case of more experienced drivers learning to automatically look at certain areas of the roadway as a result of experience (discussed further in section 2.2.4). Similar to the top-down influences discussed above, habits are formed as a result of schema development and become more automated over time. As this form of attention is dependent on experience, it will differ between drivers.

However, although habits can lead to an improved visual search amongst drivers, there is also the possibility of habits based on expectations and experience resulting in drivers missing novel and unexpected events in the driving scene. For example, in "looked but failed to see" accidents drivers often fail to notice vehicles on the road which have a lower frequency (Brown, 2002; Rumar, 1990; Summala et al., 1996). Although this failure to see objects which are not expected on the road is often associated with drivers failing to see oncoming motorcyclists, research has also shown that drivers can fail to notice an unexpected police car (Langham et al., 2002). Similarly, when driving in a new environment such as a foreign country, more experienced drivers are more likely to be influenced be the familiarity of the driving situation as a result of their earlier formed habits (Shinohara & Nishizaki, 2017b) (discussed further in section 2.2.5).

Exploration (controlled exogeneous) is the process of looking around the environment without a specific goal. This will often occur when the demands of the driving task are lower, or when the driver is static without a specific goal. When we have extra available capacity we are free to attend to different areas of the environment, this includes task irrelevant aspects of the visual scene (Hills, 1980). What a driver decides to attend to in these situations will be dependent on what is present in the environment, and the conspicuity of objects in the environment (Hughes & Cole, 1986). This mode of attention has the potential to differ between drivers as it is dependent on the individual environment and may be partially determined by the drivers' knowledge or exposure to that particular environment.

The final mode of attention in this two-dimensional model is **deliberate** (controlled endogenous). According to Trick and Enns (2009) deliberate attention is the most flexible and intelligent of the four modes of attention. In this mode, attention is allocated in a controlled manner which is also dependent on the knowledge, experience, and goals of the driver. This mode of attention is useful in situations such as highly demanding road environments, performing new activities, engaging in multiple tasks, interpreting information before acting, and overcoming maladaptive search strategies which may occur automatically (reflex and habit). This process will also vary across different drivers, once again as a result of experience, knowledge and goals.

This two-dimensional model is useful in understanding the combination of factors which can affect drivers' visual attention and will be considered at various points in this thesis. An advantage of this model, and why it is being used in the current research, is that as well as considering the influence of internal and external cues (akin to top-down and bottom-up processing), the model also considers the role of controlled attention and choosing where to look in the driving scene which is relevant for several chapters of this thesis.

In trying to understand the cross-cultural differences in visual attention between drivers, this model can be used to explore the role of experience/ exposure to an environment. For example, some aspects of attention will be consistent across all drivers regardless of experience or exposure (reflex), the other modes of attention will differ between different drivers. Below it will be discussed how experience in terms of years of licensure can lead to these changes, but this will also be relevant when considering differences as a result of different driving experiences across cultures and nationalities.

The model will also be used to look at the influence of controlled attention in the driving task, this will be particularly useful when looking at how drivers allocate attention to background objects in the visual scene in a controlled manner (exploration).

2.2.4 The impact of experience on visual search

One factor which has been repeatedly shown to influence drivers' visual search is driver experience. This is the most widely discussed top-down influence on drivers' visual attention in the literature, and is linked to habits and deliberation as described in the two-dimensional model described previously (Trick & Enns, 2009; Trick et al., 2004). Typically experience is investigated in the form of how long an individual has been driving and the transition from a novice driver to a more experienced driver, this is the literature which will be discussed in the following section. Although experience is typically thought of in terms of length of licensure, experience can also be thought of in terms of exposure and experience to a particular driving environment (which will be discussed later in this chapter). These differences in exposure to a particular environment will be key to the research presented in this thesis.

One of the earliest studies to demonstrate differences in visual search as a result of experience came from Mourant and Rockwell (1972). This study involved participants driving along two routes on real roads (a neighbourhood route and a freeway route) whilst having their eye movements recorded. As well as demonstrating the overall amount of attention allocated to the focus of expansion (FOE) as discussed earlier, this research also demonstrated that attention differs between novice and experienced drivers. In contrast to more experienced drivers, novices concentrated their fixations to smaller areas of the roadway (as opposed to using a wider spread of search) and tended not to look as far ahead on the road. Novices also spent more time looking towards the side of their lane (with the authors suggesting that this may help novice drivers maintain their lane position) and looked at their mirrors less often. Whilst this study was one of the earliest to demonstrate the impact of experience on drivers' visual search, it should be noted that the study used a very small sample of 10 participants (6 novices, 4 experienced) with all novice drivers having almost no previous driving experience, which is unrepresentative of novice drivers typically found on the road.

In terms of spread of search, although studies have shown an increased spread of visual search across more complex roads such as dual carriageways compared with simpler roads such as single lane suburban roads, this is typically only the case for more experienced drivers, with novice driers failing to increase their spread of search across more complex road types. In the on-road investigation from Crundall and Underwood (1998), there were no differences in spread of search between novice and experienced drivers on low complexity rural or suburban roads (in which a wider spread of search may not be necessary). However, on highly complex dual carriageways only the more experienced group increased their search to take in more visual information.

One explanation for these results may have been that novice drivers were unable to sufficiently allocate their visual attention as they had to allocate more attention to the task of operating the vehicle itself. In order to remove this potential confound Underwood et al. (2002) presented novice and experienced drivers with video clips of drives from their first study, and recorded their eye movements whilst participants watched these clips from the perspective of a driver. Once the additional demands of operating a vehicle were removed, novice drivers still failed to increase their visual search across more complex road types. These differences have also been replicated in a number of studies (Alberti et al., 2014; Hills et al., 2018; Konstantopoulos et al., 2010), with a recent meta-analysis also showing an overall decrease in horizontal search amongst novice drivers (Robbins & Chapman, 2019).

Further evidence for the effect of experience on visual search has shown that novice drivers often failed to fixate on areas where a potential hazard may appear (such as obscured crossings) whilst more experienced drivers fixated on these areas despite hazards not being present (Pradhan et al., 2005). Similar results have been found when viewing driving video clips of potentially hazardous situations (Borowsky et al., 2010). As with the findings related to spread of search, these results suggest that novice drivers have not yet built up enough knowledge to scan these areas for potential hazards, whilst experienced drivers instinctively search these areas for potential hazards.

Konstantopoulos and Crundall (2008) have also shown that novice drivers may not be aware of where to look when driving. Their study involved presenting novice drivers and driving instructors with images of roads and tasked them with selecting the most appropriate regions to attend to. Novice drivers were consistent within their group when selecting regions, but differed from driving instructors who prioritised looking at the rear-view mirror and side roads more so than novice drivers. This further suggests that novice drivers have a poorer visual search as a result of their lack of experience.

One further situation in which differences between novice and experienced drivers are present is during hazard perception. Based on driving experience, people will develop different mental models and schemas for what they expect to occur on the road. Hazardous events, in comparison to safe driving events, are typically uncommon. It has been shown that when viewing hazardous events there is an increase in fixation duration on the hazardous stimuli (Chapman & Underwood, 1998; Underwood et al., 2005). This is the case for all drivers regardless of experience and will come about as a result of attentional capture (a reflex as described in section 2.2.3.3). However this increase in fixation duration is often more pronounced in novice drivers, who will fixate on a hazardous event but then take longer to return to a normal visual search staggery than experienced drivers (Chapman & Underwood, 1998) as a result of their different mental models.

The findings presented in this section suggest that differences in visual attention are due to the different mental models held by novice and experienced drivers (Underwood et al., 2002). Due to their lack of driving experience, novice drivers have not yet developed the top-down knowledge needed to scan more complex road types or to understand what kinds of events may occur on these roads. As driving experience increases, so does top-down knowledge about where to look when driving. In the case of this study, by gaining experience driving along a complex dual carriageway, a driver will start to learn that they need to not only look at the road ahead, but also towards other vehicles and lanes which are to the left and the right of the point in the road straight ahead. With increased experience and exposure, these more appropriate search patterns develop and lead to drivers scanning more appropriate areas of the roadway.

2.2.4.1 Experience using different modes of transport

In addition to experience in terms of length of licensure, experience has been thought of in terms of using different modes of transport. A subset of research has focused on differences between car drivers and dual road users (individuals who drive a car and ride a motorcycle). For example, Crundall et al. (2012) presented novice drivers, experienced drivers, and dual road users with videos of junctions with different vehicles approaching whilst recording their eye movements. When tasked with responding when it was safe to cross the junction dual road users made the safest responses, particularly in the presence of approaching motorcycles. Similarly dual road users were said to have superior visual search strategy and fixated for longer on the approaching motorcycles than both driving groups, who terminated their gaze early. Novice drivers once again showed an insufficient visual search strategy as discussed previously.

As with the differences discussed between novice and experienced drivers, these differences are most likely due to different mental models between those who solely drive a car and the dual road users. The experience of riding a motorcycle makes dual road users more aware of the potential hazards on the road faced by motorcyclists, which in turn leads to a more suitable visual search strategy being used to detect approaching motorcyclists. This increased hazard perception skill amongst dual road users has been found in several studies (e.g. Horswill & Helman, 2003; Hosking et al., 2010) however it should be noted that this improvement seems to only apply to motorcycle related hazards as opposed to an overall increase in hazard perception ability (Crundall et al., 2013).

Other studies examining the eye movements made by dual road users have found similar results to Crundall et al. (2012). In a similar study, car drivers and dual road users were presented with videos from the perspective of a driver being overtaken by different vehicles whilst their eye movements were recorded (Shahar et al., 2012). It was found that compared to car drivers, dual road users attended more to overtaking motorcyclists, as well as allocating more attention to their right wing mirror and rear-view mirror.

This superior visual search pattern has been described as a "gold standard" in these studies, and dual road users are found to be less likely to have a car-motorcycle collision (Magazzù et al., 2006) and have more positive outcomes when riding a motorcycle compared to motorcyclists who do not also drive a car (Yu & Tsai, 2021).

However being a dual road user does not always lead to improved visual search on the road. Muttart et al. (2011) compared visual search patterns of dual road users when they were driving a car, and riding a motorcycle. When riding a motorcycle, participants failed to make proper glances in the direction of the most threatening oncoming vehicles, and made more glances off the road. Therefore, although the experience of using both modes of transport can lead to improvements in visual search and increased hazard perception this seems to be task specific and mostly relevant when driving a car and attending to motorcyclists on the road. This is due to having a better understanding of the needs and experiences of motorcyclists on the road (Crundall et al., 2008) and the subsequent mental model which has developed from their own experience of riding a motorcycle.

These findings provide more evidence for the role of experience in drivers visual search, whilst also demonstrating that experience should not just be thought of in terms of how long a driver has held their licence. It is also worth considering these differences in the context of this thesis which focuses on drivers from the UK and Malaysia. Although dual road users are not very common in the UK, they will be more commonplace in Malaysia due to the increased proportion of motorcycles on the road. Whilst this was not directly addressed in the current research due to the focus on car drivers' visual attention it is possible that dual road users did take part in the research.

2.2.5 Familiarity with the driving environment

Whilst a lot is known about the effect of experience in terms of length of licensure, less is known about experience in the form of exposure to a particular environment. Familiarity with an environment can lead to improved visual search, as described above, as drivers build a more suitable mental model to enable them to scan the environment.

However, familiarity with an environment does not always lead to improvements in visual search. Research from Martens and Fox (2007a) demonstrated that when participants were repeatedly expose to the same route in a driving simulator, their glance durations decreased over time. In addition, when the driving tasks changed on their final drive from a priority road to yield situation, only two out of the 12 drivers responded adequately and began to slow down. Similarly the same authors demonstrated that a decrease in glance duration across repeated exposure to a driving environment was present when either watching videos or when driving a vehicle on the road (Martens & Fox, 2007b).

Another way in which familiarity with the driving environment can lead to differences in visual search, is when driving in a novel environment such as driving abroad. It has been shown that accident risk increases when driving in a foreign environment (see Ishii et al. (2009) for a review). This is likely due to unfamiliarity with the rules of the road, traffic safety culture, or driving in the opposite side of the road. However it has also been suggested that visual search differs when driving abroad.

Shinohara and Nishizaki (2017a, 2017b) presented participants with a driving simulator task in which they drove in a familiar home environment, and when driving in a foreign environment. Amongst novice drivers, few differences were noted when driving in both environments, however more experienced drivers did show differences in their visual search, with shorter fixation durations and more saccades being observed. The authors argue that this difference is due to the fact that the more experienced drivers found it more cognitively demanding to adapt to the new environment (based on their past habits).

2.2.6 Summary

To summarise the previous section, driving involves a large amount of visual attention, and require drivers to look in the right place at the right time. Several factors can influence where people look when driving, including bottom-up and top-down factors. Of particular relevance to the current research, it has been shown that where we look when driving differs as a function of experience, including length of licensure and exposure to a particular driving environment.

2.3 Cross-cultural differences in visual attention

There has historically been an assumption amongst psychologists that basic cognitive processes such as attention, perception and memory are universal (Brinkmann, 2019), such that these processes are similar for all individuals regardless of culture or ethnic background (Nisbett, 2003; Nisbett & Norenzayan, 2002; Nisbett & Ross, 1980). With this, the vast majority of psychological research into these cognitive processes has involved participants from Western countries. In a review of articles submitted to American Psychological Association (APA) journals between 2003 and 2007, Arnett (2008) found that the vast majority of papers (98%) were written by authors from the USA, other English speaking countries (such as the UK), or Europe. Additionally, 96% were also from Western countries and shared a similar demographic, coming from Western, Educated, Industrialised, Rich, and Democratic (WEIRD) societies (Henrich et al., 2010). This is despite the fact that this group of participants is representative of a very small proportion of the world population, with Americans representing less than 5% of the world's population at the time of publication, and the combined western groups representing 12% of the world population (Henrich et al., 2010).

While psychological research is traditionally confined to western participants, findings are often applied to humans as a whole, on the assumption that basic cognitive processes such as perception should be universal. However, cross-cultural research has shown that cognitive processes such as perception in fact differ between individuals from different cultures, with differences being observed between individuals from Western countries, and individuals from Eastern countries (Henrich et al., 2010; Nisbett & Masuda, 2003; Nisbett & Miyamoto, 2005). This section of the literature review aims to discuss the differences in perception between Western and Eastern participants, as well as presenting possible explanations for these differences.

For a large proportion of the research discussed in the following sections, Western participants used in cross-cultural comparisons came from the USA. Throughout the literature these participants are mostly referred to as Americans, despite the fact that this term could refer to anybody from either North or South America. In order to maintain consistency with these studies, the term American will be used throughout this review to only refer to participants from the USA.

2.3.1 Attending to individual objects or the scene as a whole in natural scenes

One early and widely cited study to explore the potential cross-cultural differences in attention between Westerners and East Asians came from Masuda and Nisbett (2001). In this study, American and Japanese participants were presented with short, animated videos depicting fish swimming underwater. After watching the videos, participants were asked to describe what they had seen and were then given a recognition memory test. When describing the scenes, American participants described more salient focal objects (such as the fish) whereas Japanese participants referred to the scene as a whole more often. The authors suggested that American participants allocated more attention to the focal objects than the background, whereas Japanese participants were allocating their attention more globally to the scene as a whole.

When later presented with a recognition memory test, there were similar results. When presented with images of fish against the same background, a novel background, or no background, Japanese participants were significantly less likely to recognise previously presented images against a novel background than an old background. Due to any potential bias of Japanese participants being more familiar with the kinds of underwater scenes presented than mid-western Americans, a second study replicated these findings using different mammals presented against different backgrounds. This study yielded the same results.

Based on these differences, the authors proposed two different perceptual styles. American participants were said to have an object dependent style of visual perception in which they attend mostly to salient focal objects. In contrast Japanese participants were said to have a field dependent style of perception, in which their attention to focal objects is dependent on them also attending to the wider visual field. This holistic style of perception involves a larger amount of attention being allocated to background and contextual elements of a visual scene, as well as binding focal objects to their background context.

This study was one of the first, and most widely cited, to show that Western and Eastern participants attend to different aspects of the visual scene. Several studies have since replicated these findings, providing further evidence that Westerners attend to individual focal objects, whilst Easterners attend to the scene as a whole (Cramer et al., 2016; Senzaki et al., 2014; Wong et al., 2018).

Replications of these findings have also demonstrated a neural basis for the observed cultural differences. When presented with a previously seen focal object against a new background (as described above), studies have shown that East Asian participants have a longer N400 event related potential (ERP) in response to the incongruent stimuli presented to them. This has been found when viewing both natural scenes (Goto et al., 2010; Masuda et al., 2014) and social scenes (Goto et al., 2013).

Although this first study provides evidence for cultural differences in perception, it is not clear whether cultural differences emerge during encoding (do people *attend* to different aspects of the scene), retrieval (do people *remember* different aspects of the scene), or reporting (do people *selectively report* different aspects of the scene). A study by Chua et al. (2005) aimed to add to the previous findings by using eye tracking to investigate whether cultural differences are present during encoding (i.e. do participants look at different aspects of a visual scene) or in retrieval or reporting (do participants look at the same things but report these differently). Chinese and American participants were presented with images containing salient objects against a background (for example, a tiger presented against a background of jungle foliage) for a duration of 3 seconds whilst their eye movements were recorded.

Results showed distinct differences in the eye movements of American and Chinese participants. American participants looked at the focal object an average of 118ms sooner than Chinese participants, and whilst both nationalities looked at the object for longer than the background, this difference was far more pronounced for the American participants. For the first 300-400ms, no cultural differences were observed. However, after this initial onset Chinese participants fixated more on the background than focal objects, whilst Americans fixated more on the focal object. This study also presented participants with a recognition memory test. Results showed that when presenting the focal image against a new background, Eastern participants were less successful than Western participants in identifying previously presented objects, once again suggesting that Westerners have an object dependent style of perception, whilst Easterners are field dependent.

Combined these findings show differences in how viewers from Western and Eastern countries attend to visual scenes, with Westerners attending predominantly to salient focal objects whilst Easterners attend to background and contextual information too.

Further research using eye tracking to explore cultural differences in perception came from Goh et al. (2009), who presented Western (American) and Eastern (Singaporean) participants with a series of images containing focal objects against a background, whilst recording their eye movements. In this study, images changed across some trials with changes either occurring to the focal object or the background, in both cases these changes were highly salient. Eye tracking data produced similar results to those of previous research, with Western participants having longer fixations on focal objects than Eastern participants. However, Western participants also showed longer fixations when looking at the background. In trials where aspects on the image changed, Western participants tended to keep their fixations on the focal object and still showed longer fixation durations overall. In contrast, Eastern participants had shorter fixation durations, and a visual search pattern which involved them making a series of short fixations across the background and the focal object as opposed to fixating on a singular location for a prolonged amount of time. Although this study yielded slightly different results to Chua et al. (2005) in terms of fixations on background objects (with the hypothesis that Eastern participants would fixate more on these regions), the findings do support the idea that Western and Eastern observers have different patterns of visual search when viewing visual scenes.

A similar pattern of results has also been found in research using change blindness paradigms (Masuda & Nisbett, 2006). East Asian (exchange students from China, South Korea, & Japan) and American participants were presented with still images in a change blindness flicker paradigm (as previously described in section 2.2.1) in which changes either occurred to focal objects or the background. Results showed that East Asian participants were faster at detecting background changes than American participants. Similar results were found in their second study comparing American and Japanese participants on change detection using animated vignettes. Finally in a third study using a mixture of culturally specific images (from the USA and Japan) found a significant interaction such that Japanese participants detected more background changes than Americans, whereas the reverse was true for detecting focal changes. Similar to the findings of (Masuda & Nisbett, 2001), these findings suggest that East Asian participants have a more holistic style of visual attention as shown by their increased attention towards background information.

In another change blindness study, Masuda et al. (2016) recorded Canadian and Japanese participants' eye movements whilst presenting them with images in which they had to detect changes in focal objects or the background. Unlike previous work (Masuda & Nisbett, 2006) focal objects were edited to make them more salient than the background. As a result, all participants were more accurate at detecting focal changes, and there were no differences in patterns of eye movements between cultures. However, in trials which contained no change between images, there were differences in visual search patterns between the two groups. Eye tracking data showed that Japanese participants had a greater number of fixations on background areas of the scene than their Canadian counterparts. Additionally, Japanese participants showed longer fixation durations when viewing background elements, and shorter when viewing focal elements, with the reverse being true for Canadian participants. The authors argue that when a task is fairly easy, and a focal object is highly salient (as was the case in change trials) patterns of visual search are similar across cultures. However, when a task becomes more difficult and participants are required to search for a change which is not present, participants use different search patterns dependent on their culture.

These findings further support the theory that Western participants have an object dependent perceptual style, whilst Eastern participants are more field dependent as well as suggesting that cultural differences emerge when individuals initially encode visual information, thus demonstrating that Western and Eastern participants look at different aspects of the visual scene. The combination of the eye tracking and behavioural data suggests that when viewing visual scenes, Eastern participants attend to the focal object in relation to the background, such that all aspects of the image are equally as important and should be attended to. In contrast, Western participants seem to quickly fixate on salient focal objects, and maintain their attention on these areas for a prolonged period of time.

Studies using simple stimuli have also been conducted to explore whether Easterners are more influenced by contextual or background information in their perception. Ji et al. (2000) presented participants with the rod and frame test in which participants were tasked with deciding whether a rod was vertical when presented inside a frame which could be rotated independently. Results showed that American participants were more accurate on this test than East Asian participants as East Asian participants were unable to disregard the contextual information from the frame.

Similar results were obtained by Kitayama et al. (2003) using a framed line test (see Figure 2.2 for an example). In this study, participants were presented with a line in a square frame, they were then presented with another square frame and were asked to redraw the line in either its absolute length, or length relative to the frame (i.e. if the length of the line was previously one third of the frame height, the new line should be one third of the new frame height). As hypothesised, Western participants outperformed East Asians on the absolute task due to the fact that East Asian participants were unable to ignore the contextual information provided by the frame. This also led to East Asians outperforming Westerners on the relative task. These results have since been replicated in several studies which have found similar cultural differences in performance (Kitayama et al., 2009; Klein et al., 2009; Martin et al., 2019).

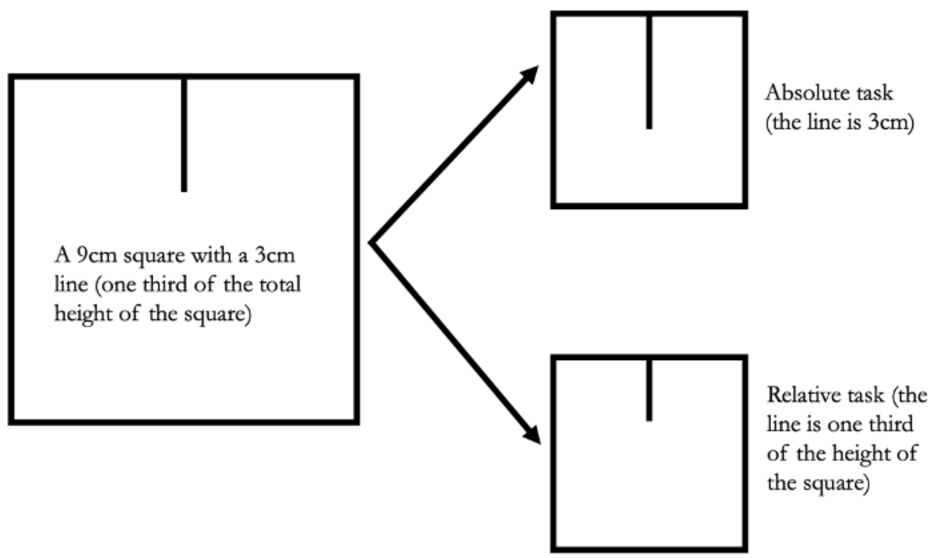

Figure 2.2: Example of the framed line test. Adapted from Kitayama et al. (2003)

Also using a variation of the framed line task, fMRI research by Hedden et al. (2008) demonstrated that participants (either from the USA or East Asia) showed greater neural activity when completing the culturally incongruent task (a relative task for Western participants, and an absolute task for Eastern participants).

There is some evidence that Western and Eastern participants perform differently when viewing simple visual illusions. When presenting participants with the Judd illusion (in which a participant is tasked with determining the centre of the line which is capped with arrows), van der Kamp et al. (2013) showed that East Asian participants (from Hong Kong) were more influenced by the arrows when determining the lines mid-point compared to their Western (Dutch) counterparts. Similarly, differences in global and local processing have been found between Western and Eastern participants using the Ebbinghaus illusion (Caparos et al., 2012; Doherty et al., 2008), and the Müller-Lyer illusion (Richardson et al., 1972). However, more recent research has failed to find cultural differences in the Müller-Lyer illusion (Krstic & Liu, 2018).

Boduroglu et al. (2009) presented East Asian and American participants with a colour change detection task in which one colour in an array of four colours would change when the array either expanded to cover a larger area or the screen, or shrunk to cover a smaller area. Compared to American participants, East Asians were better able to detect the change in trials where the array expanded, and were less accurate in trials where the array shrunk. Similar to previous findings, this suggests that Eastern participants were attending to a wider area of the visual scene as opposed to just focusing on salient focal objects. As such when the array expanded their attention was already spread wide enough to notice the change across a larger area.

Further evidence has suggested that East Asian participants are less able to ignore contextual information than Western participants. Research using a flanker task paradigm, in which a target is flanked with relevant or irrelevant stimuli, has shown that Eastern participants (in this case, Turkish) were less able to ignore contextual flanking information than Western participants (Gutchess et al., 2021). Similarly, studies using facial stimuli have shown that Eastern participants are more influenced by flanking stimuli when trying to correctly identify a central stimulus (Cohen et al., 2017; Masuda et al., 2008).

Although several studies have shown a difference in visual attention between Western and Eastern participants, there are also studies which have failed to replicate these findings or found contradictory evidence.

A study conducted by Rayner et al. (2007) found no differences in the amount of time spent attending to the background of visual scenes between American and Native Chinese participants (however it should be noted that the Chinese participants in this study were living in the USA). One issue with this study was that unlike the work of Chua et al. (2005)

images contained multiple focal objects, thus making the distinction between background and foreground more complex (Boland et al., 2008). However, work by Evans et al. (2009) aimed to directly replicate the work of Chua et al. (2005) using the same stimuli and found no cultural differences in visual search strategy. Finally, Rayner et al. (2009) found no differences in visual search between American and Chinese participants when viewing unusual scenes (although this study did not directly explore fixations on focal vs background elements of the scene).

These studies by Rayner and colleagues suggest that allocation of attention is not led by culture, as suggested in studies which have observed cross-cultural differences, but is instead led by universal processes which are shared across all humans. Findings from Masuda et al. (2016) go some way in resolving the discrepancy between studies which have observed cross-cultural differences and those which have not, by demonstrating that cross-cultural differences are dependent on the task at hand.

2.3.2 Two possible explanations for cross-cultural differences in visual attention

The research described in the previous sections presents two distinct styles of visual perception. Broadly speaking, westerners have an object orientated, analytic style of perception in which they attend to individual salient objects (which are viewed as their own individual entities). In contrast, East Asians have a more global and holistic style of attention in which they attend to both focal objects and their background/ context. In this style of perception, a visual scene is viewed as a whole more so than a series of individual objects. However, when describing the cross-cultural differences in visual attention, one should consider the underlying cause of these different perceptual styles.

2.3.2.1 The influence of culture and self-construal

Firstly, it could be argued that these differences come about as a result of differences in cultures between Westerners and East Asians. In their widely cited paper Markus and Kitayama (1991) describe two construal's of the self. First, the independent self-construal associated with Western individuals. Typically, people from Western cultures come from an individualistic society where individuals prioritise their personal goals, autonomy, and self-expression over collective or group interests (Triandis et al., 1988). These people will therefore have a more independent self-construal and view themselves an independent, individual entities with a set of personal characteristics.

In contrast, people from East Asian backgrounds (amongst others) could be described as having a more interdependent self-construal. People from Eastern countries often view themselves as part of a collectivist society, with this an emphasis is placed on relationships and your role within a larger network of social relationships. This is in contrast to the more Western view of independence (Hardin et al., 2004; Nisbett, 2003; Singelis & Sharkey, 1995).

These cultural differences are likely historically routed and have their origins in ancient Greek and Chinese philosophy. The ancient Greeks (Western) tended to place emphasis on individual objects to understand the world, whilst explaining behaviour in relation to the individual properties of objects. In contrast, ancient Chinese philosophers believed that objects were affected by a field of forces and existed within an interchanging world (Nisbett, 2003; Nisbett et al., 2001).

Differences in self-construal are evident in the way people from Western and East Asian countries describe themselves, and events. When discussing the self, Westerners discuss their unique personality traits without linking these to particular contexts. In contrast, East Asians describe themselves in terms of particular contexts (i.e. how they are at work vs how they are at home), and in terms of their relationships to other individuals (Ip & Bond, 1995). Similarly, when describing the self, East Asians have been found to make twice as many references to others, such as friends and family members, than Western participants (Markus & Kitayama, 1991).

These differing views of the self can be said to influence various aspects of cognition. For example, studies have shown cultural differences in object categorisation in which Westerners tend to group objects based on rules such as category membership. In contrast, Eastern participants group objects based on relationships and familial similarities (Chiu, 1972; Ji et al., 2004; Norenzayan et al., 2002). Similarly, research investigating causal attribution has shown that Westerners tend to explain events on the basis of the individual characteristics of those involved, whereas East Asians are more likely to explain the same events on the basis of historical and contextual factors (Lee et al., 1996; Morris & Peng, 1994).

Differences in self-construal as a result of culture have been said to contribute to the cultural differences in visual attention and perception. It is suggested that if you see yourself as an interdependent part of a much larger context in which relationships and context are essential, you will perceive non-social objects in a similar way (Markus & Kitayama, 1991). As Nisbett (2003) put it "If the world is a place where relations among objects and events are crucial in determining outcomes, then it will seem important to be able to observe all the important elements in the field" (p.37).

Further evidence for the link between self-construal and perceptual style comes from studies in which participants are primed with either an independent or interdependent self-construal. Kühnen and Oyserman (2002) primed participants with an independent or interdependent self-construal using a pronoun circling task. In the first experiment participants were presented with a letter identification Navon task. Those who were primed with an independent self-construal were faster at identifying the small local letters, whereas those primed with an interdependent self-construal were faster at identifying the global letter. These results are similar to those obtained comparing performance on the Navon task between Western and Eastern participants (McKone et al., 2010). Similarly in a second experiment those primed with an interdependent self-construal were found to be able to remember previously seen objects in the correct location (implying that objects were encoded within their context) whilst all participants were able to recall objects individually.

Self-construal priming has also been found to impact performance on a change blindness task (Choi et al., 2016). In this study Western participants were faster at detecting focal changes compared to background changes, however when primed with an interdependent self-construal the difference in reaction times between focal and contextual changes was much smaller, suggesting that interdependent priming improved performance for detecting background changes.

2.3.2.2 The influence of the environment and perceptual affordances

Although the cross-cultural differences have mostly been interpreted in terms of differences in self-construal, it is also possible that these differences are a result of the perceptual environment in which the individual was raised. In comparison to Western environments, East Asian environments are more visually complex and contain more visual clutter (Miyamoto et al., 2006). As such, it has been hypothesised that the perceptual environment itself may lead to differences in visual attention as individuals develop strategies to best suit the properties of their environment. The change blindness study from Masuda and Nisbett (2006) provides some support for this. Although there was an overall cultural difference, results showed that participants detected more background changes in Japanese scenes compared to American scenes, and more focal changes when viewing American scenes compared to Japanese scenes. This suggests that the environment led to participants attending to either more background or focal elements.

Further evidence for this theory of environmental affordances comes from research which has primed individuals with either East Asian (Japanese) or Western (American) scenes before presenting them with a change blindness task (Miyamoto et al., 2006). Results showed that when primed with images of Japanese scenes, American participants were more likely to detect contextual and background changes than those primed with American scenes. When primed with an East Asian scene which would require a more global style of visual processing, American participants adapted their visual style, thus suggesting that environmental characteristics lead to different in visual attention.

Another priming study (Ueda & Komiya, 2012) presented Japanese participants with neutral stimuli followed by either Japanese or American scenes whilst recording eye movements. Consistent with previous findings, participants scanned a wider area of the scene when viewing Japanese scenes compared to American scenes. When viewing culturally neutral single object images, those primed with Japanese scenes had a wider distribution of fixations than those who had previously seen American scenes, suggesting that priming participants with Japanese scenes led to a more global style of visual perception for later trials.

A recent study by Cramer et al. (2016) opted not to directly prime participants by presenting them with images of different scenes, but instead explored the effects of living in a new environment by comparing visual search and recognition memory between Canadians, East Asians who had lived in Canada for less than a year, and East Asians who had lived in Canada for over two years. Results showed that those who had lived in Canada for over two years performed similarly to Canadian participants on a visual search task, showing a more analytical perceptual style than East Asians who has recently immigrated. These differences in performance were not related to various measures of cultural identity (as assessed through questionnaires), therefore the authors conclude that perceptual style is malleable, and can be altered as a result of living in a different environment for as little as two years.

Further evidence against the cultural self-construal argument comes from studies investigating the Himba people of Namibia. The Himba are a highly interdependent society with strict social roles within their society. Based on this, one might expect the Himba people to exhibit a more global perceptual style as has been observed with interdependent East Asian participants. However Davidoff et al. (2008) demonstrated that this is not the case. Members of the Himba tribe were compared to British participants on a variation of the Navon task in which participants were presented with a target object (a large shape made up of smaller shapes such as a large circle made up of smaller circles) and two comparison figures which either matched the target on its global feature (the large shape was also a circle), or local features (the smaller shapes were circles) (see Figure 2.3). Despite being a highly interdependent society, the Himba participants showed a strong local preference when deciding which object best matched the target. The authors argue that this effect was a result of the Himba's environment in which they have to distinguish clearly between individual objects such as herd animals.

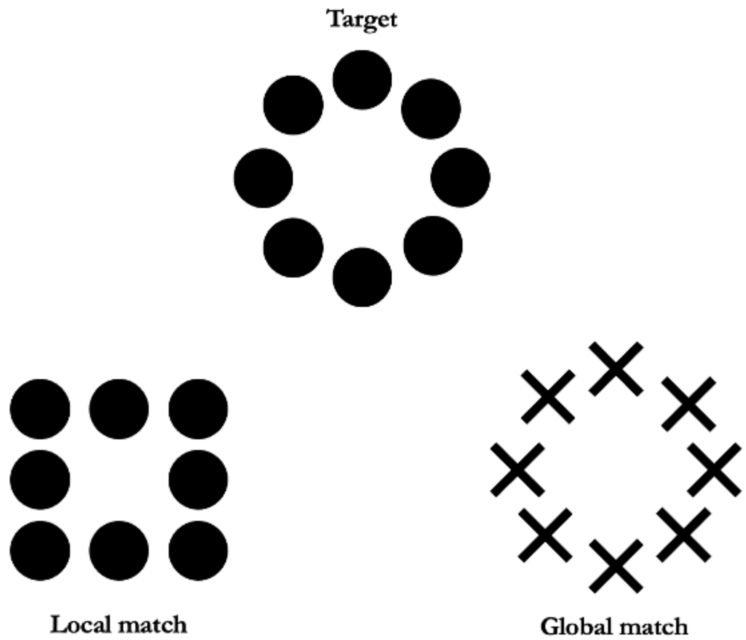

Figure 2.3: Examples of Navon type figures. Adapted from Davidoff et al. (2008)

Later work from Caparos et al. (2012) expanded this finding by comparing traditional members of the Himba tribe, British nationals, Japanese participants, and Himba people who had moved to a city during early adulthood on the same Navon style task. Results revealed that of the four groups, the traditional Himba showed the largest local bias, whereas the Himba participants who had moved to a city made more global choices. In addition Japanese participants made the most global choices overall. This further supports the environmental affordances account of cross-cultural differences in visual perception by once again demonstrating that exposure to a particular environment can lead to changes in perceptual style.

The effects of environmental affordances can be seen as akin to the role of experience in drivers' visual search. In both cases, exposure to a particular environment facilitates a need to use a particular pattern of visual search. Priming studies demonstrate that these search strategies can be developed and learnt over time similar to a novice driver adjusting their visual search as a result of increased experience.

2.3.3 Summary

This section discussed the cross-cultural differences in visual attention between Western and East Asian individuals. To summarise the differences, Westerners have been found to have a more analytical, local attentional style in which they attend to salient focal objects. In contrast, East Asians have a more global and holistic attentional style in which they also attend to background and contextual information. There are two main explanations for these differences, they are either the result of social and cultural differences between collectivist and individualistic societies, or a result of exposure to a highly complex and visually cluttered environment. Overall this section shows that there are cultural differences in visual attention which will be explored in the context of driving throughout this thesis.

2.4 Cross-cultural differences in driving

Given the literature discussed in section 2.2, it is clear that understanding where drivers look is an important topic of research with regards to understanding driver cognition and road safety. However, these findings are largely restricted to western countries, despite the fact that cross-cultural research has shown differences in visual search in non-driving tasks between western and eastern participants.

This is particularly problematic as crash rates differ greatly between different countries and global regions. Roads in western countries are particularly safe, for example the UK has one of the lowest road death rates of any country globally, with an estimated 1,400 road deaths annually (Department for Transport, 2020), which represents approximately 3.1 road deaths per every 100,000 members of the population (World Health Organization, 2018). Data from the World Health Organization (2018) also shows that within Europe, there were an estimated 9.3 road deaths per 100,000 members of the population in 2016, compared to 20.7 deaths per 100,000 members of the population in South-East Asia. Perhaps more striking is the percentage of all global road deaths occurring in high-income countries (such as those in Europe) compared to low- and middle-income countries (many of which are Eastern). Of the estimated 1.35 million annual road deaths, 7% occur in high income countries, whereas 80% and 13% occur in middle and low income countries respectively (World Health Organization, 2018). Based on these statistics, it is reasonable to assume that the differences in road deaths between these countries and regions will be related to hazardousness of the road environment, which in turn could easily impact the visual search strategies used by drivers in different regions. If it is the case that the hazardousness of the road environment, and exposure to this environment, leads to differences in visuals search this would imply a need for culture specific interventions and driver training related to visual search.

The following section will present results from studies which have directly compared drivers from different countries. As very few studies have explored the differences in drivers' visual attention, the literature predominantly focuses on driver behaviour or performance on tasks such as hazard perception.

2.4.1 Cross-cultural differences in drivers' attention and behaviour

2.4.1.1 Driver behaviour

One way in which cross-cultural comparisons have been made between drivers, is through comparisons of driver behaviour, particularly aberrant driving behaviours. Özkan et al. (2006) directly compared self-reported aberrant driving behaviours across drivers from six countries (The UK, The Netherlands, Finland, Iran, Turkey, & Greece) using the Driver Behaviour Questionnaire (Reason et al., 1990). Results showed that drivers from northern European countries (which have much lower crash rates) self-reported more "ordinary violations" such as speeding on a motorway, whereas drivers from Southern European and Middle Eastern countries scored higher on "aggressive violations" such as road rage. When exploring these behaviours in relation to accident rates, it was found that driving style (particularly aggressive violations) mediates the relationship between country and accident rate. The same results were obtained when looking at self-reported behaviours between Swedish, Finnish, Iranian, and Greek drivers such that drivers from Sweden and Finland reported more ordinary violations whereas drivers from Iran and Greece reported more aggressive violations (Warner et al., 2011). In both cases it has been argued that having poorer infrastructure, more relaxed enforcement, and higher stress on the road may lead to these aggressive violations.

More recently, Wang et al. (2019) compared the driving behaviours of young male drivers from China and Germany in a driving simulator study. Results showed that when driving in a simulator, the Chinese drivers drove at higher speeds in scenarios where they were interacting with a motorcyclist on the road, and showed longer reactions times during hazardous scenarios involving a motorcyclist, or a wild boar appearing in the roadway. The likely explanation for these differences is that the two scenarios where cultural differences were observed (interacting with a motorcyclist or a boar) are much more common on

Chinese roads, meaning that the Chinese participants were more familiar with these types of hazards compared to their German counterparts. This provides further evidence that the country we drive in and the types of hazards we are exposed to can lead to changes in driver behaviour across cultures.

Similarly, research from Uzondu et al. (2020) compared drivers from the UK and Nigeria across a series of driving tasks in a driving simulator. Results showed that Nigerian drivers engaged in several riskier behaviours when driving such as harsh braking, driving at higher speeds, and observing smaller safety margins when overtaking and in traffic conflict scenarios. As with the previously described studies, the authors argue that these differences emerge as a result of differences in traffic safety culture between the two countries.

2.4.1.2 Hazard perception

Another way in which cross-cultural differences between drivers have been explored is through hazard perception. For example, research by Ventsislavova et al. (2019) compared drivers from the UK, Spain, and China on a traditional hazard perception test, and a "what happens next?" test. In a traditional hazard perception test, drivers are tasked with responding to the presence of an emerging hazard whilst watching a video from the perspective of a driver. Whilst some studies have found that these tests are able to distinguish safe and less safe drivers (Horswill et al., 2015) others have failed to replicate these findings (Sagberg & Bjørnskau, 2006). A particular issue with traditional hazard perception tests is that the definition of a hazardous event will likely differ by country. An event that is considered a hazard to a driver from the UK may be much more commonplace and therefore seen as less hazardous to a driver outside of the UK. In contrast, a "what happens next?" test should be less culturally specific as it involves drivers simply describing what they believe will happen next after a video is stopped when a hazard is emerging.

Results from Ventsislavova et al. (2019) showed that Chinese participants performed worst in the traditional hazard perception test in which the task is to respond when a hazard begins to emerge. However, in the "what happens next?" test, no cultural differences were found. It is likely the case that the cultural differences in performance on a traditional hazard perception test are the result of an increased criterion for categorising an event as hazardous.

Hazard perception tests have also been used in comparisons between drivers from the UK and Malaysia. Lim et al. (2013) presented UK and Malaysian drivers with hazard perception clips from both countries and recorded hazard response times (responding when a hazard begins to emerge) whilst recording their eye movements. Results showed that drivers were more accurate at detecting hazards in their home country, but made more responses to potential hazards outside of the pre-defined hazard event window when viewing Malaysian road clips (likely due to the increased complexity of Malaysian roads). When comparing accuracy across nationalities, results showed that Malaysian drivers are less accurate at detecting hazards than UK drivers. Once again this is likely due to an increased criterion for classifying something as hazardous on the road, meaning that UK participants classified events as hazardous earlier than the Malaysian participants.

In terms of eye movements, it was shown that fixation durations were significantly shorter when viewing hazard perception clips of Malaysian roads, particularly amongst Malaysian drivers. It may be the case that the increased visual clutter observed on Malaysian roads and the overall increase in hazardousness led to these differences due to the fact that you are typically required to scan the environment more and make a series of quick fixations in a hazardous environment. This difference being particularly strong amongst Malaysian drivers could suggest that exposure to this hazardous environment led Malaysian drivers to adapt their visual search strategy when viewing driving scenes similar to the way visual search changes as a result of experience (e.g. Crundall & Underwood, 1998).

When using a non-traditional hazard perception test, poorer performance amongst Malaysian drivers has also been found in studies using a "what happens next" test (Lim et al., 2014) and a deceleration detection flicker test in which participants must respond to multiple sources of information, both focal and peripheral (Lee et al., 2020).

2.4.1.3 Driver cognition

Whilst the above studies compare drivers on tasks designed to test hazard perception, studies have also compared drivers across countries on different aspects of cognition, including decision making, prediction of others behaviour, and visual attention.

One such study came from Lee et al. (2015) who compared UK and Malaysian drivers on their ability to detect oncoming motorcycles using a series of static images with motorcycles present at various distances. Overall, the results revealed that Malaysian drivers are better able to detect motorcycles at farther distances than UK drivers, whilst participants were matched on their ability to detect cars. Despite this ability to better detect motorcycles, results also revealed that Malaysian drivers were more likely to judge the situation as safe to pull out of the junction in front of an oncoming motorcycle. As there are a much higher proportion of motorcycles on Malaysian roads compared to the UK, these results suggest that the higher prevalence of motorcycles makes drivers in Malaysia better at detecting them, but these drivers still show a riskier approach to pulling out in front of approaching motorcyclists.

Also comparing UK and Malaysian drivers, Sheppard et al. (2023) compared the use of explicit (indicators) and implicit cues (vehicle position) when judging the behaviour of an approaching vehicle at a T-junction. Results showed that British drivers made more use of explicit cues and were more likely to believe an explicit cue if it did not relate to the actual behaviour (i.e. a car indicating to turn left but driving straight ahead), whereas Malaysian drivers made more use of implicit cues. Once again these results are thought to be a result of the differences in environment between the two countries, in Malaysia it has been reported that road users fail to use their indicators on 60% of occasions (Ariffin et al., 2020) therefore this may not be considered a valid cue for judging the intentions of others on the road, thus leading to the use of more implicit cues.

Finally, although less widely investigated some studies have directly compared visual attention between drivers from different countries. As previously discussed, visual attention was measured when viewing hazard perception clips (Lim et al., 2013). However this has also been explored outside of hazardous driving in one study from Shinohara et al. (2017) compared fixations when driving between participants from the USA and Japan, whilst watching videos from the perspective of the driver (filmed in both the USA and Japan) under the guise that they are in an autonomous vehicle. The results showed that American participants made longer fixations than Japanese participants, suggesting that there may be differences in how we allocate attention on the road.

This study also explored fixations on four individual objects (a motorcycle and a large red sign for Japanese stimuli, a bicycle, and a clock tower for US stimuli). Results showed that Japanese participants fixated for longer on the motorcycle (and marginally longer on the bicycle) compared to American participants, whilst Americans fixated longer on the large sign than Japanese participants. Whilst these results do provide some evidence on the differences in what drivers look like as a result of culture, it should be noted that these analyses only focused on these specific objects as opposed to coding fixations on every object within the driving scene, therefore this does not provide a full picture of how drivers from different countries may differ in their attention allocation.

2.4.1.4 Summary of cross-cultural differences

Based on the available cross-cultural literature, it is clear that there are differences between drivers from different countries. First it has been shown that drivers from countries with high crash rates are more likely to engage in risky driving behaviours and perform aggressive violations on the road. Second, the ways in which we respond to hazardous events differs between cultures with drivers from countries from higher crash rates having a higher criterion for what is classified as a hazard, but also showing worse performance on non-traditional hazard perception tasks.

The examples presented show that there is a need to study these cultural differences in driving as our driving behaviours will be influenced by a combination of factors including our road infrastructure, road rules, cultural differences, all forming part of an overall traffic safety culture which will differ between countries (King et al., 2019).

2.4.2 Driving in Malaysia

The research in this thesis will be comparing drivers from the UK and Malaysia. As a former British colony, Malaysia shares several commonalities with the UK that make it suitable for comparison, including similar road rules and a left-hand driving environment. It is also a middle-income country with a relatively high percentage of car ownership. Table 2.1 summaries some of the key differences between the UK and Malaysia, particularly in relation to road environment.

Table 2.1: Comparison between the UK and Malaysia (based on the World Health Organisation global status report on road safety).

	UK	Malaysia
Population	65,788,572	31,187,264
Income group	High	Middle
Annual fatalities (2018)	1804	7152
Deaths per 100,000 (2018)	3.1	23.6
Annual fatalities (2021)	1068	4539
Deaths per 100,000 (2021)	2	14
% of cars	92.95	47.53
% of PTWs	3.31	45.91
Max motorway speed	70 mph	110 km/h
Max urban speed	30 mph	90 km/h
Max rural speed	60 mph	90 km/h

As well as being a suitable comparison, Malaysia is an interesting case to explore due to the extremely high crash rate in the country. Statistics from the World Health Organization (2018, 2023) show that there are between 14 (based on data collected in 2021) and 23.6 road deaths per 100,000 members of the population annually (based on data from the Royal Malaysia Police). This is higher than the average for the region of South-East Asia and is only surpassed within the region by Vietnam (with a rate of 24.5 per 100,000 in 2018, and 18 per 100,000 in 2021). It should be noted that these numbers are significantly lower in the most recent World Health Organisation global status report on road safety (World Health Organization, 2023) which is based on crash data obtained in 2021 which showed a significant reduction in road accidents due to lockdowns in light of the COVID-19 pandemic. More recently accident rates have increased to pre-pandemic levels however reporting of the most up to date statistics differs by country (World Health Organization, 2023).

Road deaths in Malaysia have been on the rise since the 1970's, and in 2012 were estimated to be increasing by 2% a year (Sarani et al., 2012). It should be noted that a large proportion of road fatalities in Malaysia involve motorcyclists, with data from 2009 showing that motorcyclists made up 60% of all fatalities on Malaysian roads, whilst representing 47% of vehicles on the road (Manan & Várhelyi, 2012).

As a developing country Malaysia has a gradually improving road infrastructure with more roads being built and roads being made safer (Malaysian Institute of Road Safety Research, 2017), there is also an increasing proportion of car ownership as opposed to motorcycles (Almselati et al., 2011). With this mixture of old and new infrastructure, the visual environment on Malaysian roads is highly complex, with a large amount of visual clutter.

With this, it should be noted that, as with all low and middle income countries, several factors related to infrastructure, legislation, vehicle standards, and post-crash care will contribute to the number of road deaths (Dhibi, 2019; Heydari et al., 2019). However, the Malaysian government committed to reducing road accidents by 50% between 2014 and 2020 as part of their road safety plan (Jawi et al., 2013; Malaysian Road Safety Department, 2014), and plans to reduce road deaths as part of the World Health Organisations decade of road safety. Although efforts are being made to reduce road deaths alongside improvements in road and infrastructure, and road users moving from motorcycles to safer cars, crash rates are still high. Therefore, there is a need to consider the impact of the driver on accidents in terms of behaviour, cognition, and attention.

2.4.2.1 Driving behaviour in Malaysia

Whilst there is a small amount of literature directly comparing drivers from the UK and Malaysia on driver cognition (described in section 2.4.1.3), research has also explored several behaviour related factors which may be linked to the increased crash risk in Malaysia.

For example, an on-road observation of motorcyclist behaviour in Malaysia indicated that this group of road users are prone to engaging in risk taking behaviours. This is particularly true for younger riders, and those from lower income backgrounds (Borhan et al., 2018). Similarly, a survey comparing drivers from Malaysian and Singapore found that Malaysians are more willing to engage in risky driving behaviours than those from Singapore (a neighbouring high-income country) (Khan et al., 2015). This comparison also found that Malaysian drivers engage in more road violations such as drink driving and have more relaxed attitudes towards road safety overall.

Finally, Malaysian drivers have been found to engage in speeding when driving with 50% of the sampled Malaysian drivers reportedly ignoring the speed limit (Othman et al., 2015), with addition research suggesting that some drivers have relaxed attitudes towards speeding overall, and thus engage in it more regularly (Mohamad et al., 2019).

2.4.3 Summary

The research discussed in the final section of this literature review has demonstrated that there are differences in driver behaviour and cognition between cultures. The reasons for these differences are multifaceted and include overall traffic safety culture, different traffic rules, and exposure to different driving environments, however they may provide a valuable insight into different crash rates between countries. In particular this section highlighted the behaviour of Malaysian drivers and the differences in behaviour and cognition between drivers from Malaysia and the UK. Whilst this is a new and growing field within psychology, thus far very little research has explored whether there are cross-cultural differences in visual attention between drivers of different nationalities.

2.5 General summary

To conclude, this chapter has discussed the key literature across three areas of psychology relevant to this thesis. Within the driving literature, it has been shown that several factors can influence drivers' visual attention, with a particular focus being placed on the role of experience. However, although a lot is known about drivers' visual attention, this has often been limited to drivers from Western countries. Within the cross-cultural literature differences have been found in visual search between Western and East Asian participants, where one of the possible explanations for these differences in experience and exposure to a particular environment leading to differences in visual attention. A key argument in this thesis will be that experience (in the form of driving in a different country) will result in differences in visual search in a similar manner to the role of experience in terms of length of licensure. Finally, this chapter discussed some of the currently known differences in driver behaviour and cognition between drivers from different countries, as well as discussing the specific case of Malaysian drivers which will be a focus of the current research. Based on this past literature, the aim of this thesis is to explore whether the previously identified cross-cultural differences in visual search are present in driving by comparing drivers from the UK and Malaysia.

Chapter 3: Focus groups with Malaysian drivers

3.1 Introduction

As discussed in section 2.2, most research into drivers' visual attention has been conducted with drivers from Western countries (particularly the UK), whilst less research has been conducted with Malaysian drivers. The research in this thesis will be comparing drivers from the UK and Malaysia but will be conducted in the UK by a British researcher, with limited first-hand experience of driving in Malaysia and the Malaysian road environment.

From the points outlined in section 2.4.2 it is clear that there are differences in the road environment between the UK and Malaysia. These differences include the road infrastructure in Malaysia (Malaysian Institute of Road Safety Research, 2017), the differences in traffic composition particularly the higher proportion of motorcycles compared to the UK (Manan & Várhelyi, 2012) and the overall increase in accident rates (World Health Organization, 2018). Whilst the existing literature and available government data may provide some information on the driving experience in Malaysia, and images and videos of the Malaysian road environment provide some information on the appearance of the roadway, this might not provide a detailed picture of the experience of Malaysian drivers. Instead, an alternative way to understand and provide a clearer picture of the driving experience and road environment in Malaysia is to speak to drivers themselves across a series of focus groups.

The aim of these focus groups is to answer three questions.

1. What is the overall experience of driving in Malaysia?

Ahead of conducting further research into the potential cultural differences in drivers' visual search, it is important to gain an understanding of the experience of driving in Malaysia. This will include a description of how the participants believe they behave themselves when driving, as well as the behaviour of other road users. In the past literature is has been shown that Malaysian road users (particularly motorcyclists) are willing to engage is risky behaviours (Borhan et al., 2018; Khan et al., 2015), with speeding being commonly observed (Mohamad et al., 2019; Othman et al., 2015). Whilst past data provide evidence of the prevalence of certain driving behaviours, the impact these behaviours will have on other road users has not yet been considered in the literature.

As well as the behaviour of road users, the focus group discussions will place on emphasis on the unwritten rules of the road. Each country will have their own set of rules for the road, these may be formal rules such as those presented in a highway code, or informal unwritten rules which all drivers use based on their individual culture (Lurie, 1968). As these unwritten rules will be known by the drivers from a particular country, it is useful to learn about these during the focus group discussions.

2. What does the Malaysian road environment look like?

Whilst it is possible to gain some understanding of the appearance of the physical road environment from existing sources as described above, speaking directly to road users will likely provide a more detailed picture of the road environment, and may produce extra information such as which aspects of the roadway are viewed as hazardous, items which may appear in the road unexpectedly, and hazards and are unique to Malaysian roads.

The purpose of gaining an understanding of the physical appearance of the road environment (and to some extent the experience of driving in Malaysia) is to allow later studies in this thesis to include trials and stimuli which accurately resemble the Malaysian road environment. When exploring cultural differences, it will be important to ensure that stimuli used do not just represent one country as this will be overly familiar to one group of participants. An alternative would be to use culturally ambiguous stimuli throughout; however, it will be interesting to explore whether the differences between UK and Malaysian roads lead to differences in visual attention when participants are presented with both sets of stimuli. Therefore, the data obtained from these focus groups can be used to design stimuli used in later experimental studies in this thesis to ensure they are an accurate representation of the Malaysian road environment.

3. Where do Malaysian drivers believe they look whilst driving?

In addition to learning about the driving experience and physical appearance of the Malaysian roadway, a final aim of these focus groups is to gain an initial insight into where drivers believe they may look when driving in Malaysia. In the first instance this will be based on participants' descriptions of the environment and their experiences on the road, where possible participants will be prompted to describe what aspects of the road environment attract their attention. Second, it may be useful to understand where drivers are taught to look during driver training.

3.2 Method

For this research a series of four focus group were conducted with Malaysian drivers. The number of focus groups was a result of the availability of Malaysian drivers willing to take part in the research, however it has been suggested that 90% of all themes in focus group analyses are discoverable based on three to six focus groups (Guest et al., 2017).

In order to achieve the stated aims of the study, a question guide was developed prior to data collection (this can be found in Appendix A). The questions focused on:

- Experiences of driving in Malaysia
- How this compares to the UK (either as a driver or a pedestrian and passenger)
- The unwritten rules on the road
- Ways in which drivers violate the rules on the road
- Visual attention whilst driving, and the visual environment on the road
- Driver training

This study received full ethical approval from the University of Nottingham School of Psychology ethics committee (reference: S1220).

3.2.1 Participants

Focus groups were ran with groups of 5-8 participants, all of whom were Malaysian drivers currently living in the UK and studying at the University of Nottingham. A total of 26 drivers (10 male, 16 female) participated across the four focus groups. Participants were aged between 20 and 26 ($M = 21.58$, $SD = 1.79$) and had been living in the UK for between 1 week, and 32 months ($M = 6.18$ months, $SD = 9.54$). Length of driving licensure ranged from 7 months to 8 years, with an average licensure of 3.63 years ($SD = 1.63$ years). In total, only 4 of the participants had previously driven in the UK.

3.2.2 Procedure

Focus groups were conducted in a seminar room in the University of Nottingham during February and March 2020. The room was private and allowed for no interruptions during the discussions. Participants and the researcher all sat around a large table to facilitate discussion between participants. Each focus group was run in a semi-structured manner, in which the pre-planned questions were used to guide the discussion, however the order of the questions and their level of probing could differ between sessions in order to allow the discussion to develop organically.

At the start of each focus group, participants were provided with an information sheet explaining the purpose of the research, a consent form, and a demographic questionnaire. Participants were instructed to be honest, open and to interact with each other and share their experiences. It was emphasised that anything said during the session would be anonymous and that any names would be removed from the transcript. Each group was audio recorded with consent from all participants.

3.2.3 Analysis

Recordings from each focus group (total length 185 minutes) were digitally transcribed using an automated transcription service. Transcripts were later checked for accuracy and clarity by comparing each transcript to the original audio recording. This also allowed familiarisation with the data ahead of coding. All stages of the analysis were conducted using NVivo software.

In order to answer the questions described above, a content analysis was used (Hsieh & Shannon, 2005). The research questions were set before data collection (as reflected in the question guide) however they were refined as a result of the data analysis, this allowed some initial research questions to be dropped in order to only report the findings most relevant to the current thesis. Whilst the questions were set prior to analysis, a flexible approach was taken which allowed the content to be coded both bottom-up and top-down.

The first stage of coding (open coding) identified individual units of information which were present in the data. This was achieved using a data driven bottom-up approach in which the codes were generated based on the data present in the transcripts. The aim of this process was to avoid researcher bias which might be present if data was entirely coded using a top-down approach from the research questions.

In the second stage of coding these individual units were grouped into separate categories where units shared a similar theme or concept. This was influenced predominately by the data however there were consideration to how these categories would map onto the overall topics, meaning that this data was also coded in a top-down manner (these categories can be found in Table 3.1).

Finally, these individual categories were grouped into four higher order topics which were linked to the initial research questions. This final stage was both based on the data (bottom-up) as well as the research questions set out at the start of the study (top-down).

Across the entire coding process all decisions were record, and reflexivity was considered throughout. One particular consideration was that of researcher bias as an outside (not a Malaysian driver). Regular reflection aimed to minimise the influence of these biases, whilst acknowledging the challenges of coding qualitative data from an outsider perspective. The focus was always on ensuring that the interpretations remained true to the participants' narratives.

3.3 Results

The four higher order topics of conversation (including their lower order categories) and their number of references can be found in Table 3.1. The individual items which made up each of the categories can be found in Table 3.2.

Table 3.1: Content analysis topics and categories

Topic and category	Number of references	Number of groups	Average number of references	Average % coverage
Experience of driving in Malaysia	**36**	**4**	**9**	**8.23%**
Chaotic roads	15	4	3.75	2.81%
Dangerous roads	14	4	3.5	3.59%
Constant vigilance	7	3	1.75	1.83%
What do the roads look like	**60**	**4**	**15**	**27.79%**
Clutter and distractions	20	4	5	10.32%
Road infrastructure	16	4	4	8.41%
Traffic	24	4	6	13.45%
Other road users	**76**	**4**	**19**	**27.83%**
Motorcyclists	12	4	3	9.16%
Behaviour	46	4	6	9.90%
Rule violations	40	4	10	13.49%
Where do people look	**31**	**4**	**7.75**	**15.70%**
General looking behaviour	17	4	4.25	9.11%
Distractions	14	4	3.5	7.21%

Table 3.2: Individual items in each category and topic

Topic	Category	Individual items
Experience of driving in Malaysia	Chaotic roads	Asian roads; Chaos; Frustration
	Dangerous roads	Danger; Hazards; Scary; Stress
	Constant vigilance	Alertness and awareness; Monitoring
What do the roads look like	Clutter and distraction	Accidents; Animals and wildlife; Distractions; Light; Roadside adverts; Rubbish; Sensory overload
	Road infrastructure	Maintenance; Parking; Potholes; Road signage; Roadway; Weather
	Traffic	Frustration; Traffic density

Other road users	Motorcyclists	Attending to motorcyclists; Risky; Status
	Behaviour	Aggression; Anger; Bullying; Owning the road; Recklessness
	Rule violations	Enforcement; Indicators/ signalling; Legal guidance; Speeding; Unwritten rules
Where do people look	General looking behaviour	Attention; Driver training; Mirrors;
	Distractions	Adaptation; Animals and wildlife; Roadside adverts; Rubbish

3.3.1 The experience of driving in Malaysia

At the start of each focus group, participants were asked how they would describe driving in Malaysia. Two words which were often used to describe driving in Malaysia were “chaotic” and “scary”. When explaining what makes driving in Malaysia so chaotic, participants reported that “there’s not really hard regulations on how we drive” and “people are not as friendly in Malaysia when it comes to driving.” Participants also described particular road users as being scary (motorcyclists and bus drivers) due to their speed and unpredictable behaviour.

Similarly, participants believed that driving in Malaysia was “dangerous”, with one participant saying “there are certain risks involved” when driving in Malaysia. Certain aspects of driving were described as particularly dangerous such as driving during bad weather or interacting with motorcyclists (who themselves were described as dangerous road users, discussed further in section 3.3.3).

In order to deal with the chaotic and dangerous road environment, participants reported that they had to remain alert and aware, described as “constantly monitoring” the environment, with one participant stating that “you've got to be very alert on the road when you're driving in Malaysia because someone could just like cut you in front and you wouldn't know. So that's one thing that we've got to be very vigilant about.”

3.3.2 What do the roads in Malaysia look like?

A large amount of discussion was dedicated to describing the look of the roadway in Malaysia, and the kinds of things drivers encounter on the road. Participants mentioned visual clutter and visual distractions in the form of objects by the side of the road and in the roadway. This included rubbish, other miscellaneous objects, and occasionally dead animals. In many cases participants described instances in which objects moved into the roadway and caused a hazard. One participant described the following incident.

> "I've seen tyres on the road I've seen tissue paper thrown all over the road on a highway like all across all lanes right down the highway. I think probably must have been like a truck carrying loads of tissue papers, like spilt them all over the road. It was really scary because in Malaysia it gets really like rainy and windy and we have like thunderstorms, and it is scary to drive in really heavy rains because you can't really see what's in front of you. Because when you have heavy rains like your whole your windscreen just goes white and so it's kind of scary and like when things start flying on your screens."

Aside from the distraction of encountering objects in the roadway, some participants said they found themselves being distracted by the visual clutter by the side of the road and often found themselves looking at it, with one participant describing this as "sensory overload". However, others noted that they were used to this and were able to ignore these distractions and after the first year of driving they reported that they "know what's coming so just ignore it". This is discussed further in section 3.3.4 in relation to where drivers believe they look on the road.

Another roadside object commonly mentioned was roadside advertisements. This included both static billboards, and digital LED billboards. These were reported as being highly present on Malaysian roads. Some described the LED billboards as distracting, particularly when driving at night and seeing the bright lights from the billboard. However, as with roadside clutter many participants said that they were used to seeing these billboards and the main distraction they encountered from them was the brightness of the light.

Participants also discussed the road infrastructure and overall quality of the road network. The roads were described as "complicated" by one participant, with many also commenting on the quality of the roads which they believed were not smooth and were poorly maintained. Across all four focus groups participants placed on emphasis on the prevalence of potholes on the road. These were described as widespread and an annoyance, as well as being hazardous with participants saying that they often had to swerve to avoid potholes. When asked to describe the appearance of Malaysian roads, one participant responded by saying:

> "Plenty of potholes. So there is a joke, like how you know drunk people when you see them driving on a road in the UK they would be like everywhere, but if they drive straight, it means that there sober. So it's the other way in Malaysia. So if you

> start seeing drivers going like that it means they're sober, but if they're going straight riding through the potholes, they are probably drunk."

Road signage was also described by some as a distraction, with participants reporting instances where road signs were obstructed with "trees just covering half the sign sometimes" or signed being "stuck with stickers promoting things". Road signs were also described as being poorly maintained, damaged, and vandalised.

Parking on the road was also discussed when describing the roadway. Participants reported that drivers often park "literally anywhere your car fits". This also included double parking in which cars park next to each other and block another car into a space. One participant described an instance in which cars double parked by parking side by side in the roadway, resulting in the width of the roadway narrowing due to parking on both sides. This then resulted in cars being parked in the middle of the roadway after other cars moved. "It's scary when the event ends and then some of the cars go and then there's just one car in the middle of the road. He's just parking there".

Finally, a large amount of discussion was dedicated to the topic of traffic and traffic jams. All participants described the large amount of traffic on Malaysian roads and the prevalence of traffic jams. They described instances in which short journeys could take up to 3 hours to complete, with some drivers leaving their cars due to the traffic not moving. Although this was not seen as hazardous by drivers (due to the lack of movement of vehicles) it was described as an annoyance.

3.3.3 Other road users

A large amount of time was dedicated to discussing other road users including the types of vehicles present on the road, and their behaviour when driving. When discussing other road users, the most common topic of discussion was motorcyclists and other powered two wheelers. Motorcycles are highly prevalent on Malaysian roads and were discussed by participants in all focus groups. Participants believed that motorcycles had "no respect for the roads" and described them as "zooming in and out of traffic". They were described as "frustrating" and for most participants, one of the biggest hazards on the road.

Motorcyclists were seen as aggressive on the roads with participants reporting instances in which they "just pass by and hit your side mirrors" or "they just hit my car and then they left". Similarly, one driver reported instances in which they tried to get the attention of a slow-moving motorcyclist but received an aggressive response.

> "The most annoying ones are the ones who like they can't keep up with speed, but they like drive right in the middle of your road like right in the middle in front of you and like they're just blocking the way and they can't move quick. And if you honk them or you flash your lights they like, turn around, give you a finger or something."

Participants also said that they were always vigilant and looking out for motorcyclists, but believed they were often hard to spot, especially in cases with poor lighting or when a motorcyclist is wearing all black. Instead, participants said they could often hear them approaching before seeing them.

When describing the behaviour of road users in general (which could include motorcyclists), participants reported that there are "a lot of reckless drivers" on Malaysian roads, and described other road users as "aggressive", "hot tempered" and "crazy". When discussing reckless driving, one participant said that it was often linked to drivers feeling they owned the road. There was a general belief amongst participants that other road users saw themselves as having control over the road and always having the right of way. These views are shown in the following two quotes.

> "It's even engrained in the language we use on the road really. It's like, if people drive crazy you say, you think it's your father's road, or you think it's your grandfather's road. It implies that if you're driving crazy because it's your road, your father's road, your family's road."

> "They feel like they have the right of way, even if you, say you were stationary and then they might not know that any moment you might move right. They just come in front of you. As though they have right of way. And then if you start moving again, sometimes they come so fast you don't even see them, or the blind spot, right? And yeah, they just become very aggressive and then they will ask you to wind down your mirror and you don't wind down your mirror because they will start shouting."

Other road users were also said to assert their dominance on the road, which some participants described as "bullying", there were also several reported instances in which other road users were rude. For example, one participant reported that they did not like to use their indicator because another road users will try to prevent you from changing lanes and driving in front of them by speeding up before you can make a manoeuvre.

Finally, in relation to other road users, participants discussed several ways in which drivers and motorcyclists violate the rules of the road. When describing driving in Malaysia, one participant said, “there’s not really hard regulation on how we drive around so we can speed and everything”. This was the case for both other road users, and the participants themselves when describing their own behaviour on the road. With this, the most commonly reported rule violation was speeding. This was seen as widespread and something almost all drivers engage in, with one participant describing speeding as part of the driving culture in Malaysia. Another rule which was commonly violated was drivers not using indicators to signal their turns or lane changes. This was again described as a very common occurrence, and very frustrating to the participants.

3.3.4 Where do people look when driving?

Participants described where they would typically look whilst driving in Malaysia. Whilst this topic has links to the previous topics discussed, it emerged independently as a topic of conversation across the four focus groups.

Overall, when asked about where they look whilst driving, most participants described the ways they were taught to look from their time learning to drive. This was often more formalised with participants reporting looking at their rear-view and side mirrors, as well as their blind spots. Participants were somewhat less aware of where they looked on the roadway itself. Some described how there is often nothing to look at (particularly when driving along a highway) and instead said they looked at their speedometer. However, in suburban environments participants described how they had to look out for distractions and objects entering the roadway. This included rubbish such as plastic bags blowing into drivers’ windscreens, stray or wild animals walking into the roadway, and pedestrians. In the case of pedestrians, one participant reported that “some people cross like suddenly. Like if you're speeding, you wonder who's crossing or who’s going because they wouldn't expect you. Then you won’t know what’s like going on there.”

Several participants said their attention would be drawn to visual clutter in and around the road (as described in section 3.3.2). Participants reported that this kind of clutter could be attention grabbing and difficult to ignore, whereas other reported actively looking at roadside clutter or billboards. However as previously discussed, participants did believe that they became better at ignoring this kind of clutter over time.

Participants also discussed how they spend a lot of time looking at other vehicles on the road (see section 3.3.3), particularly through their mirrors, to determine how fast they are approaching or to predict their behaviour. When looking at other vehicles, participants described this as "constant monitoring" as was seen as a necessary skill in order to drive in Malaysia.

3.4 Discussion

The results presented in this chapter provide an insight into the experience of driving in Malaysia, the physical appearance of the roadway, and some indications of where Malaysian drivers believe they may look when driving.

Across all the focus groups, there was a consensus that driving in Malaysia was chaotic and dangerous. The chaotic nature of the Malaysian road environment comes from a combination of factors including the amount of traffic and proportion of motorcycles on the road, the behaviour of other road users, and the overall quality of the roadway (including things like potholes). Descriptions of other road users (particularly motorcyclists) driving in a reckless manner and engaging in several rule violations are consistent with past literature showing a high willingness to engage in risky driving behaviour amongst Malaysian road users (Borhan et al., 2018; Khan et al., 2015). Although not explicitly explored in past research, it could be argued that the mixture or new and old infrastructure on Malaysian roads including a large proportion of low quality roads could contribute to the chaotic nature of driving in Malaysia described by participants (Malaysian Institute of Road Safety Research, 2017).

Participants' descriptions of the physical environment were also supported by past literature including descriptions of poor road quality (Malaysian Institute of Road Safety Research, 2017), the high prevalence of motorcycles and powered two wheelers (PTWs) (World Health Organization, 2018), and the presence of LED billboards (Yellappan et al., 2016). The discussion of objects unexpectedly entering the roadway has not been discussed in the past literature, however being aware of this fact is useful in helping to understand the increase in hazards on Malaysian roads, and why participants described the driving environment as chaotic and dangerous.

In linking these findings to visual attention and where drivers may look, the data presented in this chapter provide further evidence that East Asian environments (in this case Malaysian roads) are more visually cluttered than Western environments. This supports the research from Miyamoto et al. (2006) which suggests that East Asian environment contain more visual clutter, with this leading to differences in visual search. The environmental affordances argument suggests that as a result of increased visual clutter in the environment, East Asians use a visual search strategy which involves more attention being allocated to background aspects of a visual scene in a holistic manner.

The focus group data does provide some evidence that the increased visual clutter on Malaysian roads may lead to a more holistic attentional style. When participants described the need for constant monitoring and increased alertness, they are likely referring to the need to attend to the scene as a whole and take in a large amount of visual information in order to drive safely.

In order to take in a lot of information on the road, one would assume that Malaysian drivers should have a wider spread of attention. In the driving literature, a wider spread of attention has been demonstrated as a result of driving experience in terms of length of licensure (Crundall & Underwood, 1998; Underwood et al., 2002), however the current findings suggest that these differences may also be present as a result of driving in a Malaysian driving environment. Participants also reported looking at several objects outside of the roadway such as roadside clutter and billboards. This may provide further support for the argument that East Asians attend more to background aspects of a visual scene vs focal objects. Based on the findings from these focus groups, both of these points will be explored further in later experimental studies.

3.4.1 Limitations

As with all qualitative data, there is a trade-off to be made between obtaining in-depth data from a small sample or having a larger sample size. In the current study the small sample size will not be representative of all Malaysian drivers. This is particularly true as the sampled participants, although regular drivers, could still be considered new drivers. Whilst this may be a limitation when interpreting results regarding to the driving experience and how comfortable drivers are on the road, novice drivers are still able to accurately describe the physical appearance of the roadway and the behaviour of other road users as these descriptions should not be influence by the number of years spent driving. Similarly, the current research only includes data from the perspective of a car driver. There is a lack of data from motorcyclists or riders of other PTWs which are more common in Malaysia.

Despite these limitations it should be noted that the drivers sampled in the current study will be representative of the participants who will participate in future studies presented in this research.

Another limitation of this research is the lack of UK drivers as a comparison group. Initially, it was planned to conduct an equal number of focus groups with UK drivers living in Malaysia to understand the experience of driving in Malaysia from the UK driver perspective. However, due to the restrictions on international travel during the COVID-19 pandemic it was not possible to recruit UK drivers in Malaysia even with the option of collecting data online.

Although this is a limitation, the findings from Malaysian drivers alone still present an in-depth understanding of the experience of driving Malaysia. It is also believed that this is the first such study to explore the overall experience of driving in Malaysia using a qualitative approach. The data from Malaysian drivers will be used throughout this thesis whilst also having the potential to influence future research studies. However, future research may wish to compare the experiences of drivers from both countries.

3.4.2 Using these findings in the design of future studies

As described earlier in this chapter, the goal of this research was to gain a better understanding of the Malaysian driving environment based on the responses of Malaysian drivers. In the remaining studies in this thesis participants will be presented with a mixture of stimuli which resemble the UK and Malaysian road environments. There are two main reasons for this. First, by having stimuli from both countries it will ensure that any cultural differences which emerge are not simply the result of stimuli only being familiar to drivers from one nationality (i.e., in the case of only using UK stimuli which are unfamiliar to Malaysian participants).

Second, by having stimuli from both countries it becomes possible to see if participants' visual search differs when driving in an environment they are more familiar with as opposed to a novel environment. Similarly, it is possible to test whether visual search differs amongst participants as they drive in a more complex or novel environment (as previously seen in the cultural priming studies described in section 2.3.2.2)

From the results obtained in this study, several steps will be taken to ensure Malaysian stimuli accurately reflect the Malaysian road environment based on the views of the focus group participants.

1. Malaysian roads should include a higher traffic density than UK roads. This can be achieved by increasing the number of vehicles present in driving simulator studies, and selecting images of Malaysian roads which contain a large amount of traffic.

2. This traffic should consist of a larger proportion of motorcycles than are present on UK roads.
3. Where stimuli are dynamic (such as driving simulator studies) the behaviour of other vehicles on the road should reflect the behaviour of real Malaysian road users where possible. This would include vehicles driving at a higher speed, performing more aggressive manoeuvres, and driving in a less predictable manner.
4. Malaysian stimuli should involve more visual clutter in terms of the number of objects present in the environment compared to UK stimuli. This will include aspects such as native foliage, roadside objects, and billboards.

3.4.3 Conclusions

In conclusion, the current study set out to explore the experience of driving in Malaysia and the physical appearance of the road environment from the perspective of Malaysian drivers. Results revealed that participants view driving in Malaysia to be chaotic or scary, and describe the roads as visually cluttered due to other road users such as motorcyclists, and distractions such as roadside clutter and billboards. These findings will later be used to influence the design of future studies and stimuli to ensure that Malaysian stimuli are an accurate representation of the Malaysian roadway.

Chapter 4: Where do drivers choose to look?

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4.1 Introduction

As discussed in section 2.2.3.3 attention whilst driving can be allocated in either a controlled or an automatic manner (Trick & Enns, 2009; Trick et al., 2004). Whilst modes of attention such as automatic reflexes (i.e. an emergency service vehicle appearing and grabbing your attention) are unlikely to differ between drivers from different countries, more controlled modes of attention such as choosing where to look have the potential to differ between drivers.

Previous research with UK drivers has shown that there are differences in where drivers self-report choosing to look in driving scenes as a result of different levels of driving experience. It was shown that when drivers are asked to select which regions of the roadway they would attend to, novice drivers consistently fail to prioritise key regions such as rear-view mirrors and side roads (Konstantopoulos & Crundall, 2008). This suggests that experience can impact visual attention 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).

In Chapter 3: Malaysian drivers described where they look when driving. Participants reported looking at things such as other road users and other relevant aspects of the scene, but also reported looking at roadside clutter, billboards, and other potentially irrelevant aspects of the driving scene (section 3.3.4). Participants also described having to constantly monitor the visual environment due to its high visual complexity. These findings provided some initial evidence on where Malaysian drivers might choose to look when driving, but did not provide a comparison to drivers from the UK.

The cross-cultural literature on visual attention (section 2.3) suggests that Eastern viewers are more likely to attend to background aspects of a visual scene than Westerners (Nisbett

& Masuda, 2003). Based on the data described in Chapter 3, it could be argued that reporting attending to roadside clutter and billboards could be seen as attending to the background aspects of the visual scene, whereas attending to vehicles and objects straight ahead would be considered attending to focal objects.

Attending to these background aspects of the scene could also be associated with a wider spread of visual search on the road. As previously discussed, 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 cross-cultural literature), 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.

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 were collected online (due to restrictions on in-person testing at the time of data collection) with the aim of exploring whether drivers Malaysian and 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.

Several hypotheses are made in this study. First, it was hypothesised that Malaysians would have wider horizontal and vertical distributions of visual search (reflected by clicks on regions further from the centre of the image/ the focus of expansion [FOE]) than UK participants. Second, in relation to road type it was hypothesised 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).

Third, it was 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.

Finally, if it is the case that any cultural differences are a result of differences in self-construal it would be hypothesised that a wider distribution of clicks and more clicks in background regions would correlate with interdependent self-construal, whilst a narrower distribution and more clicks on focal regions would correlate with independent self-construal.

4.2 Method

4.2.1 Design

The study utilised a 2 x 2 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.

4.2.2 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 4.1.

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

Table 4.1: 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	.004	.44
Driving experience (years)	0.67-44.83	7.35 (8.66)	0.92-20	5.16 (4.31)	2.13	.035	.33
Annual mileage*	30-40000	5631.69 (6079.16)	1.24-31068.50	4872.13 (5883.26)	0.84	.403	.13
Hours driven per week	0-30	4.79 (4.57)	0-35	6.82 (5.16)	2.79	.006	.41
SCS Independence	3.13-6.40	4.68 (0.64)	2.87-7.00	4.78 (0.67)	1.04	.301	.15
SCS Interdependence	2.53-6.00	4.62 (0.60)	3.60-6.77	5.00 (0.58)	4.29	<.001	.63

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

4.2.3 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 Figure 4.1 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.

Figure 4.1: Examples of images used for suburban housing areas in the UK (left) and Malaysia (right).

4.2.4 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. Participants were also asked to complete the 30 item Self-Construal Scale (SCS) (Singelis, 1994). This scale is by far the most widely used measure of self-construal in the cross-cultural literature. The scale is also based on the original definition of self-construal from Markus and Kitayama (1991), which means that both independent and interdependent self-construal are measured separately as orthogonal dimensions (demonstrating that individuals can hold independent and interdependent traits simultaneously) as opposed to opposite ends of one spectrum (Cross et al., 2011). Whilst a variety of other measures exist in the literature (see Cross et al., 2011 for a review) the SCS is a reliable and widely used measure and is therefore used throughout this thesis to measure self-construal.

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 Figure 4.2). 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.

Figure 4.2: Example of participant making response to an image of a UK motorway. Blue circles represent the location of each individual click

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 minutes on average to complete.

4.2.5 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.

4.3 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 4.1). 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 ($r = -.24$, $p = .001$) and the proportion of focal regions selected ($r = -.24$, $p = .001$) as well as correlations between experience and vertical distribution of search ($r = -.21$, $p = .004$) and the proportion of focal regions selected ($r = -.22$, $p = .002$). 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 ($r = .92$, $p<.001$), 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 ($t(185) = .68$, $p = .51$, $d = .01$). There were correlations between screen size and the proportion of context relevant regions selected ($r = .42$, $p<.001$), the proportion of context irrelevant regions selected ($r = -.33$, $p<.001$), and the distribution of clicks in the vertical axis ($r = -.26$, $p<.001$). However these were similar across both nationalities therefore screen size was not controlled for in the remaining analyses.

4.3.1 Response time

Response time data was skewed so a log transformation was preformed to normalise the data for analysis purposes. Analyses of the transformed data and backtransformed means are reported. The average response time across all trials was 16.60s (SD = 8.48). A univariate analysis (controlling for licensure) found that this was higher for Malaysian participants (M = 18.59s, SD = 9.56) than UK participants (M = 14.62s, SD = 6.83) ($F(1, 177) = 10.45$, $p = .001$, $\eta_p^2 = .06$). This was underpinned by Malaysian participants taking longer between their first and final clicks (M = 13.37s, SD = 8.51) than UK participants (M = 9.78s, SD = 7.15) ($F(1, 177) = 13.59$, $p<.001$, $\eta_p^2 =.07$). There were no differences between participant groups in the time between being first presented with the image and making their first selection ($F(1, 177) = 1.79$, $p = .18$, $\eta_p^2 = .01$).

4.3.2 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 Figure 4.3 for an example).

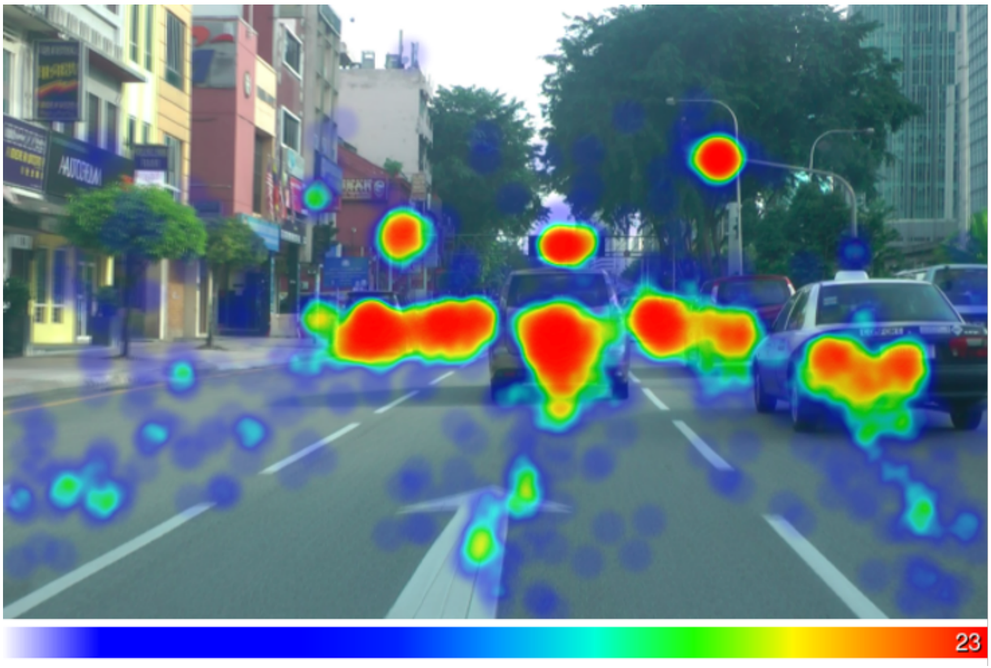

Figure 4.3: Distribution of clicks across all participants on a Malaysian city centre road

Both the horizontal and vertical distribution of clicks were analysed using 2 (nationality) x 2 (road country) mixed ANCOVAs. Means and standard deviations can be seen in Table 4.2. All data met the assumptions of normality and homogeneity of variance.

Table 4.2: Descriptive statistics for the distribution of clicks in both axes

	UK (n=87)		Malaysian (n=95)	
	M	SD	M	SD
Horizontal				
UK stimuli	233.15	67.76	243.70	69.35
Malaysian stimuli	316.50	61.14	325.05	62.78
Vertical				
UK stimuli	64.85	20.12	86.41	41.03
Malaysian stimuli	95.25	34.45	105.91	33.00

For the horizontal distribution, there was no effect of nationality (F(1, 179) = 1.09, p = .30, η_p^2 = .01). However there was a main effect of road country (F(1, 179) = 415.11, p<.001, η_p^2 = .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) = .12, p = .73, η_p^2 = .001).

In the vertical axis there was a main effect of nationality (F(1, 179) = 10.82, p = .001, η_p^2 = .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, p <.001, η_p^2 = .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, p = 0.02 , η_p^2 = .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, p<.001, η_p^2 = .09). Whilst there was no difference between participant groups when viewing images of Malaysian roads (F(1, 179) = 3.06, p = .08, η_p^2 = .02) (see Figure 4.4).

There were no significant correlations between the proportion of clicks in any region, or individual object categories, and higher levels of independence or interdependence as measured by the SCS (all ps>.05).

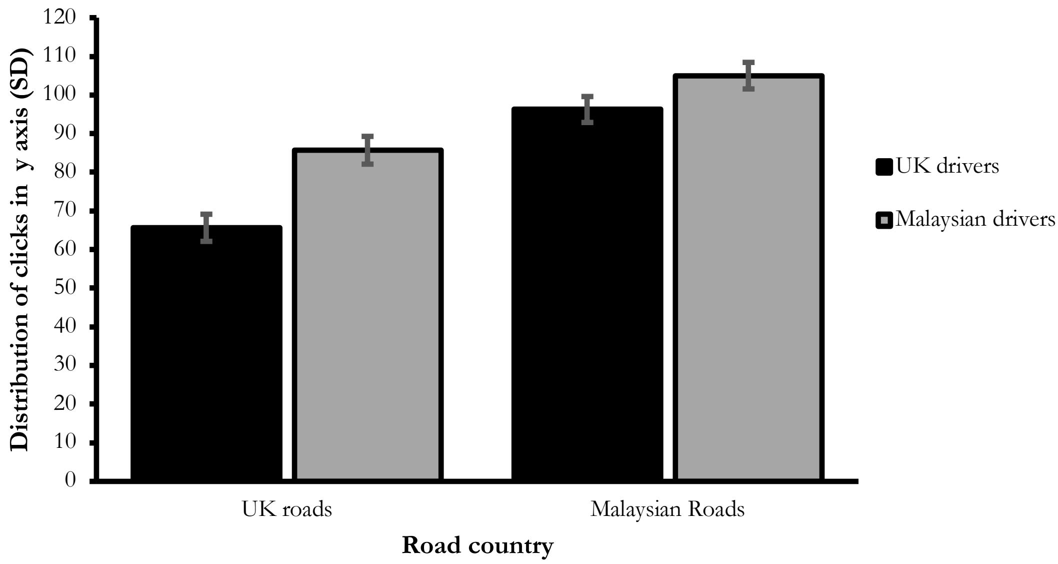

Figure 4.4: Distribution of clicks in the y axis as a function of nationality and road country (± 1 SEM)

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 compared the proportion of first clicks in each region between nationalities, descriptive statistics can be seen in Table 4.3. Analyses revealed no differences between UK and Malaysian drivers on the proportion of first clicks in focal regions (F(1, 172) = 3.12, p = .08, η_p^2 = .02), context relevant regions (F(1, 172) = 2.77, p = .10, η_p^2 = .02), or context irrelevant regions (F(1, 172) = .48, p = .49, η_p^2 <.00).

Table 4.3: Descriptive statistics for the proportion of first clicks in each region

	UK (n=81)		Malaysian (n=94)	
	M	SD	M	SD
Proportion of first clicks				
Focal	45.81	24.28	52.47	24.28
Context relevant	39.06	19.83	33.82	19.90
Context irrelevant	15.13	13.34	13.71	14.70

Table 4.4: Descriptive statistics for the proportion of clicks in each region

	UK (n=87)		Malaysian (n=95)	
	M	SD	M	SD
Focal v Background				
Focal	27.05	9.78	29.61	10.74
Background	72.95	9.78	70.39	10.74
Context relevant v irrelevant				
Context relevant	49.89	10.00	43.85	10.79
Context irrelevant	23.06	13.97	26.53	14.80

The descriptive statistics for the proportion of clicks in each region can be seen in Table 4.4. All data met the assumptions of normality and homogeneity of variance. 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, p<.001, η_p^2 = .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, p<.001, η_p^2 = .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, p<.001, η_p^2 = .56).

In order to further examine attention to background/contextual aspects of the scenes, a 2 (nationality) x 2 (context relevance) 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, p<.001, η_p^2 = .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, p = .22, η_p^2 = .01) but there was a two-way interaction between nationality and region type (F(1, 179) = 8.10, p = .01, η_p^2 = .04). As can be seen in Figure 4.5 (context relevant and context irrelevant), UK participants selected more context relevant regions than Malaysian participants F(1, 179) = 7.87, p <.001, η_p^2 = .07) and Malaysian participants selected marginally more context irrelevant regions than UK participants (F(1, 179) = 3.41, p = .07, η_p^2 = .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, p <.001, η_p^2 = .49) than Malaysian participants (F(1, 93) = 18.88, p <.001, η_p^2 = .17).

There were no significant correlations between distribution of clicks across either the horizontal or vertical axes, and higher levels of independence or interdependence as measured by the SCS (all ps>.05).

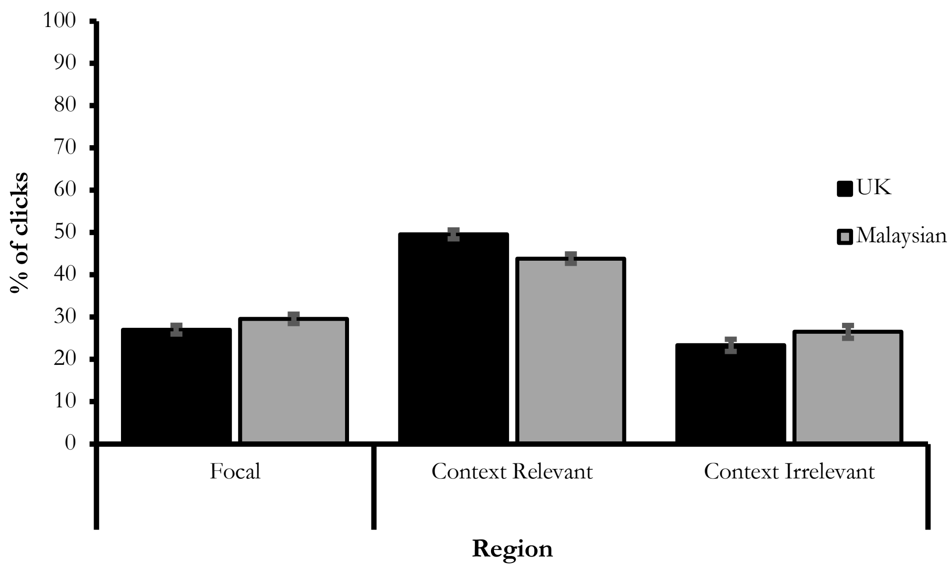

Figure 4.5: The average proportion of clicks made by participants from both countries in each of the three regions (± 1 SEM)

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. Figure 4.6 shows a breakdown of the objects contained within each region. As previously described (in section 4.2.5), 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 revealed an effect of nationality on the proportion of other vehicles selected ($F(1, 179) = 11.96$, $p = .001$, $\eta_p^2 = .06$) (UK > Malaysians), and a marginally significant difference in the proportion of general background space selected (background areas not containing a specific object) ($F(1, 179) = 6.81$, $p = .01$, $\eta_p^2 = .04$) (Malaysians > UK) (adjusted $\alpha = .008$ when corrected for multiple comparisons).

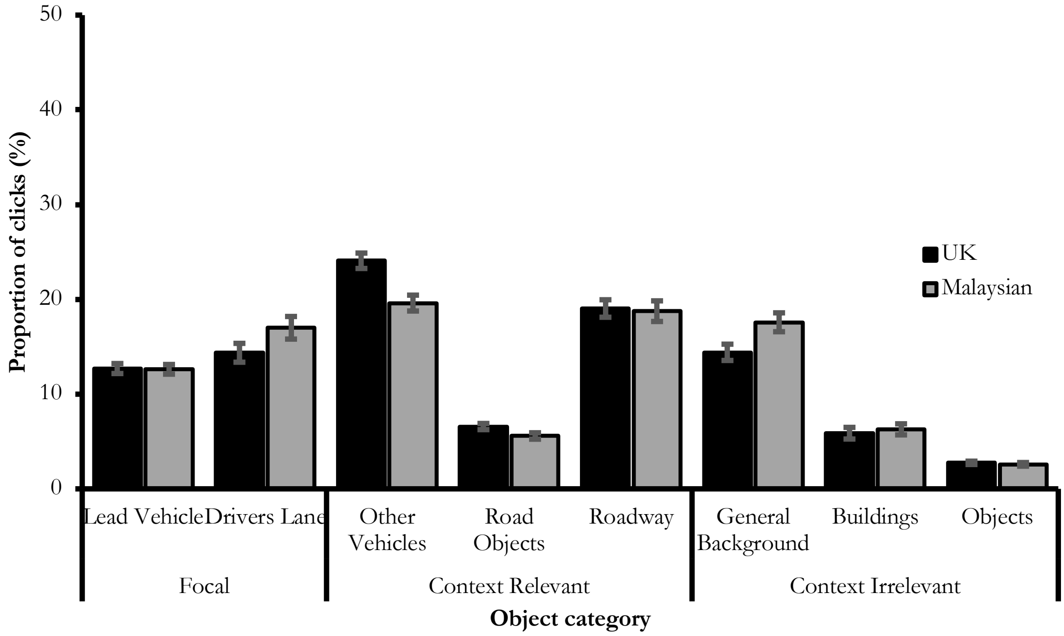

Figure 4.6: The average proportion of clicks made by participants from both countries across the different object categories (± 1 SEM)

4.4 Discussion

This study aimed to investigate whether drivers from Malaysia would choose to look at different areas of the roadway compared to drivers from the UK. Results revealed differences in how drivers from the two countries choose to look at non-focal objects.

4.4.1 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. 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 the initial hypothesis. 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 six 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), with attention often being measured using eye tracking. 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 (Chua et al., 2005; Masuda & Nisbett, 2001) 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 wider 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 such 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.

4.4.2 Focal and contextual regions

Contrary to the initial hypothesis, 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 the 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.

As there was no relationship between the proportion of clicks in any of the regions, and self-construal as measured by the SCS, it is likely that any cross-cultural differences observed are not the result of self-construal or culture, but instead are the result of experience and exposure to a particular road environment. 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 one's 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.

4.4.3 Limitations

Whilst these findings suggest that there may be differences in where drivers from the UK and Malaysia choose to look whilst driving, they should be considered within the context of 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.

4.4.4 Summary

To summarise, the findings presented in this chapter 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. The next step in this research is to explore these differences further using more dynamic stimuli which better represent the visual and cognitive demands of the driving task.

Chapter 5: Change detection in driving and non-driving scenes

5.1 Introduction

The results presented in Chapter 4 have provided some evidence that there may be differences in which aspects of the scene UK and Malaysian drivers choose to attend to. However as discussed in section 4.4.3 the previous study made use of static images as stimuli and gave participants an unlimited response time. Whilst this provided insight into where drivers believe they would choose to look, static images with an unlimited viewing time are not particularly representative of a dynamic driving environment due to the fact that drivers must attend to multiple sources of information in a visually complex and ever-changing environment.

A common way to investigate visual attention using more dynamic stimuli is through studies of change blindness, the phenomenon where an observer fails to notice a change in a visual stimulus (Rensink et al., 1997) (see section 2.2.1). Although there are several change blindness paradigms, the most common method used is the change detection flicker task. In this task, participants are presented with two images separated by a blank screen, the images are identical apart from one change, which the participant is tasked with identifying (Rensink et al., 1997; Simons & Rensink, 2005). As changes can only be detected in areas which are attended to, detection accuracy becomes a useful measure of visual attention. In addition, reaction times can provide an insight into which areas of the scene are attended to and prioritised first, as well as showing which changes require a longer processing time.

Change detection tasks have been used to explore attention across a variety of domains, including drivers' visual attention. As driving involves navigating through a complex and ever changing environment, the ability to detect changes can be seen as essential for safe driving (Caird et al., 2005). With that, it has been estimated that approximately 10% of accidents may be a result of drivers' failures to detect changes in the environment (Beanland et al., 2013).

Within change blindness studies, it is well established that people are better able to detect changes which are task relevant or related to an individual's expertise or knowledge (Rensink et al., 1997; Werner & Thies, 2000). Amongst drivers, studies have shown that they are better able to detect changes related to the driving task and safe driving, such as changes to vehicles and road signs due to the activation of a driving related schema whilst completing the task. With this drivers often fail to notice changes to aspects of the visual scene which are not related to safe driving, even if they would be considered highly salient and should be attended to through bottom-up processing (Beanland et al., 2017; Galpin et al., 2009; Lee et al., 2007; Mueller & Trick, 2013; Velichkovsky et al., 2002; Zhao et al., 2014).

Within the change detection and driving literature there is also some evidence that the visual complexity of the road environment can impact drivers' change detection. It has been demonstrated that changes on less cluttered, rural roads are more detectable than those on complex urban roads (Beanland et al., 2017; Filtness et al., 2020). This is likely a result of the increased perceptual load in highly complex environments, making change detection more difficult. This is particularly true for detecting safety irrelevant changes on complex urban roads (Filtness et al., 2020).

Although studies into drivers' change blindness provide an insight into where drivers allocate their attention when driving, as with several studies into drivers' visual attention the past research has predominantly focused on drivers from Western countries. However, outside of the driving domain change detection tasks have been used to explore cross-cultural differences in visual attention. As described in section 2.3.1 Masuda and Nisbett (2006) found that East Asian participants were more accurate and faster at detecting contextual background changes in a change blindness task compared to Western participants. Similar results have also been found when using a one shot paradigm as opposed to a flicker task (Miyamoto et al., 2006).

This previous research suggests that the ability to detect changes in a change blindness task may be influenced by several factors: the relevance of the change, the environment, past experience, and culture. The aim of the current research was to explore whether cultural differences in change detection emerge between UK and Malaysian participants when viewing driving related stimuli. In particular, the effects of the safety relevance of the change, and the change location were investigated. It was hypothesised that all drivers would be better able to detect safety relevant changes than safety irrelevant changes as reflected by higher accuracy and faster reaction times. Second, it was hypothesised that Malaysian drivers would be more accurate at detecting irrelevant changes in the background compared to UK drivers.

Finally, if it is the case that any cultural differences are a result of cultural background more so than exposure to a particular environment, it would by hypothesised that accuracy and faster RTs to background changes would correlate with interdependent self-construal, whilst accuracy and faster RTs to focal changes would correlate with independent self-construal.

5.2 Study 1

5.2.1 Method

5.2.1.1 Design

This study utilised a 2 x 2 x 3 x 2 mixed design where the between groups variable was the nationality of the participant (UK or Malaysian). The within groups variables were the country of the stimuli (UK or Malaysia), the region of the image where the change occurred (focal, background context relevant, or background context irrelevant), and the safety relevance of the change (relevant or irrelevant to safe driving). As it was not possible to create stimuli in which a change was categorised as "background task irrelevant" whilst also being safety relevant, safety relevance acted as a nested variable in which it was only manipulated for stimuli where the change was either focal or background context/ task relevant.

Several additional factors were systematically varied across the stimuli but were not used for analysis purposes. These include the types of roads used (rural, urban, suburban), the location of the change (left, centre, or right), and the change type (appear, disappear, change). The dependent variables were accuracy (the number of changes correctly identified), and reaction time in seconds.

5.2.1.2 Participants

Participants were recruited through online advertisements within the University of Nottingham UK and Malaysia campuses, as well as advertisements on social media. Initially 148 participants completed the study, however 53 were removed prior to analysis. Two participants were removed as they failed to complete all the trials in the experiment, whilst an additional six were removed as they failed to press the space bar to respond to any stimuli, and therefore had no reaction time data.

Forty-five (29 UK, 16 MY) participants were removed as their average RT to incorrect trials was less than 15s. It would be expected that participants' average RT for incorrect trials should be close to 30s as they should mostly be trials where the participant is unable to find the change and they should therefore watch all iterations of the image. However, preliminary analyses revealed a bimodal distribution for RTs to incorrect trials. This suggests that those with fast responses to incorrect trials actually did not complete the task correctly, and instead tried to skip these trials quickly in order to finish the experiment. An independent samples t-test revealed that those with incorrect RTs under 15s had a lower accuracy overall (M = 53.01%, SD = 17.34) than those with incorrect RTs over 15s (M = 71.54%, SD = 10.69) (t(138) = 7.77, p<.001).

The final sample of 95 participants consisted of 48 British (8 male, 40 female) and 47 Malaysian (16 male, 29 female, 2 other) participants. Further demographics and how these differed between groups can be found in Table 5.1. As with the study presented in Chapter 4, if there was a difference in length of driving licensure, this would be controlled for in all further analyses. All participants were eligible to enter a prize draw for one of two £20 vouchers, and undergraduate psychology students were able to receive course credit.

Table 5.1: Demographic data for Study 1

Nationality	UK (n=92)		Malaysian (n=95)		t-test		
	Range	*M* (SD)	*Range*	*M* (SD)	*t*	*p*	*d*
Age	18-27	20.00 (2.57)	18-42	23.35 (5.02)	4.10	<.001	.85
Driving experience (years)	0.58-10.42	2.53 (2.52)	0.17-26	6.16 (6.42)	3.65	<.001	.75
Annual mileage*	0-20000	4682.17 (4775.51)	0-50000	4959.82 (8414.44)	0.20	.846	.04
Hours driven per week	0-15	4.38 (4.03)	0-20	5.17 (4.78)	0.31	.382	.18
SCS Independence	3.33-5.60	4.39 (0.57)	3.27-6.27	4.80 (0.56)	3.28	.002	.70
SCS Interdependence	2.93-5.53	4.57 (0.56)	3.53-5.89	4.91 (0.51)	2.94	.004	.62

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

5.2.1.3 Stimuli

Stimuli were created by extracting still images from videos filmed from the perspective of a driver across a series of roads in the East Midlands in the UK, and the Klang Valley in Malaysia. In total there were 60 images (30 from each country) extracted to create stimuli for the study (48 change trials, 12 no-change trials). Table 5.2 outlines the types of trials used in the study, and a full list of images can be found in Appendix B.

Table 5.2: The types of trials used in Study 1

Country	Region	Safety relevance	Count	Example
UK	Focal	Relevant	4	A new vehicle entering the driver's lane
UK	Focal	Irrelevant	4	A logo on a lead vehicle being removed
UK	Background (Relevant)	Relevant	4	A speed limit sign decreasing from 40 to 30mph
UK	Background (Relevant)	Irrelevant	4	A school crossing sign changing to a roundabout sign
UK	Background (Irrelevant)	Irrelevant	8	The advert on a digital billboard changing
UK	No change	N/A	6	No change between images
Malaysia	Focal	Relevant	4	A lead vehicle braking (brake lights appearing)
Malaysia	Focal	Irrelevant	4	The colour of a lead vehicle changing
Malaysia	Background (Relevant)	Relevant	4	A traffic light changing from green to red
Malaysia	Background (Relevant)	Irrelevant	4	A spare tyre disappearing from the back of an SUV in another lane
Malaysia	Background (Irrelevant)	Irrelevant	8	A sign being removed from a roadside building
Malaysia	No change	N/A	6	No change between images

Prior to data collection, the images were piloted with a group of 5 drivers who did not then take part in the final study (3 from the UK who had only driven in the UK, 1 from the UK who had driven in both countries, and 1 Malaysian who had driven in both countries). To ensure that stimuli used in the final study were not too easy or too difficult, any stimuli with an accuracy below 20% were removed and replaced in the final stimuli set (no stimuli had an accuracy of 100% during piloting).

5.2.1.3.1 Change present trials

Changes were made in the 48 target trials using GIMP (GNU Image Manipulation Program). Changes either occurred in focal, background context relevant, or background context irrelevant objects. Focal referred to any region or object within the drivers' lane (the lane where the road was filmed from). This included lead vehicles and road markings. Background context relevant referred to regions or objects outside of the current lane which were still applicable to the driving task. This varied depending on the particular photo, but included other vehicles, signage, traffic lights, and pedestrians. Finally, background context irrelevant referred to any other regions or objects which were not relevant to the driving task. These included task irrelevant objects such as billboards and buildings.

Changes in focal and context relevant regions could either be directly relevant to the drivers' safety (i.e. vehicles appearing, changes to traffic lights, reduced speed limits) or be related to the driving task but not safety (i.e. vehicles changing colour), whereas context irrelevant changes were all safety irrelevant by nature. Examples of change present trials can be seen in Figure 5.1.

Figure 5.1: Examples of change detection stimuli. The top row shows a logo vanishing from a delivery van (focal safety irrelevant), the second row shows a speed limit change (context relevant safety relevant), the bottom row shows a window being removed from a building (context irrelevant).

5.2.1.4 Procedure

Participants were first presented with a short questionnaire containing questions related to general demographics, driving experience, and time spent living and driving in other countries. They were then directed to the main experimental task. This experiment was completed online on participants' own devices, therefore it was not possible to control for viewing distance.

The experimental task was created using PsychoPy (Peirce, 2019) and presented online using Pavlovia (pavlovia.org). The change blindness task utilised a flicker paradigm in which the first image was presented for 1000ms, followed by a blank screen for 500ms, then the changed image for a further 1000ms, followed by another blank screen. This procedure was repeated up to 10 times (giving each trial a maximum duration of 30s), or until the participant made a response. In order to identify the change, participants were presented with the original image split into 9 sections, and were asked to identify via a keyboard response which section the change occurred in (see Figure 5.2). If participants saw no change, they were also able to respond pressing 0 to identify that no change occurred. Participants were initially presented with four practice trials in which they received feedback, while no feedback was provided for the experimental trials. For the main trials stimuli were split into two blocks based on road country, with participants being randomly assigned to one of two orders. Within each block the 30 images were presented in a random order.

After the change blindness task, participants returned to the questionnaire and completed the self-construal scale (SCS) (Singelis, 1994). On average, the experiment took 45 minutes to complete.

This research received full ethical approval from the University of Nottingham School of Psychology (ref: S1294).

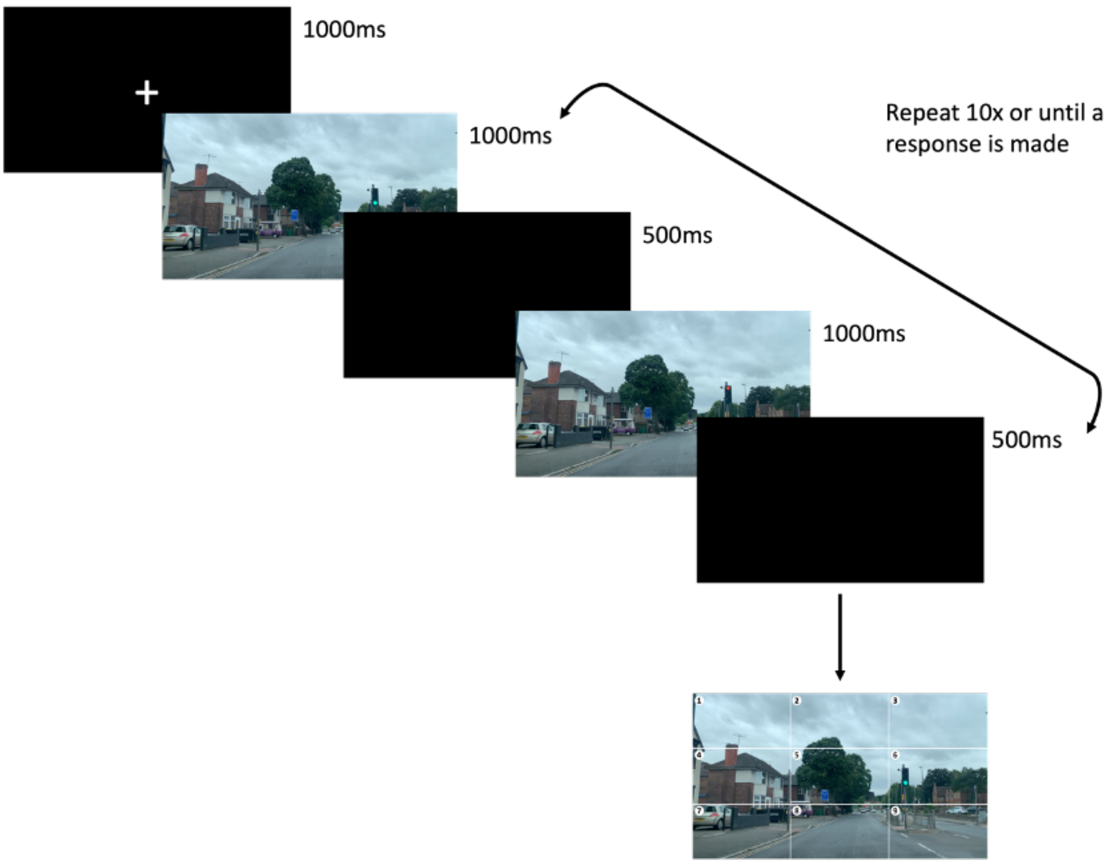

Figure 5.2: Trial progression sequence

5.2.1.5 Analysis

Only change present trials were used for analysis, with change absent trials acting as fillers during the experiment. For analysis purposes, average accuracy and RT to correct trials was calculated for each of the conditions. These were later entered into a series of repeated measures ANCOVAs (controlling for length of licensure). All data were analysed using SPSS v28.

5.2.2 Results

Independent samples t-tests found differences between UK and Malaysian participants on the variables of age, and driving licensure (see Table 5.1). To see whether these variables correlated with dependent variables, a series of bivariate correlations were conducted. There were no significant correlations between age or licensure for overall accuracy (Age: r = -.11, p = .31, Licensure: r = -.18, p = .08) or reaction time (Age: r = .06, p = .58, Licensure: r = .10, p = .35). A further correlation analysis revealed that licensure and age were highly correlated (r = .80, p<.001), therefore due to the significant difference in licensure between the two groups this was still used as a covariate in the remainder of the analyses (however age was not).

5.2.2.1 Accuracy

Participants' overall accuracy across the change present trials ranged from 37.50% to 86.50% (M = 71.53%, SD = 10.69). Descriptive statistics for each of the ANCOVAs exploring differences in accuracy can be seen in Table 5.3. Accuracy data met the assumptions for normality and homogeneity of variance.

Table 5.3: Mean accuracy for each of the three ANOVAs reported

	UK (n=48)		Malaysian (n=47)	
	M	SD	M	SD
Nationality x Country				
UK stimuli	75.17%	11.07	75.80%	10.16
Malaysian stimuli	68.31%	12.91	66.84%	13.90
Nationality x Safety Relevance				
Safety relevant	83.59%	12.87	85.90%	9.17
Safety Irrelevant	65.82%	11.88	64.03%	12.51
Nationality x Region				
Focal	71.61%	13.70	69.68%	12.36
Context Relevant	83.07%	14.47	83.38%	11.96
Context Irrelevant	60.55%	14.25	60.90%	17.65

In order to first establish whether there was an interaction between participants' nationality and stimuli country, a 2 (nationality) x 2 (country) mixed ANCOVA was conducted. Participants from both groups were equally accurate overall, with no effect of nationality being found ($F(1, 92) = .22$, $p = .64$, $\eta_p^2 = .002$). Although there was a main effect of country such that accuracy was higher for changes occurring on UK roads (M = 75.49%, SE = 1.08) than Malaysian roads (M = 67.59%, SE = 1.36) ($F(1, 92) = 23.34$, $p<.001$, $\eta_p^2 = .20$). There was no interaction between nationality and country ($F(1, 92) = .50$, $p = .48$, $\eta_p^2 = .01$). As it is difficult to match stimuli between countries, and given the lack of significant interaction between nationality and country, stimuli were collapsed against country for the remainder of the analyses.

To explore the effect of safety relevance, a 2 (nationality) x 2 (safety relevance) mixed ANCOVA was conducted. There was a significant main effect of safety relevance such that accuracy was higher when changes were relevant to driver safety (M = 84.75%, SE = 1.15) compared to safety irrelevant changes (M = 64.94%, SE = 1.23) ($F(1, 92) = 157.82$, $p<.001$, $\eta_p^2 = .63$). There was no main effect of nationality ($p = .48$) and no interaction ($p = .20$).

Finally, to explore the main hypothesised cross-cultural difference across the changes in different regions, a 2 (nationality) x 3 (region) mixed ANCOVA was conducted, with orthogonal contrasts comparing the difference between focal and combined background regions, and the two individual background regions (context relevant and irrelevant).

There was an overall main effect of region ($F(2, 184) = 50.52$, $p<.001$, $\eta_p^2 = .35$), but no significant interaction between nationality and region ($F(2, 184) = 1.17$, $p = .31$, $\eta_p^2 = .01$) (see Figure 5.3).

Orthogonal contrasts for the main effect of region revealed that accuracy was higher for background changes (average accuracy for context relevant and irrelevant) (M = 71.99%, SE = 1.48) compared to focal changes (M = 70.65%, SE = 1.35) ($F(1, 92) = 4.42$, $p = .04$, $\eta_p^2 = .05$). When comparing the two types of background change, accuracy was higher for context relevant changes (M = 83.24%, SE = 1.35) than irrelevant changes (M = 60.74%, SE = 1.61) ($F(1, 92) = 100.60$, $p<.001$, $\eta_p^2 = .52$).

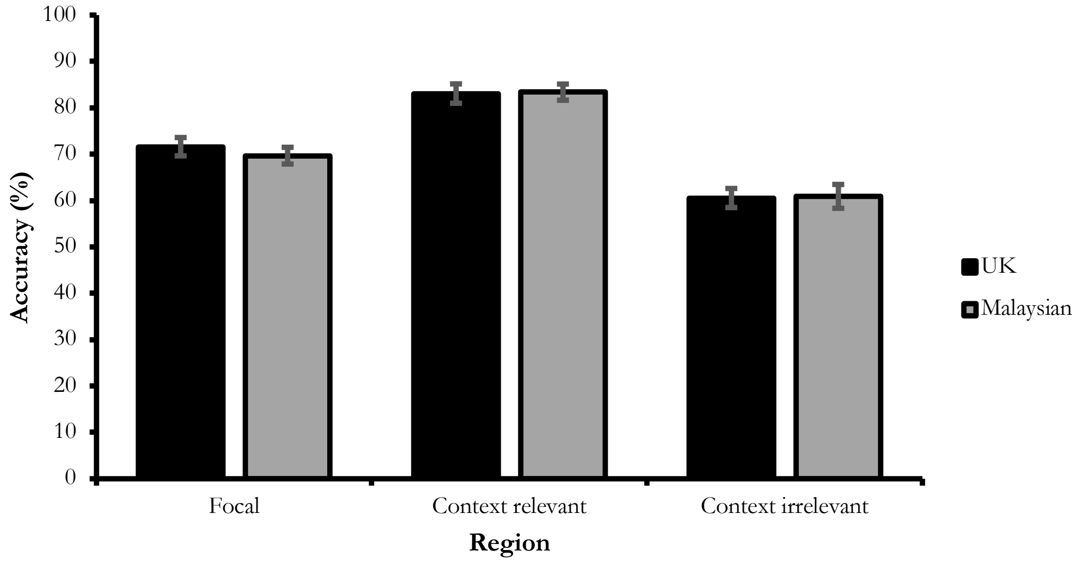

Figure 5.3: Accuracy for each region across both nationalities (± 1 SEM)

A final analysis aimed to explore whether the lack of cross-cultural effect in the previous analysis (as shown by the non-significant interaction between nationality and region) was due to the fact that the main effect of safety relevance was so large. It could be possible that any cross-cultural differences are masked by the large effect of safety relevance. For this analysis, all background changes which were safety irrelevant were averaged to be compared to safety irrelevant focal changes. Data were entered into a 2 (nationality) x 2 (region) mixed ANCOVA. Results once again revealed a significant main effect of region with accuracy being higher for background changes (M = 67.38%, SE = 1.37) compared to focal changes (M = 57.60%, SE = 1.91) ($F(1, 92) = 20.63$, $p<.001$, $\eta_p^2 = .18$). There was also a significant interaction ($F(1, 92) = 4.10$, $p = .05$, $\eta_p^2 = .04$) (see Figure 5.4). Bonferroni corrected pairwise comparisons revealed that this interaction was underpinned by a significant difference in accuracy between focal and background changes amongst Malaysian drivers, with accuracy being higher for background changes (MD = 14.27%, $p<.001$), whilst there was no difference for UK drivers (MD = 5.30%, $p = .08$).

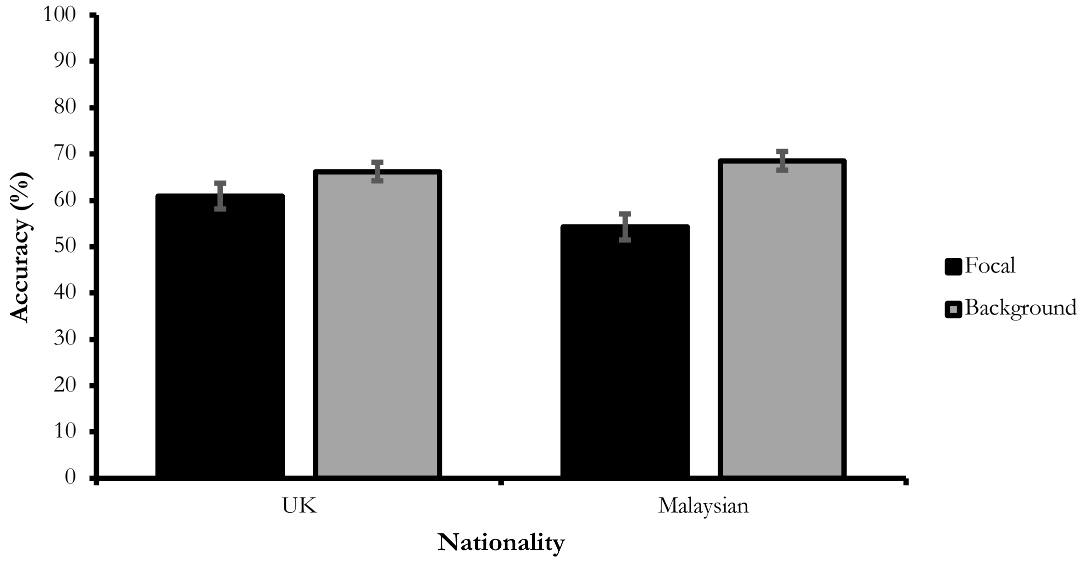

Figure 5.4: Accuracy for focal and background changes for safety irrelevant trials (± 1 SEM)

5.2.2.2 Reaction times

Participants' average reaction times (RTs) for correct trials ranged from 6.28s – 22.33s (M = 9.91s, SD = 2.36s). Preliminary analyses revealed a positive skew in RT data (z_{Skew} = 9.40, p<.001), therefore, data were log transformed for analysis purposes. Log means were then back transformed for the purpose of reporting. Descriptive statistics for the ANOVAs ran on RT can be found in Table 5.4. RT data met to assumption for homogeneity of variance.

Table 5.4: Backtransformed mean RTs in each of the three ANOVAs

	UK (n=48)		Malaysian (n=47)	
	M	SD	M	SD
Nationality x Country				
UK stimuli	8.84	1.23	9.21	1.35
Malaysian stimuli	9.91	1.23	10.57	1.26
Nationality x Safety Relevance				
Safety relevant	7.72	1.32	8.04	1.38
Safety Irrelevant	10.36	1.19	11.16	1.24
Nationality x Region				
Focal	8.63	1.27	8.49	1.36
Context Relevant	8.73	1.27	9.52	1.34
Context Irrelevant	10.80	1.30	11.68	1.29

As with accuracy a 2 (nationality) x 2 (country) mixed ANCOVA was first conducted. There was no main effect of nationality ($F(1, 92) = 1.01$, p = .32, $\eta_p^2 = .01$), however there was a main effect of country with participants having faster reaction times for changes on UK roads (M = 8.90s, SE = 1.03) compared to Malaysian roads (M = 10.05s, SE = 1.02) ($F(1, 92) = 13.66$, $p<.001$, $\eta_p^2 = .13$). As with accuracy, there was no significant interaction between nationality and country, so stimuli were collapsed against country for the remainder of the analyses ($F(1, 92) = .40$, $p = .53$, $\eta_p^2 = .01$).

To explore the role of safety relevance, a 2 (nationality) x 2 (safety relevance) mixed ANCOVA was conducted. There was a main effect of safety relevance such that RTs were faster for safety relevant changes (M = 7.87s, SE = 1.03) compared to safety irrelevant changes (M = 10.76s, SE = 1.02) ($F(1, 92) = 86.28$, $p<.001$, $\eta_p^2 = .48$). There were no other significant main effects or interactions.

To explore the hypothesised cross-cultural differences, a 2 (nationality) x 3 (region) mixed ANCOVA was conducted, with orthogonal contrasts comparing the difference between focal and combined background regions, and the two individual background regions (context relevant and irrelevant). There was a significant effect of region ($F(2, 184) = 30.55$, $p<.001$, $\eta_p^2 = .25$), however there was no effect of nationality, and no interaction between nationality and region ($F(2, 184) = 1.56$, $p = .21$, $\eta_p^2 = .02$).

Orthogonal contrasts for the main effect of region revealed a significant difference between RTs for changes in focal regions and the average for both background regions such that RTs were faster for focal changes (M = 8.55s, SE = 1.03), compared to background changes (M = 10.17s, SE = 1.03) ($F(1, 92) = 20.98$, $p<.001$, $\eta_p^2 = .19$). The second contrast revealed that RTs were faster for context relevant background changes (M = 9.10, SE = 1.03) compared to context irrelevant changes (M = 11.22, SE = 1.03) ($F(1, 92) = 39.90$, $p<.001$, $\eta_p^2 = .30$) (see Figure 5.5).

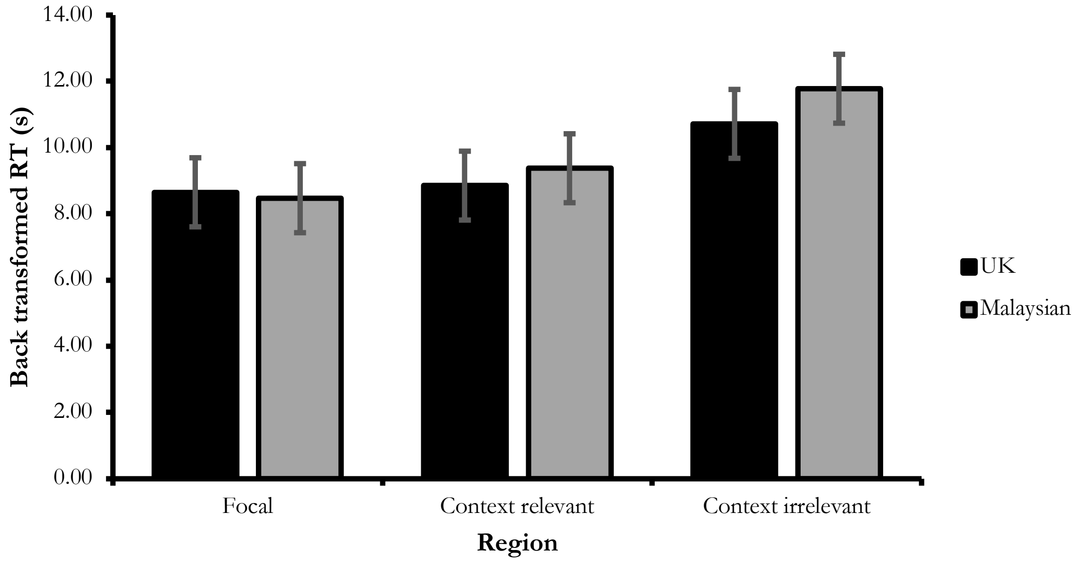

Figure 5.5: RTs across the 3 regions between UK and Malaysian participants (± 1 SEM)

Finally, as with accuracy an additional 2 (nationality) x 2 (region) analysis comparing RTs for focal and background changes when they were all irrelevant to driving safety was conducted. There was a main effect of region such that participants were faster to respond to focal changes (M = 9.31s, SE = 1.05) compared to background changes (M = 13.80s, SE = 1.04) ($F(1, 75) = 19.83$, $p<.001$, $\eta_p^2 = .21$). There was no effect of nationality, ($p = .63$) but there was a marginally significant interaction between nationality and region ($F(1, 75) = 3.74$, $p = .06$, $\eta_p^2 = .05$).

Figure 5.6 suggests that UK drivers were slower at detecting focal changes compared to Malaysian drivers, however pairwise comparisons show no significant difference (MD = 1.10s, $p = .34$), however there was a marginally significant mean difference for background changes with UK drivers being slightly faster than Malaysians (MD = 1.18s, $p = .07$).

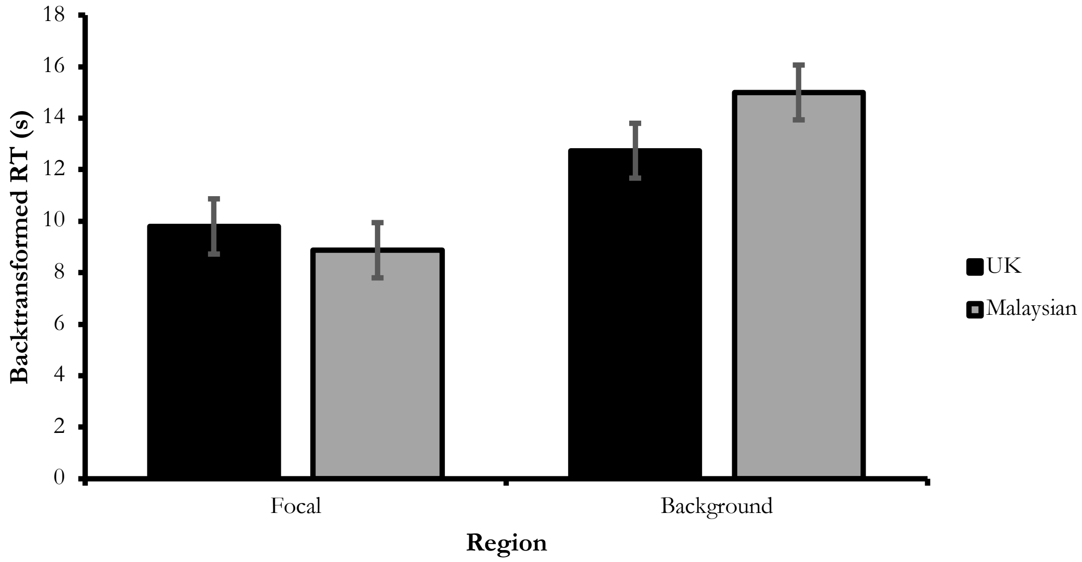

Figure 5.6: Interaction between nationality and region on change detection RT (± 1 SEM)

5.2.2.3 Relationship to self-construal

Finally, a series of bivariate correlations were conducted to see if there was a relationship between accuracy and reaction time for changes occurring within the 3 main regions with independence or interdependence as measured by the SCS. These analyses revealed no significant relationships (see Table 5.5).

Table 5.5: Pearson's r correlations between self-construal and accuracy/ RT

Variables	Accuracy FO	Accuracy CR	Accuracy CI	RT FO	RT CR	RT CI
Independence	0.09	0.10	0.04	0.06	0.02	0.06
Interdependence	0.04	0.06	0.04	0.05	0.12	0.04

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

5.2.3 Discussion

The aim of this study was to determine whether previously identified cross-cultural differences in change detection (Masuda & Nisbett, 2006; Miyamoto et al., 2006) are present between UK and Malaysian drivers when responding to driving scenes in a change detection task. This is the first study to explore the previously identified cross-cultural differences in a driving context, as well as expanding the previous literature showing drivers' change detection in a non-western sample. Overall, the results showed that there is a strong effect of safety relevance on change detection, but no cross-cultural differences.

In linking to the past literature exploring drivers' change detection, it was hypothesised that all participants would be better able to detect changes which were relevant to safety compared to those which were not. The results of the current study support this hypothesis and show a strong effect of safety relevance for both accuracy and reaction time. It is well established that it is easier to detect contextually relevant changes in a change blindness task (Rensink et al., 1997), with drivers consistently being better able to detect safety relevant changes when compared to safety irrelevant changes (Beanland et al., 2017; Galpin et al., 2009; Lee et al., 2007; Mueller & Trick, 2013; Velichkovsky et al., 2002; Zhao et al., 2014). The current results show that this finding is true across multiple locations, showing that the ability to detect safety relevant changes better than safety irrelevant changes is universal and does not differ between cultures.

Contrary to the initial hypothesis, no cultural differences in either accuracy or reaction times were found when comparing UK and Malaysian drivers across the different regions. This finding does not support past research which has shown cross-cultural differences in change detection between Western and Eastern participants with Eastern participants outperforming Westerners on detecting background changes (Masuda & Nisbett, 2006; Miyamoto et al., 2006). Although one past study failed to find cultural differences on change detection accuracy, it was found that all participants were more accurate at detecting focal changes (Masuda et al., 2016). However, in the current study participants were overall more accurate at detecting background changes, although this is seemingly influenced by the higher accuracy for context relevant background changes compared to context irrelevant changes.

In addition, whereas previous studies have shown that the ability to detect changes in focal or background regions is influenced by self-construal (e.g. Choi et al., 2016), this was not found in the current study.

In explaining this finding in relation to previous work, it may be the case that the hypothesised cross-cultural differences were not observed in the current study due to fact that participants were responding to driving stimuli. As described earlier in this thesis both drivers' visual attention, and cross-cultural differences in visual attention are said to be a result of knowledge driven top-down knowledge and experience. In the case of drivers' visual attention, exposure to the driving environment leads to drivers developing a search strategy where they attend to safety relevant aspects of the driving environment in order to avoid a collision, even in cases where they are not actively driving as shown in the current study. The cross-cultural differences are thought to come about as a result of exposure to a particular environment where the increased visual clutter in an East Asian environment leads to Easterners attending more to background aspects of the scene and scanning a wider area.

In the current research, it may be the case that these two top-down influences on attention were in direct conflict with each other, with the driving related scheme masking any potential cross-cultural differences which could have been observed. This explanation is somewhat supported by the data shown in Figure 5.4 where an interaction between culture and region emerges when all changes are safety irrelevant. Although these changes still occur within driving stimuli, when these changes are not related to safety some cross-cultural differences begin to emerge.

As the above analysis was conducted post-hoc, a second study was conducted in which participants were presented with a mixture of driving and non-driving related stimuli where changes occurred in either focal or background regions. If it is the case that the lack of cultural effects in study 1 is due to the fact that they are masked by the driving task, it can be hypothesised that a cross-cultural difference would emerge in non-driving stimuli, but not when detecting changes in driving stimuli.

5.3 Study 2

5.3.1 Method

5.3.1.1 Design

As with Study 1, this study used a mixed design. The between groups variable was the nationality of the participant (UK or Malaysian). The within groups variables were the stimuli type (driving or non-driving), and the region where the change occurred (focal or background). The factor of region was reduced to two levels in order to allow direct comparison between performance across non-driving stimuli (where context-relevance is no longer a relevant factor) and driving stimuli.

Within the driving stimuli there was also an additional within groups variable of safety relevance of the change (relevant or irrelevant to safe driving). The location of the changes (left, centre, or right) and the change type (appear, disappear, change) were systematically varied across trials, but were not used for analysis purposes.

The dependent variables were accuracy (the number of changes correctly identified), and reaction time in seconds.

5.3.1.2 Participants

Participants were recruited through online advertisements within the University of Nottingham UK and Malaysia campuses, as well as advertisements on social media. The initial sample consisted of 80 participants, however 13 were removed prior to analysis due to having incorrect reaction times below 15s.

The final sample of 67 participants consisted of 36 British (3 male, 33 female) and 31 Malaysian (7 male, 22 female, 2 other) drivers. Further demographics can be found in Table 5.6.

Table 5.6: Demographic data for Study 2

Nationality	UK (n=36)		Malaysian (n=31)		t-test		
	Range	*M* (*SD*)	*Range*	*M* (*SD*)	*t*	*p*	*d*
Age	18-43	20.03 (4.24)	18-45	21.60 (5.02)	1.37	.174	.34
Driving experience (years)	0.08-26	2.37 (4.31)	0.16-28	3.57 (5.08)	1.05	.300	.26
Annual mileage*	100-15,000	4286.60 (3894.20)	3.11-30,028	4068.01 (6330.49)	0.16	.876	.04
Hours driven per week	0-35	5.50 (6.48)	45292.00	6.27 (5.78)	0.51	.613	.13
SCS Independence	3.13-5.60	4.45 (0.65)	3.20-6.80	4.67 (0.72)	1.30	.198	.33
SCS Interdependence	3.53-5.67	4.60 (0.49)	3.00-6.87	4.62 (0.87)	0.09	.929	.02

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

5.3.1.3 Stimuli

The study consisted of 40 trials (32 change present) evenly split between driving and non-driving images, in both the UK and Malaysia. For driving trials, stimuli were a subset of 20 (16 change present) images used previously in Study 1. This subset of images was selected to ensure that there was a mix of trials in which the change involved an object appearing, disappearing, or changing. A breakdown of the trials used in Study 2 can be found in Table 5.7, and the full list of stimuli can be found in Appendix C.

Table 5.7: The types of trials used in Study 2

Country	Task	Region	Safety relevance	Count	Example
UK	Driving	Focal	Relevant	2	A speed limit sign painted onto the road disappearing
UK	Driving	Focal	Irrelevant	2	The lead vehicle changing colour
UK	Driving	Background	Relevant	2	A speed limit roundel disappearing
UK	Driving	Background	Irrelevant	2	A window on a building by the side of the road vanishing
UK	Driving	No change	N/A	2	No change between images
UK	Non-Driving	Focal	N/A	4	Logo on a store front changing colour
UK	Non-Driving	Background	N/A	4	A poster appearing on the side of a building
UK	Non-Driving	No change	N/A	2	No change between images
Malaysia	Driving	Focal	Relevant	2	A motorcycle entering the roadway
Malaysia	Driving	Focal	Irrelevant	2	The lead vehicle changing colour
Malaysia	Driving	Background	Relevant	2	A car appearing on a side road
Malaysia	Driving	Background	Irrelevant	2	A roadside advert changing
Malaysia	Driving	No change	N/A	2	No change between images
Malaysia	Non-Driving	Focal	N/A	4	A clock face being removed from a tower
Malaysia	Non-Driving	Background	N/A	4	A small tower at the side of a building disappearing
Malaysia	Non-Driving	No change	N/A	2	No change between images

For non-driving images, photos were taken of outdoor scenes from the perspective of a pedestrian in the East Midlands in the UK, and the Klang Valley in Malaysia. These consisted of a total of 20 images (10 from each country), 16 of which contained a change. Changes were once again made in these new images using GIMP (GNU Image Manipulation Program). Changes either occurred in focal regions (defined as a salient focal object towards the centre of the image) or background regions (objects or aspects of the scene away from the focal object). An example of the newly created non-driving stimuli can be seen in Figure 5.7.

New stimuli and backups were piloted with a group of 10 drivers (2 Malaysian). Six of the image pairs had accuracies of either 10% or 100% and were subsequently not used in the main study. All remaining image pairs had accuracies ranging from 30-90%.

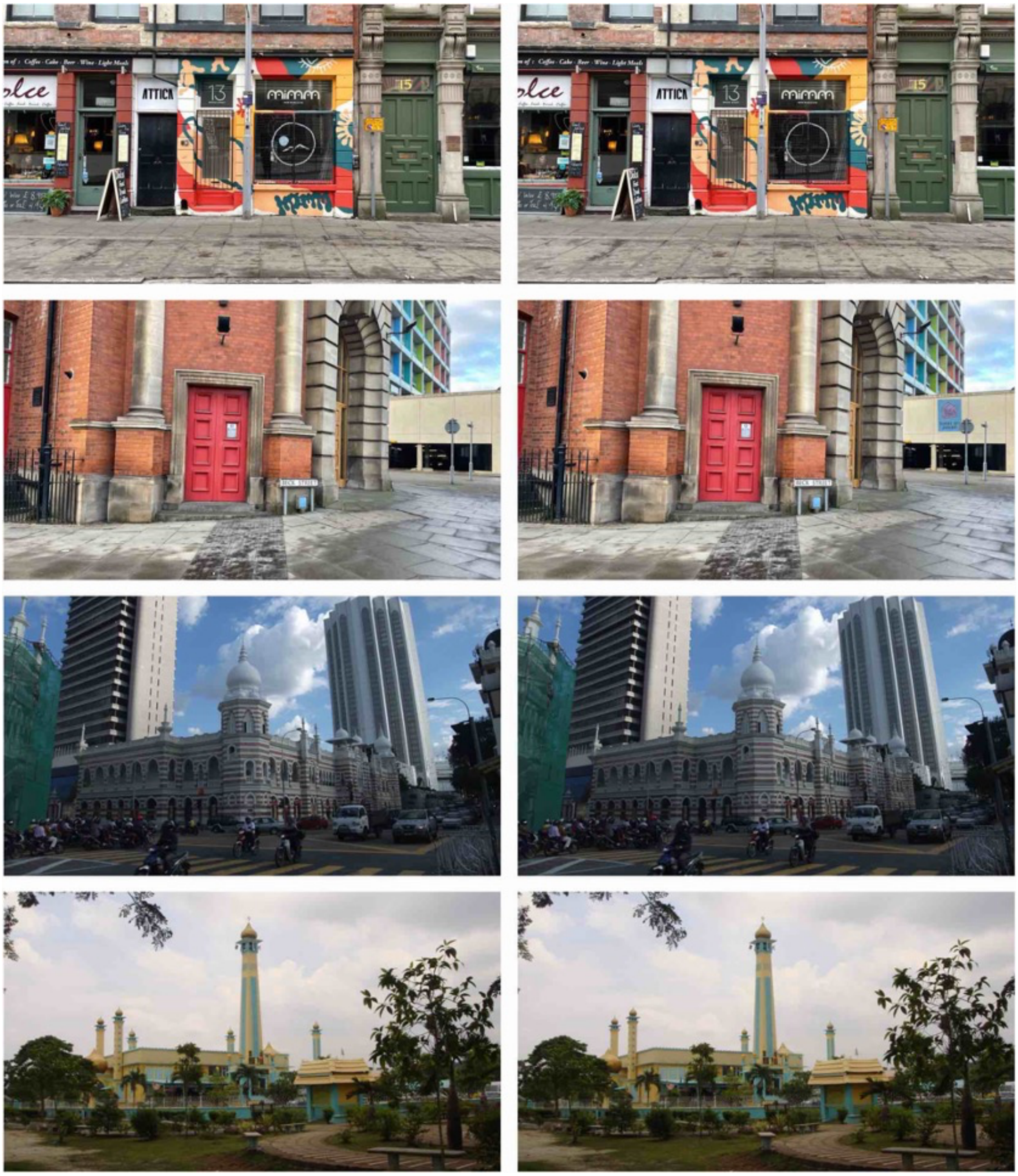

Figure 5.7: Examples of non-driving change detection stimuli from the UK and Malaysia used in Study 2. The top row shows a shop sign changing (UK focal), the second row shows an advert appearing on a parking structure (UK background), the third row shows a window being removed from a building (Malaysia focal), and the bottom row shows a tower being removed from the back corner of a building (Malaysia background)

5.3.1.4 Procedure

The procedure for Study 2 was identical to Study 1 with data collected online on participants' own devices. Due to the inclusion of non-driving images the stimuli were split into 4 blocks (UK driving, Malaysia driving, UK non-driving, Malaysia non-driving). Participants were randomly assigned to complete either the driving or the non-driving block first, and to complete trials with UK or Malaysian images first within the block. In their second block the order of the countries was the same as block one (so a participant who completed UK driving images first would start their non-driving block with UK images).

5.3.1.5 Analysis

For analysis purposes, average accuracy and RT to correct trials was calculated for each of the conditions. These were later entered into a series of repeated measures ANOVAs. All data were analysed using SPSS v28.

5.3.2 Results

5.3.2.1 Accuracy

Participants' overall accuracy across the change trials ranged from 40.63% to 96.88% (M = 68.84%, SD = 11.17). An independent samples t-test revealed that the overall accuracy in Study 2 was similar to the overall accuracy in Study 1 (t (160) = 1.55, p = .12, d = .25). There was also no significant difference in accuracy for the driving related stimuli used across the 2 studies (t (160) = .61, p = .54, d = .10). Descriptive statistics for the analyses of accuracy can be found in Table 5.8. Accuracy data met the assumptions for normality and homogeneity of variance.

Table 5.8: Mean accuracy across each of the three ANOVAs reported

	UK (n=36)		Malaysian (n=31)	
	M	SD	M	SD
Nationality x Country				
UK stimuli	70.66%	9.66	74.60%	12.49
Malaysian stimuli	63.37%	14.80	67.34%	16.90
Nationality x Safety Relevance				
Safety relevant	84.38%	13.15	83.07%	16.94
Safety Irrelevant	54.86%	20.55	60.89%	21.59
Nationality x Task x Region				
Driving Focal	74.31%	16.62	75.81%	21.15
Driving Background	64.93%	19.32	68.15%	18.50
Non-Driving Focal	67.71%	16.20	77.42%	15.95
Non-Driving Background	61.11%	12.24	62.50%	15.14

In order to explore whether there was an interaction between stimulus country and nationality, a 2 (nationality) x 2 (country) ANOVA was conducted. As with Study 1, participants from both nationalities had a similar overall accuracy as shown by the non-significant main effect of nationality (F(1, 65) = 2.12, p = .15, η_p^2 = .03). Although there was a main effect of country, with accuracy being higher for changes occurring in UK scenes (M = 72.63%, SE = 1.36) compared to Malaysian scenes (M = 65.35%, SE = 1.94) (F(1, 65) = 13.93, p<.001, η_p^2 = .18), there was no interaction between country and nationality (F (1, 65) <.001, p = .99, η_p^2 < .001) therefore stimuli were collapsed against country for the remainder of the analyses.

To explore the effect of safety relevance on change detection for driving stimuli, a 2 (nationality) x 2 (relevance) ANOVA was conducted. There was a main effect of safety relevance such that accuracy was higher for relevant changes (M = 83.72%, SE = 1.84) compared to irrelevant changes (M = 57.87%, SE = 2.58) (F(1, 65) = 90.88, p<.001, η_p^2 = .58). There were no other main effects or interactions.

Finally, to explore the potential cross-cultural differences in attention to focal or background objects in both tasks, a 2 (nationality) x 2 (task) x 2 (region) ANOVA was conducted. There was a main effect of region such that accuracy was higher for focal changes (M = 73.81%, SE = 1.79) compared to background changes (M = 64.17, SE = 1.57) (F(1, 65) = 23.19, p<.001, η_p^2 = .26). All other main effects were non-significant. Results revealed no significant interactions, in particular there was no interaction between nationality, task, and region (F(1, 65) = .68, p = .41, η_p^2 = .01).

5.3.2.2 Reaction times

Participants' average reaction times (RTs) for correct trials ranged from 5.17s – 15.05s (M = 9.48s, SD = 2.07), an independent samples t-test showed that the average RT in Study 2 was not significantly different to the average RT in Study 1 (t (160) = 1.22, p = .23, d = .19). There was also no significant difference in RTs for the driving stimuli used across the 2 studies (t (160) = .27, p = .79, d = .04). RTs were once again log transformed for analysis purposes and back transformed for the purpose of reporting. Descriptive statistics for each analysis can be seen in Table 5.9. RT data met the assumption for homogeneity of variance.

Table 5.9: Backtransformed mean RTs across each of the three ANOVAs reported

	UK (n=36)		Malaysian (n=31)	
	M	SD	M	SD
Nationality x Country				
UK stimuli	7.79	1.30	7.87	1.33
Malaysian stimuli	10.56	1.23	10.46	1.44
Nationality x Safety Relevance				
Safety relevant	7.58	1.41	7.47	1.47

Safety Irrelevant	11.81	1.38	12.24	1.46
Nationality x Task x Region				
Driving Focal	8.93	1.49	8.61	1.45
Driving Background	9.40	1.34	10.33	1.45
Non-Driving Focal	8.30	1.39	8.51	1.55
Non-Driving Background	8.51	1.36	8.77	1.27

As with accuracy, a 2 (nationality) x 2 (country) ANOVA was conducted to explore whether there was a main effect of country or an interaction between country and nationality on reaction times. RTs were similar for participants in both groups, as shown by a non-significant main effect of nationality ($F(1, 65) = .00$, $p = .99$, $\eta_p^2 = .00$). There was a main effect of country such that RTs were faster for UK stimuli (M = 7.83s, SE = 1.03) compared to Malaysian stimuli (M = 10.52s, SE = 1.04) ($F(1, 65) = 50.75$, $p<.001$, $\eta_p^2 = .44$). However there was no significant interaction between country and nationality ($F(1, 65) = .06$, $p = .81$, $\eta_p^2 = .001$), therefore stimuli were collapsed against country for the remainder of the analyses.

Second, RTs to driving stimuli were explored using a 2 (nationality) x 2 (relevance) ANOVA. There was a main effect of safety relevance with safety relevant changes being detected faster (M = 7.53s, SE = 1.04) than safety irrelevant changes (M = 12.02s, SE = 1.04) ($F(1, 64) = 73.05$, $p<.001$, $\eta_p^2 = .53$). There were no other main effects or interactions.

To explore the hypothesised cross-cultural differences a 2 (nationality) x 2 (task) x 2 (region) ANOVA was run. There was once again a significant main effect of task as described above ($F(1, 65) = 5.23$, $p = .03$, $\eta_p^2 = .08$). There was also a marginally significant main effect of region, with participants responding faster to focal changes (M= 8.59s, SE = 1.04) compared to background changes (M = 9.23s, SE = 1.30) ($F(1, 65) = 3.94$, $p = .051$, $\eta_p^2 = .06$). There were no other significant main effects, and all interactions were non-significant, including the hypothesised interaction between nationality, task, and region ($F(1, 65) = .65$, $p = .42$, $\eta_p^2 = .01$).

5.3.2.3 Relationship to self-construal

Finally, a series of bivariate correlations were conducted to see if there was a relationship between self-construal, and accuracy and reaction time for changes in focal or background regions. These analyses revealed no significant relationships (see Table 5.10)

Table 5.10: Correlations between self-construal & accuracy/ RT

Variables	Accuracy FO	Accuracy BG	RT FO	RT BG
Independence	0.03	0.07	0.03	0.01
Interdependence	0.05	0.08	0.12	0.001

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

5.3.3 Discussion

Following the results of Study 1 in which no cross-cultural effect was found when participants were asked to detect changes in driving stimuli, the aim of Study 2 was to explore the possibility that cross-cultural differences only emerge when presented with non-driving stimuli. Whilst the effect of safety relevance for changes occurring in driving stimuli was still significant, there was no cross-cultural effect for either driving or non-driving stimuli.

Overall, there was a main effect of task such that RTs were faster for non-driving stimuli, suggesting that participants needed less time to process these stimuli compared to changes occurring in driving scenes. Within the driving stimuli it was also observed that RTs were significantly faster for safety relevant changes compared to safety irrelevant changes. Whilst it could be argued that safety irrelevant changes in the driving stimuli should be processed at the same speed as any changes in the non-driving stimuli as they are both not related to safety, it may be the case that the driving task itself is slowing down the processing speed for safety irrelevant changes in favour of faster more automatic processing of safety relevant changes as seen by the main effect of safety relevance. When this factor is removed (as is the case in the non-driving stimuli), participants are able to identify changes faster overall as their primary task is no longer identifying safety critical changes.

When looking at the just the driving stimuli, there was once again a strong main effect of safety relevance such performance was better when detecting safety relevant changes compared to safety irrelevant changes. This finding supports the findings from Study 1 as well as the past literature showing the same effect (Beanland et al., 2017; Galpin et al., 2009; Lee et al., 2007; Mueller & Trick, 2013; Velichkovsky et al., 2002; Zhao et al., 2014).

In relation to the hypothesised cross-cultural differences, previous studies have shown a cross-cultural difference such that East Asians are better at detecting background changes than Western participants (Masuda et al., 2016; Masuda & Nisbett, 2006), however this finding was not replicated in Study 1. It was proposed that the lack of cultural difference was due to the fact that safety relevance was such a strong factor, and this effect of safety may have overridden any cultural differences. Therefore, it was hypothesised that in the current study a cross-cultural difference would emerge for non-driving stimuli, but not for driving stimuli. However, the results did not support this hypothesis as there was no cultural effect for either non-driving or driving stimuli. Also, as with Study 1 neither accuracy or RT in detecting changes in focal or background regions correlated with self-construal, suggesting that this does not influence change detection ability.

This finding would therefore suggest that the previously demonstrated cross-cultural differences are not present in the current research. As this was shown for both driving and non-driving stimuli, it is not the case that the safety relevance associated with a change blindness driving task is masking any potential cultural differences. One explanation for this finding may be related to the differences in the stimuli used in the current study compared to past research. Previous studies into cultural differences in attention and change detection have often used stimuli where a highly salient focal objects has been superimposed onto a background (Chua et al., 2005; Masuda et al., 2016) or more naturalistic scenes with more background objects, but still containing focal objects which have been superimposed against a background (Masuda & Nisbett, 2006). In these stimuli, the ability to make a clear distinction between the background and a focal object is much easier. In contrast the current study used photos of real-world scenes where the focal objects occurred naturally in most cases, and were not overly salient in comparison to the background. It may be the case that when presented with highly naturalistic scenes, it is not as easy to distinguish between focal and background elements, therefore any differences in attention to focal vs background elements of a scene will not be as observable.

5.4 Limitations

There are two primary limitations to the current study which should be considered when discussing the findings. First, due to the highly naturalistic nature of the stimuli used in this research it was not possible to fully match stimuli between the two countries. Similarly, it may be the case that certain changes in certain stimuli were naturally more salient than others due to the fact that the stimuli were all real-world photographs.

A second potential limitation to consider is the fact that participants completed both studies online using their own devices. Whilst checks were in place to exclude participants who did not complete the task as instructed (such as those who showed fast RTs for incorrect trials), it was not possible to monitor participants' progress throughout the task. In addition, completing the study online meant factors such as distance from the screen, visual angle, or screen brightness could not be controlled for. These factors may have meant that certain stimuli were not as salient for some participants depending on their device, however this will not have varied systematically between participants from both countries.

Despite this potential limitation, research has shown that online data collection for cognitive and perceptual tasks can yield results which are comparable to highly controlled laboratory-based experiments (e.g. Germine et al., 2012; Woods et al., 2015), with the additional benefits of being able to collect data from a larger sample size across multiple countries.

5.5 Conclusions

The aim of this chapter was to investigate whether there are cultural differences in attention, as measured by a change blindness paradigm, in both driving and non-driving stimuli. Across two studies, the previously demonstrated effects of safety relevance were replicated with strong effect sizes providing further evidence that drivers are better at attending to safety relevant aspects of the driving scene whilst often failing to attend to safety irrelevant aspects of the scene. This is also one of the first studies to replicate this finding in a sample of drivers from a non-western country. This not only provides further evidence that this effect is universal amongst drivers regardless of differences in driving experience across countries, but also demonstrates that a change detection task may be a useful method to measure drivers' visual attention across cultures.

Contrary to past studies, no cross-cultural differences emerged with regards to participants from Eastern countries allocating more attention to background aspects of the scene compared to Westerners. As this finding was consistent across both driving and non-driving stimuli, it could be argued that the previously observed cross-cultural differences are not present when viewing highly naturalistic scenes as previously discussed.

5.5.1 Next steps

Although the current study did use a more dynamic task that the study presented in Chapter 3, it is still not fully representative of a real driving task, nor does it provide a direct measure of where drivers look during the task. The final two studies in this thesis explored the potential cultural differences in drivers' attention using both driving simulation and eye tracking to present participants with a more realistic task alongside a more direct measure of attention.

Chapter 6: Where do drivers look when driving in a simulated environment?

6.1 Introduction

The studies presented in Chapters 4 & 5 used online methods to explore drivers' visual attention in an indirect manner with participants choosing where they would look, or identifying changes in a change detection task. To overcome these limitations, the current study aimed to explore drivers' visual attention using a more true-to-life driving task (driving simulation) alongside a more direct method for exploring visual attention (eye tracking).

Eye tracking is a useful tool to investigate drivers' visual attention and has been widely used within the field since the early 2000's (see Taylor et al. (2013) for a review). The literature discussed in section 2.2.2 (Chapman & Underwood, 1998; Crundall & Underwood, 1998; Underwood et al., 2002) used eye tracking to explore the differences in visual search between novice and experienced drivers. These studies found that more experienced drivers distributed their fixations across a wider area on the road compared to novice drivers who tended to fixate mostly on the road straight ahead, this finding was further supported by a recent meta-analysis Robbins and Chapman (2019). In addition, several studies exploring the differences in visual search between novice and experienced drivers found that novice drivers made less fixations and had a higher mean fixation duration. However it should be noted that in the Robbins and Chapman (2019) meta-analysis, there were no overall differences in number of fixation or fixation duration between novice and experienced drivers. Overall, these past findings suggest that experience can lead to differences in how drivers attend to their environment, and although the effects of experience on fixation count and duration are mixed, it is clear that experience can have an overarching influence on where drivers look.

As discussed throughout this thesis, it has been argued that these differences in visual search come about as a result of different mental models as a result of driver experience. One way in which these mental models influence visual search is through differences in spread of search on different road types. The results of these previous studies have shown that drivers typically have a wider spread of search when driving on more complex roads such as dual carriageways or urban city centre roads, compared to driving along a quieter rural road (Chapman & Underwood, 1998; Crundall & Underwood, 1998). This is particularly true for more experienced drivers who have had repeated exposure to these more complex roads and have learnt to increase their spread of search in order to attend to potential hazards which may occur further away from the centre of the road.

Although past literature has predominantly focused on experience in terms of length of licensure, the findings showing different visual search strategies across road types suggests that experience can come about as a result of exposure to a particular driving environment. In the case of the current research, experience has been thought of in terms of exposure to a particular driving environment and country.

In the cross-cultural literature it has been shown that participants from East Asian countries often attend to a wider angle of a visual scene, with attention being allocated to centrally located focal objects as well as the background (Boduroglu et al., 2009; Masuda & Nisbett, 2001). It has also been shown that East Asian participants make more fixations, with shorter fixations durations, when viewing a scene compared to Westerners (Chua et al., 2005; Goh et al., 2009).

So far in this thesis, focus group data has suggested that Malaysian drivers may attend more to the scene as a whole and have a wide spread of search in order to remain vigilant whilst driving (see Chapter 3), similarly in Chapter 4 results showed that Malaysian drivers would choose to attend to regions further from the centre of an image in the vertical axis (although no difference was found in the horizontal axis).

If it is the case that East Asians have a wider spread of search as suggested by past cross-cultural literature, one may expect to see a wider spread of search whilst driving compared to drivers from the UK, similar to the differences observed between novice and experienced drivers in past studies. Although findings regarding number of fixations and fixation duration varying as a function of driving experience are mixed, the cross-cultural literature would also suggest that Malaysian drivers may make more fixations and have a shorter mean fixation duration than UK drivers.

The aim of the current study is to explore the potential cross-cultural differences in visual search using a driving simulator task in which participants are tasked with driving along a series of urban and rural roads. Overall, it is hypothesised that Malaysian participants will have a wider spread of search in both the horizontal and vertical axes, make more fixations, and have a shorter mean fixation duration than UK participants. It was also hypothesised that participants would have a wider spread of search, more fixations, and a shorter mean fixation duration when driving on urban roads due to their increased complexity and the requirement to scan a wider area of the roadway compared to rural roads, as well as when driving on Malaysian roads compared to UK roads again due to their increased complexity.

6.2 Method

6.2.1 Design

This study utilised a 2 x 2 x 2 mixed design. The between groups variable was the nationality of the participant (either UK or Malaysian). The within groups variables were the road type (either rural or urban), the road country (UK or Malaysia). The study was also split into two phases, a free drive (where participants could drive as they naturally would) and a controlled drive (where participants were informed of what speed to drive).

The dependent variables obtained from the eye tracking data were the horizontal and vertical spread of search (as calculated by the standard deviation of fixation locations in each axis), number of fixations, and mean fixation duration (ms). Participants' average speed across each of the drives (in mph) was also recorded.

6.2.2 Participants

Participants were UK and Malaysian drivers recruited from the University of Nottingham, with Malaysian participants being international students studying abroad in the UK. In order to participate all participants needed to be UK or Malaysian nationals with a full driver's licence. Participants were eligible to take part if they had no experience of driving in the other country, had minimal to no experience driving abroad in general (less than one month in total), and had not lived in another country for more than half of their lifetime. Additionally, all Malaysian participants were required to have lived in the UK for less than one year.

The initial sample consisted of 49 UK and 52 Malaysian participants; however 20 participants were removed from this sample (7 UK, 13 Malaysian), 14 due to simulator sickness, 3 due to poor eye tracking data (less than 75% of samples recorded), and 3 due to living abroad for more than half of their lifetime. The final sample consisted of 81 participants (42 UK and 39 Malaysian). Additional demographics and inferential statistics can be found in Table 6.1.

None of the UK participants had lived abroad for a prolonged period of time (6 participants had lived abroad for less than one year) and had no experience driving in another country. Malaysian participants had been living in the UK between 1 and 7 months (M = 4.21 months, SD = 2.03) and had no experience driving outside of Malaysia.

Table 6.1: Demographic data

Nationality	UK (n=42)		Malaysian (n=39)		t-test		
	Range	*M (SD)*	*Range*	*M (SD)*	*t*	*p*	*d*
Age	18-31	20.33 (3.01)	18-23	21.21 (1.11)	1.73	.09	.37
Driving experience (years)	0.25-11.58	2.72 (2.92)	0.92-5.25	3.27 (1.14)	1.14	.26	.25
Annual mileage*	0-20,000	4581.52 (4549.56)	2.49-17,398	4761.33 (4761.98)	0.17	.87	.04
Hours driven per week	0-20	3.66 (4.67)	1-28	9.16 (6.33)	4.37	<.001	0.99
SCS Independence	2.13-5.80	4.51 (0.72)	3.33-6.00	4.71 (0.67)	1.29	.20	.29
SCS Interdependence	3.67-6.33	4.58 (0.46)	2.80-6.33	5.02 (0.74)	3.20	.003	.71

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

Due to recruitment issues arising from the COVID-19 pandemic, the first 9 participants in this study (plus 2 who were removed due to poor eye tracking data) completed the study before the UK national lockdown. The remaining participants took part after the lockdown.

All participants either received a £5 inconvenience allowance, or course credit for taking part in the study, however course credit was only received by a subsection of participants in the UK sample as they were psychology undergraduate students.

6.2.3 Apparatus, materials and stimuli

Testing took place in the Nottingham Integrated Transport and Environment Simulation facility's high fidelity driving simulator (NITES1) located at the University of Nottingham UK campus (see Figure 6.1). This consists of a fully instrumented BMW mini housed within a 360° projection dome mounted on a six-degrees of freedom motion platform (which was not used for any of the studies in the current research). Scenarios are presented to participants across six high-resolution projectors (each with a 1600 x 1200-pixel resolution) projecting onto the wall of the dome, as well as two LCD wing mirrors. Scenarios were created using XPI simulation software (XPI Simulation, London, UK).

It is possible to operate the simulator with a manual or automatic transmission, however an automatic transmission was used throughout the study as the majority of Malaysian drivers only drive using an automatic transmission.

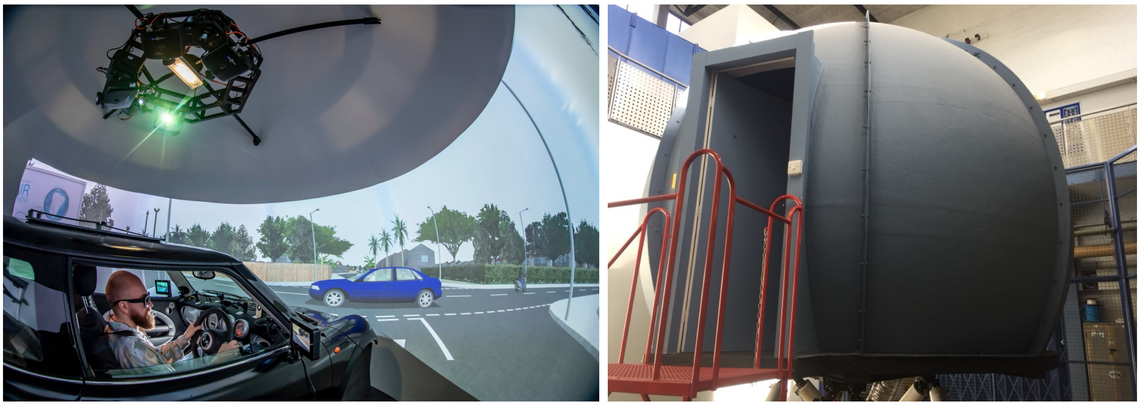

Figure 6.1: The NITES 1 driving simulator, a fully instrumented BMI mini (left) housed within a 360° projection dome

The trials used in the current study consisted of four different scenarios (see Figure 6.2) two rural and two urban. These scenarios were built using the NewWorld road layout available in the NITES driving simulator. This layout consists of a series of roads including urban, rural, and suburban roads, and motorways. One advantage of this layout was that many areas of the roadway have a fairly culturally neutral appearance (i.e. not containing objects which are overtly associated with British roads) making them easy to adapt as described below.

Rural scenarios consisted of a single lane rural road which was bordered by hedges and fences with trees also present at either side of the road. In the Malaysian version of this trial the foliage was adjusted to reflect a Malaysian road environment, this including adding new models of palm and banana trees which are typical of Malaysian rural environments. The road had a speed limit of 60mph. In both cases, 3 vehicles are present on the other side of the road driving at a speed of 60mph. In the UK trials these vehicles were all cars, in the Malaysian trial these were a mixture of cars and powered two wheelers (PTWs).

Urban scenarios consisted of a single lane road through an urban city centre. The road was bordered by buildings, and had a speed limit of 30mph. In the UK version of these roads, traffic was predominantly made up of cars which were present both in the participants lane and on the other side of the road. In the Malaysian version the amount of traffic was increased to better reflect the increased traffic on Malaysian roads. The Malaysian urban trial also contained a much larger proportion of PTWs. Native foliage was once again added to the scene. Both the rural and urban scenes were checked by Malaysian drivers to ensure that they were accurate representations of roadways in Malaysia.

In all trials, participants were tasked with following the road straight ahead until the scenario ended. Each trial took approximately 1 minute to complete.

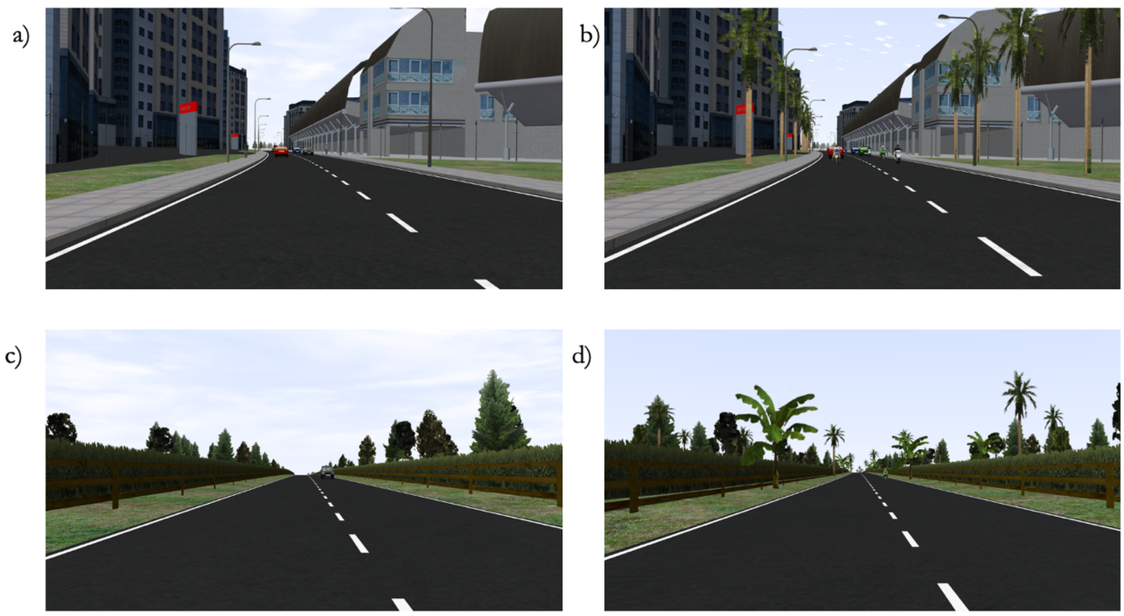

Figure 6.2: Urban (top row) and rural roads (bottom row) used in the study made to resemble both the UK (left) and Malaysia (right)

Eye movements were recorded using Tobii Pro Glasses 2. These wearable eye tracking glasses allow participants to move freely in the vehicle whilst having their eye movements recorded. The glasses track participants' pupil and corneal reflection at a recording rate of 50hz. The glasses also include a wide-angle (82 degrees horizontal, 52 degrees vertical) HD scene camera in the centre which captures drivers' natural viewing behaviour.

In addition to the driving task, participants were asked to complete a series of short questionnaires. This included a general background questionnaire exploring demographic details and driving history, the Self-Construal Scale (SCS) (Singelis, 1994), and a simulator sickness questionnaire (SSQ) (Kennedy et al., 1993).

6.2.4 Procedure

Before starting the experiment, participants were provided with an information sheet and gave informed consent before completing the background questionnaire, and SCS. Participants were also asked to complete the SSQ before the study to check for any signs of sickness before starting the experiment. If the participant was happy to continue, they were then taken to the simulator and were provided with eye tracking glasses which were calibrated using a single point calibration before starting the recording.

Prior to the experimental trials, participants were given a short practice drive in order to become familiar with the operation of the driving simulator and to allow the researcher to check for any signs of simulator sickness. This drive was along a straight stretch of road which was not used in the later experimental trials. Participants completed the SSQ once more after the practice drive and any participants with signs of simulator sickness were removed from the study.

The experimental trials were split into two main blocks, free drives (always completed first) and controlled drives. In the free drive trials participants were instructed to follow the road and drive as they naturally would in the real world. In the controlled drive trials participants were explicitly informed to obey the speed limit (30mph on urban roads, 60mph on rural roads) and to obey any road signs. By having participants complete the free drives first their behaviour would not be influenced by the instructions given for the controlled drives, this enabled natural driving behaviour to be observed including differences in speed. In contrast, the controlled drives ensured that all participants spent the same amount of time driving in each trial, therefore giving a more useful insight into how visual search differs when participants are given the same exposure to an environment which will not be influenced by factors such as driving speed which limit how long a participant spends in the environment.

Within each block the four trials (UK rural, UK urban, Malaysian rural, Malaysian urban) were counterbalanced such that half of the participants drove on the UK roads first and half drove on the Malaysian roads first. The road type was also counterbalanced so half the participants began with a rural road and half began with an urban road. The order of these initial four trials was then repeated for the controlled driving condition to ensure that the same amount of time had passed between participants completing an identical trial. This counterbalancing was within groups to ensure that participants from one country did not all start with roads from their home country by chance.

After completing the drives participants were asked to complete the SSQ one final time to check for any signs of simulator sickness. At the end of the experiment participants were debriefed on the experimental aims and were asked to sign a special requirement form indicating that they would not operate a vehicle on the road for the next 30 minutes to ensure there were no carry over effects from driving in a simulated environment which may endanger drivers on real roads.

6.2.5 Data analysis

Eye tracking data were extracted using Tobii pro analyser software. Fixations were classified using the Tobii I-VT fixation gaze filter which classified a fixation as a point in which the participants' gaze was within 0.5° for a minimum of 60ms.

To account for differences in speed and time spent completing each trial, the number of fixations per minute are reported as opposed to the number of fixations within each trial.

When calculating the spread of search, the x and y coordinates for each fixation were taken (with a fixation directly ahead being classified as 0°), the standard deviation of these fixation locations within each trial was then calculated as a measure of spread.

All data were analysed using SPSS v28.

6.3 Results

In order to explore the cross-cultural differences in visual search, 4 dependent variables (fixations per minute, mean fixation duration [MFD], spread of search in the horizontal and vertical axes) were subject to a 2 (nationality) x 2 (road country: UK vs Malaysia) x 2 (road type: urban vs rural) analysis of variance. All data met the assumptions of normality and homogeneity of variance.

6.3.1 Free drive

Descriptive statistics from each of the four ANOVAs in the free drive condition can be seen in Table 6.2.

Table 6.2: Descriptive statistics for each dependent variable in the free drive condition

	UK (n=42)		Malaysian (n=39)	
	M	SD	M	SD
Fixations per minute				
UK Urban	148.22	23.08	137.35	26.52
UK Rural	118.22	28.92	114.80	32.62
Malaysia Urban	137.92	28.72	132.98	27.83
Malaysia Rural	122.74	33.10	118.29	33.36
Mean fixation duration				
UK Urban	276.12	105.13	321.79	110.71
UK Rural	400.05	189.22	441.67	199.51
Malaysia Urban	302.32	133.71	364.82	134.89
Malaysia Rural	395.39	206.28	428.20	173.38
Horizontal spread				
UK Urban	8.01	2.10	6.28	1.85
UK Rural	6.96	3.10	5.83	2.37
Malaysia Urban	6.87	1.88	5.86	1.34
Malaysia Rural	6.65	2.93	5.46	2.16
Vertical spread				
UK Urban	9.08	2.35	6.08	3.21
UK Rural	9.86	2.36	6.36	2.64
Malaysia Urban	8.54	2.66	5.56	2.82
Malaysia Rural	9.29	2.94	5.90	2.28
Average speed				
UK Urban	26.24	5.62	27.80	11.44
UK Rural	50.32	11.52	50.32	12.81
Malaysia Urban	25.26	4.32	26.35	10.48
Malaysia Rural	48.23	11.54	55.32	13.10

6.3.1.1 Fixations per minute and fixation duration

When analysing the number of fixations per minute, there was no main effect of nationality ($F(1, 79) = 1.10$, $p = .30$, $\eta_p^2 = .01$). There was a significant main effect of road type such that participants made more fixations per minute whilst driving on urban roads (M = 139.12, SE = 2.10) compared to rural roads (M = 118.51, SE = 3.44) ($F(1, 79) = 66.23$, $p<.001$, $\eta_p^2 = .46$). There was also a significant interaction between road type and road country ($F(1, 79) = 15.17$, $p<.001$, $\eta_p^2 = .16$). Bonferroni corrected pairwise comparisons showed that there were more fixations per minute on UK urban compared to Malaysian urban roads (MD = 7.34, p = .003), whereas there were more fixations per minute on Malaysian rural roads compared to UK rural roads (MD = 4.01, p = .03) (see Figure 6.3). There were no other significant main effects or interactions.

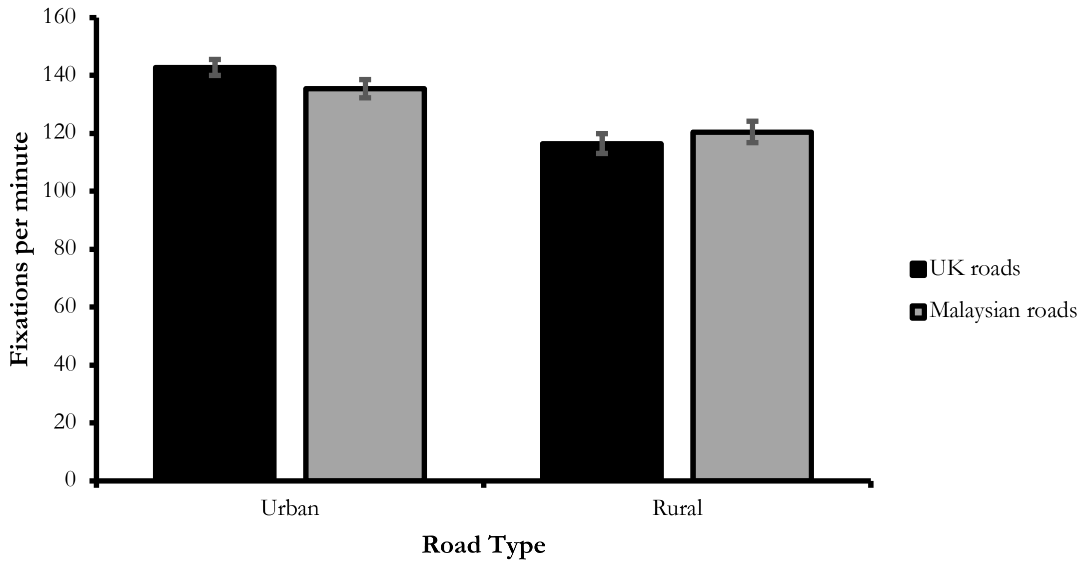

Figure 6.3: Interaction between road type and country on the number of fixations per minute (± 1 SEM)

The analysis of MFD also revealed no main effect of nationality (F(1, 79) = 1.93, p = .17, η_p^2 = .02). There was once again a main effect of road type such that fixations were longer on rural roads (M = 416.33ms, SE = 21.07) compared to urban roads (M = 316.26ms, SE = 13.00) (F(1, 79) = 69.80, p<.001, η_p^2 = .47). There was also a main effect of road country such that fixations were longer on Malaysian roads (M = 372.68ms, SE = 17.35) compared to UK roads (M = 359.90ms, SE = 15.67) (F(1, 79) = 5.55, p = .02, η_p^2 = .07). Finally there was a significant interaction between road type and country (F(1, 79) = 16.10, p<.001, η_p^2 = .02). Bonferroni corrected pairwise comparisons revealed that MFDs were longer on Malaysian urban compared to UK urban roads (MD = 34.62ms, p<.001), but showed no difference between Malaysian and UK rural roads (MD = 3.06ms, p = .25) (see Figure 6.4)

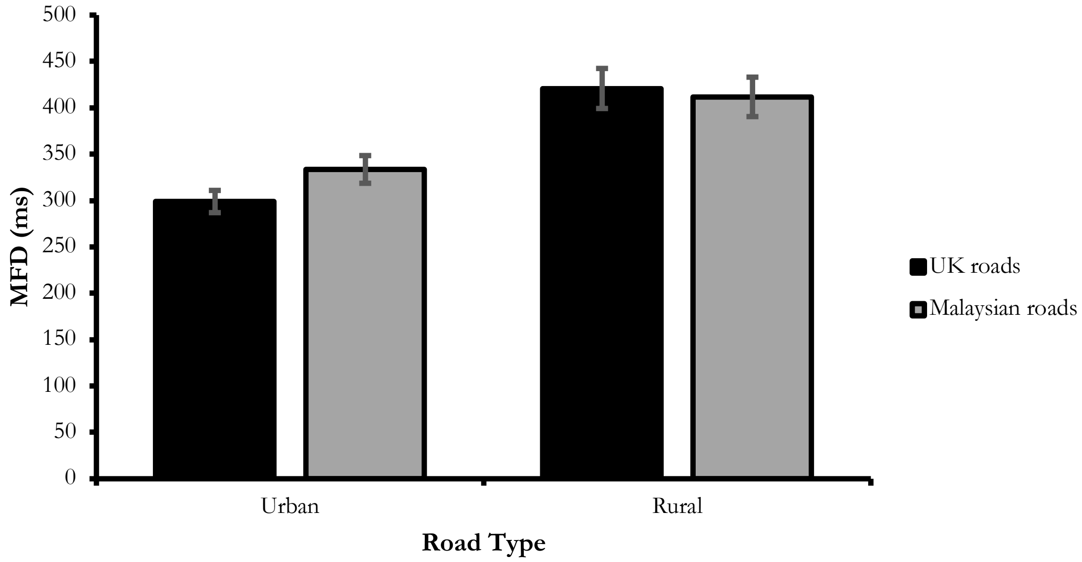

Figure 6.4: Interaction between road type and county on MFD (± 1 SEM)

6.3.1.2 Spread of search

The analysis of spread of search in the horizontal axis revealed a significant main effect of nationality such that UK drivers had a wider spread of search (M = 7.12, SE = .29) than Malaysian drivers (M = 5.86, SE = .30) ($F(1, 79) = 9.28$, $p = .003$, $\eta_p^2 = .11$).

There was also a significant main effect of road type, with horizontal spread of search being wider on urban roads (M = 6.76, SE = .18) compared to rural roads (M = 6.22, SE = .28) ($F(1, 79) = 5.94$, $p = .02$, $\eta_p^2 = .07$). There was a main effect of country, with horizontal spread being wider on UK roads (M = 6.77, SE = .24) compared to Malaysian roads (M = 6.21, SE = .20) ($F(1, 79) = 15.61$, $p<.001$, $\eta_p^2 = .17$). There were no significant interactions.

Finally when looking at spread of search in the vertical axis there was once again a main effect of nationality with UK drivers showing a wider vertical spread (M = 9.19, SE = .35) than Malaysian drivers (M = 5.98, SE = .36) ($F(1, 79) = 40.83$, $p<.001$, $\eta_p^2 = .34$).

There was a significant main effect of road type, with vertical spread of search being wider on rural roads (M = 7.85, SE = .27) compared to urban roads (M = 7.32, SE = .29) ($F(1, 79) = 4.65$, $p = .05$, $\eta_p^2 = .06$). There was also a significant main effect of country, with vertical spread being wider on UK roads (M = 7.85, SE = .26) compared to Malaysian roads (M = 7.33, SE = .27) ($F(1, 79) = 12.90$, $p<.001$, $\eta_p^2 = .14$). There were no significant interactions.

6.3.1.3 Average speed

For the average speed, there was a main effect of nationality such that Malaysian drivers drove significantly faster (M = 41.87mph, SE = .89) than UK drivers (M = 37.51mph, SE = .85) ($F(1, 79) = 12.58$, $p<.001$, $\eta_p^2 = .14$). There was also a main effect of road type such that participants drove faster on rural roads (M = 52.97mph, SE = 1.32) compared to urban roads (M = 26.41mph, SE = .90) ($F(1, 79) = 195.92$, $p<.001$, $\eta_p^2 = .71$). Finally there was a main effect of country with participants driving faster on UK roads (M = 40.60mph, SE = .66) compared to Malaysian roads (M = 38.79mph, SE = .63) ($F(1, 79) = 18.73$, $p<.001$, $\eta_p^2 = .19$). There were no significant interactions.

6.3.2 Controlled drive

As with the free drive condition, the four dependent variables were analysed using 2 x 2 x 2 mixed ANOVAs for the controlled drives in which participants were asked to drive at the same speed. One UK participant was unable to complete the controlled drives due to technical issues. Descriptive statistics from each of the four ANOVAs in the controlled drive condition can be seen in Table 6.3.

Table 6.3: Descriptive statistics for each dependent variable in the controlled drive condition

	UK (n=41)		Malaysian (n=39)	
	M	SD	M	SD
Fixations per minute				
UK Urban	144.77	25.13	138.67	22.63
UK Rural	126.47	29.56	116.23	25.79
Malaysia Urban	137.76	23.95	138.18	26.59
Malaysia Rural	123.99	31.11	120.96	28.06
Mean fixation duration				
UK Urban	280.75	101.19	321.22	85.86
UK Rural	365.81	153.50	407.24	124.55
Malaysia Urban	307.59	118.91	336.04	104.98
Malaysia Rural	374.24	165.86	395.63	129.83
Horizontal spread				
UK Urban	8.16	2.24	6.70	1.53
UK Rural	6.74	2.80	5.23	1.93
Malaysia Urban	7.63	1.86	6.54	1.55
Malaysia Rural	5.98	2.44	4.85	1.53
Vertical spread				

UK Urban	10.64	2.19	9.55	2.19
UK Rural	11.10	2.11	9.73	1.93
Malaysia Urban	10.66	2.05	9.80	2.27
Malaysia Rural	11.04	1.76	9.41	1.59

6.3.2.1 *Fixations per minute and fixation duration*

When looking at the number of fixations per minute, there was once again no main effect of nationality ($F(1, 78) = .82$, $p = .37$, $\eta_p^2 = .01$). There was still a main effect of road type such that participants made more fixations per minute whilst driving on urban roads (M = 139.85, SE = 2.59) compared to rural roads (M = 121.91, SE = 3.11) ($F(1, 78) = 62.39$, $p<.001$, $\eta_p^2 = .44$). There was no longer an interaction between road type and road country, however a significant interaction between nationality and road country emerged ($F(1, 78) = 8.48$, $p = .01$, $\eta_p^2 = .10$). Bonferroni corrected pairwise comparisons showed that UK participants made more fixations per minute when driving on UK roads compared to Malaysian roads (MD = 4.74, $p = .01$), however despite the effect being in the opposite direction for Malaysian participants, the difference was non-significant (MD = 2.12, $p = .21$) (see Figure 6.5).

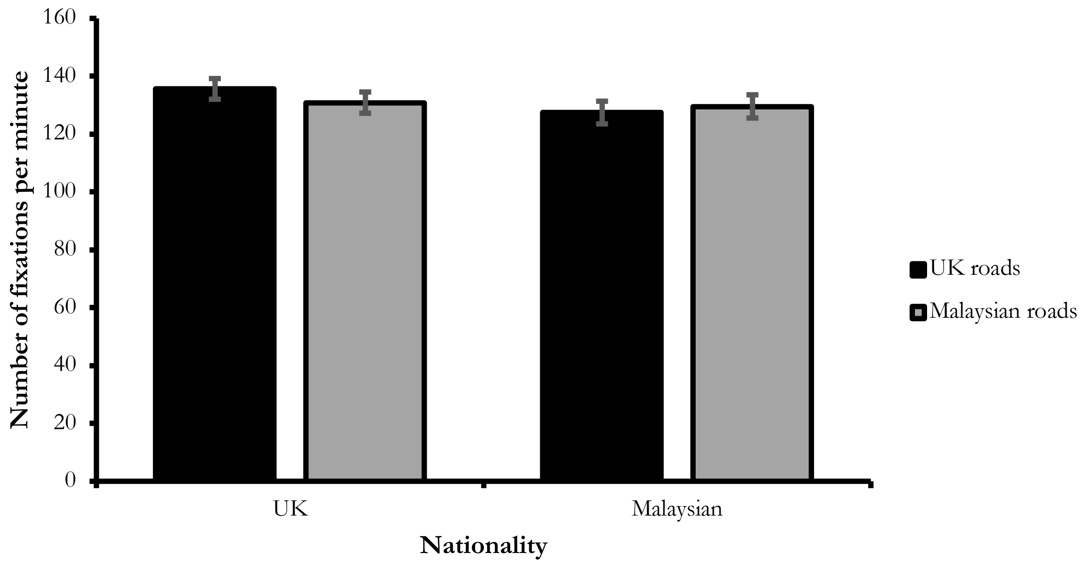

Figure 6.5: Interaction between participant nationality and road country for the number of fixations per minute (± 1 SEM)

The analysis of mean fixation duration also revealed no main effect of nationality ($F(1, 78) = 1.63$, $p = .21$, $\eta_p^2 = .02$). As with the free drive there was once again a main effect of road type such that fixations were longer on rural roads (M = 385.73ms, SE = 15.74) compared to urban roads (M = 311.40ms, SE = 11.24) ($F(1, 78) = 64.16$, $p<.001$, $\eta_p^2 = .45$). There was also a significant interaction between road type and country ($F(1, 78) = 7.51$, $p = .01$, $\eta_p^2 = .09$).

As with the free drive condition, Bonferroni corrected pairwise comparisons revealed that MFDs were longer on Malaysian urban compared to UK urban roads (MD = 20.83ms, $p<.001$), but showed no difference between Malaysian and UK rural roads (MD = 1.59ms, $p = .83$) (see Figure 6.6).

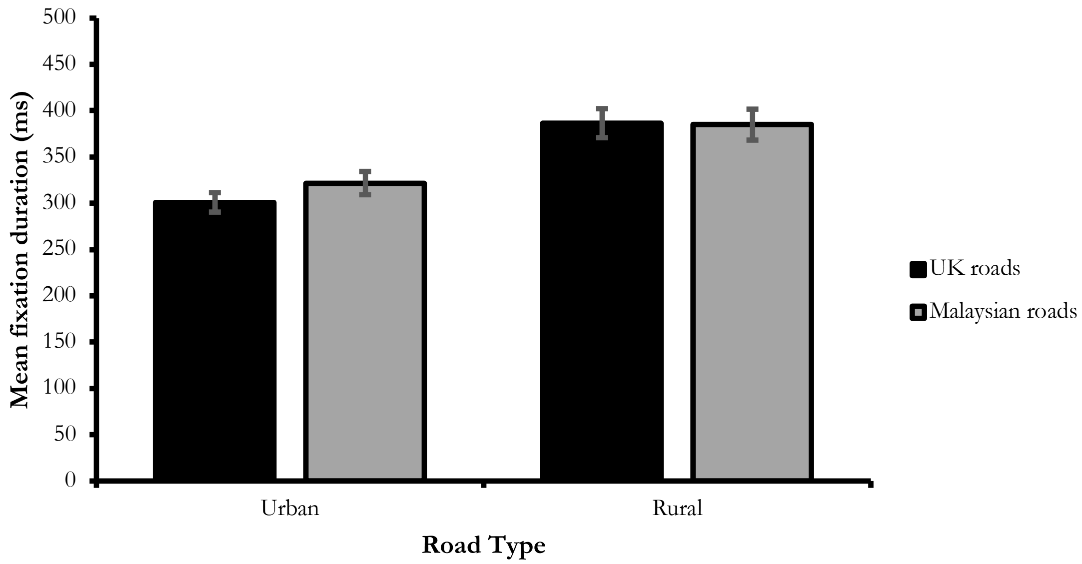

Figure 6.6: Interaction between road type and country on the mean fixation duration (± 1 SEM)

6.3.2.2 Spread of search

The results for spread of search in the horizontal axis in the controlled drive matched those for the free drive. There was a main effect of nationality such that UK drivers had a wider spread of search (M = 7.13, SE = .27) than Malaysian drivers (M = 5.83, SE = .28) ($F(1, 78) = 11.27$, $p = .001$, $\eta_p^2 = .13$). There was a main effect of road type such that horizontal spread was wider on urban roads (M = 7.26, SE = .19) compared to rural roads (M = 5.70, SE = .24) ($F(1, 78) = 75.74$, $p<.001$, $\eta_p^2 = .49$). Finally there was a significant main effect of country, with horizontal spread being wider on UK roads (M = 6.71, SE = .22) compared to Malaysian roads (M = 6.25, SE = .18) ($F(1, 78) = 13.95$, $p<.001$, $\eta_p^2 = .15$).

In the vertical axis, there was only a main effect of nationality such that UK drivers had a wider vertical spread (M = 10.86, SE = .27) than Malaysian drivers (M = 9.62, SE = .28)

($F(1, 78) = 10.10$, $p = .002$, $\eta_p^2 = .12$). There were no main effects of road type or country as seen in the free drive condition.

6.4 Discussion

This study investigated the cultural differences in where drivers look across different road types using a more naturalistic driving task and a more direct measure of visual attention that the previous studies presented in this thesis. Participants from the UK and Malaysia were tasked with driving along a series of urban and rural roads in a high-fidelity driving simulator whilst their eye movements were recorded. Overall, it was hypothesised that there would be a difference in visual attention between drivers from both nationalities such that Malaysian drivers should make more fixations with a shorter duration and show a wider spread of search than UK drivers.

For both the number of fixations per minute and mean fixation duration there was no effect of nationality, thus not supporting the initial hypotheses. The lack of cross-cultural differences for these two outcomes are contradictory to past cross-cultural research which has shown that East Asian observers make more fixations (Chua et al., 2005) and have shorter mean fixation durations (Goh et al., 2009) compared to Westerners in non-driving tasks.

Although differences in number of fixations and fixation duration were hypothesised on the basis of cross-cultural differences, the a recent meta-analysis from Robbins and Chapman (2019) found no effects of driving experience on either number of fixations or mean fixation duration. It may therefore be the case that fixation count and duration are fairly consistent across drivers when driving in the same environment, regardless of experience (either in the form of length of licensure, or experience driving in a particular environment or country).

The present findings suggest that the average number of fixations per minute and fixation durations are universal across drivers when controlling for the driving environment. However, differences were found between different road types, with drivers from both nationalities making more fixations per minute and having a shorter mean fixation duration on urban roads compared to rural roads. This finding supports the results of past studies which have shown an increase in the number of fixations on more complex roads such as urban roads compared to less complex rural roads (Chapman & Underwood, 1998; Crundall & Underwood, 1998). When driving in an urban environment, there are a large number of objects and areas of the roadway which need to be attended to in order to drive safely. Therefore, drivers should make a series of short fixations across the environment in order to attend to all relevant aspects of the scene. In contrast, there is much less to attend to on rural roads therefore drivers are more likely to fixate on a single point (such as the road straight ahead) for longer and make less fixations overall.

It should be noted that although findings from previous research on the effect of road type on number of fixations and fixation duration were replicated, the average fixation duration in the current research was shorter than those described in previous studies. For example, Crundall and Underwood (1998) observed mean fixation durations of approximately 380ms and 365ms on rural roads (for experienced and novice drivers respectfully) compared to 324ms and 335ms on suburban roads. Whilst there is no normative data on drivers fixation duration, similar results are reported in the meta-analysis by Robbins and Chapman (2019) indicating that the fixations durations reported in this study are slightly shorter than those in previous work. The most likely explanation for this is the duration of the trials in this research, whilst earlier studies on drivers' visual attention often involve longer drives such as a 20 minute on-road drive (Crundall & Underwood, 1998), the current research involved a series of short drives typically lasting closer to 1 minute. On longer routes, participants will make more long fixations on the FOE at several points in the journey, however in a short drive the number of extremely long fixations will be reduced, therefore reducing the overall mean fixation duration for each participant. However it should be noted that these shorter fixation durations are still similar to the typical fixation duration of 200-300ms as shown in the eye tracking literature more broadly (Holmqvist & Andersson, 2017) suggesting that although short within the driving literature, the fixations durations are still within a normal range. Additional factors which could influence fixation duration are discussed within the limitations of this research.

As well as a significant effect of road type, there was also a significant effect of road country on mean fixation duration in the free drive condition such that participants had longer fixations on Malaysian roads. Similarly, in both the free and controlled drives there was a significant interaction between road type and road country on MFD such that there were longer fixations on Malaysian urban roads compared to UK urban roads, but no differences between countries for rural roads.

A possible explanation for these findings is related to the amount of visual clutter and the higher proportion of motorcycles on Malaysian roads (particularly the Malaysian urban road). Whilst it was hypothesised that a higher amount of visual clutter would lead to shorter fixations which are scattered across the scene, it could be the case that these additional objects were more difficult to process and thus required longer fixations in order to be processed fully. This is particularly relevant with the higher prevalence of motorcycles on the Malaysian trials. Past research has shown that when presented for a limited time of 250ms, drivers' are less likely to identify an approaching motorcycle compared to a car (D. Crundall et al., 2008) suggesting that a longer fixation duration is required when attending to motorcycles on the road. In the case of the current study the effect of road country may be a result of this additional processing time needed to attend to motorcycles sufficiently.

Road country also interacted with road type for fixations per minute in the free drive condition. On the rural roads, there were more fixations per minute on the UK roads compared to Malaysian roads. This is likely a result of the increased visual information on the Malaysian roads compared to the UK, which gave participants more objects which they may choose to fixate on. One might expect the same pattern of results to be true to urban roads, however the interaction showed that the reverse was true with more fixations per minute being found on the UK version of the urban road. It could be the case that in an urban environment, the increased visual complexity led to participants instead making fewer fixations with a longer duration (supported by the longer MFDs reported on Malaysian roads) as the increased complexity and higher attentional demand made it harder to process information, or led to attentional narrowing amongst the participants.

Finally in relation to the number of fixations, although there was no main effect of nationality, there was an interaction between nationality and road country in the controlled drive such that participants from both countries had a higher number of fixations per minute when driving on roads which more closely resembled their home country. Although it might be reasonable to expect that familiarly with a driving environment would lead to less fixations (Martens & Fox, 2007b) the current environments, whilst possibly resembling a familiar environment, were novel to all participants. Instead, the observed interaction may be due to the fact that when driving in an environment more closely resembling their home country, participants felt more comfortable driving and therefore felt free to explore the environment more with more fixations. In contrast, when driving in an unfamiliar environment participants may have not felt as comfortable exploring. Although this may explain the current interaction, it should be noted that this effect was not present when analysing fixation duration or spread of search. Although out of the scope of the current work, future research should explore the role of familiarity with a driving environment further, particularly with cross-cultural comparisons.

For spread of search, it was hypothesised that Malaysian drivers should have a wider spread of search in both the horizontal and vertical axes. Despite this hypothesis, results revealed a cross-cultural difference for spread of search in both axes such that UK participants had a wider spread of search. This finding does not support previous cross-cultural findings which have shown that East Asian participants have a wider spread of search and attend to a wider angle a visual scene (Boduroglu et al., 2009; Chua et al., 2005; Goh et al., 2009; Lee et al., 2016; Liu et al., 2013), or the findings from the driving literature suggesting that experience leads to an increase in spread of search (Chapman & Underwood, 1998; Robbins & Chapman, 2019). Although these findings did not support the initial hypothesis, additional findings may help to better interpret these results.

First, as hypothesised there was a main effect of road type for spread of search in the horizontal axis such that participants had a wider spread when driving on urban roads compared to rural roads. This finding is similar to the findings for fixation count and duration as previously described, with an increase in visual complexity in the road environment leading to a spread of search characterised by a larger number of short fixations covering a wide visual angle.

There was also an effect of road country on spread of search in the horizontal axis, such that spread was wider on UK roads compared to Malaysian roads. It was originally hypothesised that spread of search would be wider on Malaysian roads due to their increased complexity (in the same way that spread of search increases when moving from a rural to an urban roads). One possible explanation for these findings is that although there was an increase in visual clutter on Malaysian roads, this may have led to drivers exhibiting attentional narrowing due to the perceived danger and hazardousness or the environment, as opposed to a wider spread of attention. The narrowing of attention during hazardous driving tasks has previously been demonstrated in studies where participants watched videos from the perspective of a driver (Chapman & Underwood, 1998; Crundall et al., 2002). It is argued that in these cases of highly hazardous driving, attentional resources are limited therefore drivers (particularly novice drivers) are unable to distribute their attention to the wider scene as a whole. Similarly, increased traffic density has been shown to increase drivers' workload in simulated driving (Teh et al., 2014) which in turn may lead to a narrowing of visual attention (Ma et al., 2020). These findings would support the results showing a narrower spread of search on the Malaysian roads. In future work, it may be interesting to examine the impact of visual clutter in the environment separately to increased traffic density to explore whether these two factors influence visual attention differently.

In the case of the observed cross-cultural differences, it could be the case that repeated exposure to a highly hazardous driving environment such as Malaysia had led to Malaysian drivers developing an attentional style which shows attentional narrowing on all driving tasks. It should be noted that if this difference is a result of the Malaysian drivers showing attentional narrowing as a result of repeated exposure to hazardous driving environments, this may be exacerbated by the fact that the drivers in the current study had an average length of licensure of about 3 years. Analyses of crash data suggest that drivers with less than 3 years driving experience are over represented in crash statistics and may therefore be still considered novice drivers (Clarke et al., 2006). Similarly in the recent meta-analysis on drivers' visual search from Robbins and Chapman (2019), drivers with less than 3 years experience were classified as the novice driver group. With just over 3 years average driving experience, it may be the case that the current sample show some attentional narrowing due to their lack of driving experience, however with more experienced drivers this may change and lead to an increased spread of search as predicted. Although it is not possible to test this is the current sample, further research should be conducted.

Finally, when looking at the differences in vertical spread of search, the wider spread of search found amongst UK drivers could once again be explained in terms of attentional narrowing amongst Malaysian drivers. An alternative, simpler explanation for this finding could be that UK drivers were more likely to make fixations in the car on their speedometer compared to Malaysian drivers (as reflected by the difference in average speed). Compared to spread of search in the horizontal axis, there is not as much need to distribute attention along the vertical axis. One exception in the current study would be making fixations in the vehicle on the speedometer which means that more fixations will occur further away from the FOE, thus leading to this reported increase in spread. However due to the differences in speed between participants, it is not believed that this difference in vertical spread of search is a strong cultural difference in how attention is allocated to the roadway.

Similarly, in the free drive condition, results showed that spread of search was wider on rural roads compared to urban roads. On the urban road trials, speed was largely controlled by the other vehicles on the road. In contrast the lower traffic density on rural roads meant that drivers had to control their own speed. It is possible that both of these findings are explained by the fact that UK drivers simply made more fixation in the car on their speedometer than Malaysians.

6.4.1 Limitations

There is one primary limitation to consider when interpreting the findings of the current study, namely the amount of driving experience the current sample had. As discussed in the context of spread of search and the potential attentional narrowing on hazardous roads, the participants in the current study could be considered novice drivers due to the fact that the entire sample had an average of approximately 3 years driving experience. Although the risk for being involved in an accident drops drastically after the first 6 months of driving (Mayhew et al., 2003), studies exploring drivers' visual attention have considered those with less than 3 years driving experience to be novices (Robbins & Chapman, 2019).

Despite this, within the current study there was no difference in driving experience between the two groups, ensuring this factor does not confound results. Instead, the current findings should be considered reliable for younger, less experienced drivers in both countries. Moving forward, future research may wish to expand on the current findings to see whether cross-cultural differences in visual search begin to emerge as driving experience increases, which could possibly have wider implications for driving in new environments as a more experienced driver.

Finally, although not strictly a limitation of the current work, it is worth discussing the differences in fixation duration which can arise as a result of different methods used. First, it may be the case that the use of a wearable eye tracker vs a static system could lead to differences in the amount and duration of fixations recorded. Unlike a static system, wearable eye trackers have less control over factors such as lighting and participant head movements, there will also be differences between systems in terms of precision and sampling rate (Holmqvist & Andersson, 2017). One study has directly compared wearable vs static eye tracking systems on the same task and found no major differences on several eye tracking measures (Dowiasch et al., 2020). However, this research did find differences in gaze accuracy and saccade duration such that the stationary eye tracker had a higher accuracy.

With regards to head movements, it is possible that the fixation algorithm used in the current research is more likely to split fixations on a single object into multiple shorter fixations when a head movement occurs. When using a static system, algorithms will be able to code smooth pursuit movements as a single fixation on an object. However, with the addition of head movements it is possible that the combination of a moving target and a moving observer leads to the algorithm classifying a smooth pursuit as several shorter fixations.

Differences in sampling rate may also lead to differences in glance duration across eye tracking systems. Wearable eye trackers typically have a lower sampling rate (with the Tobii 2 glasses used in this research sampling at 50Hz), whereas stationary eye trackers will often have a higher sampling rate (for example the Tobii Pro Spectrum has a sampling rate of 1200Hz, whereas the EyeLink 1000 Plus has a sampling rate of 2000Hz). A lower sampling rate may fail to capture rapid changes in eye position when compared to a system with a higher sampling rate. This can lead to a delay in detecting the start and end of fixations, potentially causing the algorithm to group together multiple short fixations into a single longer fixation, thus reporting longer fixation durations (Andersson et al., 2010). As the current research reported shorter fixations than previous studies, this may not be the main reason for these differences, however it should still be considered as a factor which can influence glance data.

As well as differences between eye trackers, differences in eye tracking measures can arise when comparing simulated driving to driving in the real world. Validation studies conducted in the NITES 1 driving simulator have shown that fixations in a simulated environment are shorter than those in the real world (Foy, 2017), however, a similar study also conducted in NITES 1 found the opposite, showing longer fixation durations when driving in a simulator compared to the real world (Robbins, Allen, & Chapman, 2019). Finally, a study examining visual attention in a medium fidelity simulator in California found no differences in fixation duration between simulated and real world driving (Leonardo et al., 2024). The discrepancy in these results demonstrates that the tool used in this research can lead to differences in fixation durations, however the direction of these differences is inconsistent. This is likely due to the specific tasks used in each individual study, however it may warrant further investigation in future research which is outside of the scope of the current project.

6.4.2 Summary and conclusions

In conclusion, contrary to the initial hypotheses the current study did not show an increased spread of search, with more fixations and a shorted fixation duration amongst Malaysian drivers. Instead, certain aspects of drivers' visual search were found to be universal between drivers from the UK and Malaysia, whilst spread of search was found to be wider in both the horizontal and vertical axes for UK drivers. Moving forward the next step of this research is to explore whether there are cultural differences in visual search across a series of different driving tasks.

Chapter 7: A comparison of where drivers look when static or moving

7.1 Introduction

The final study in this thesis also explored the cross-cultural differences in visual search using a driving simulator task and eye tracking. Whilst the previous study described in Chapter 6 explored the general differences in visual search, it did not explore which objects people attend to in the visual scene.

Thus far in this thesis, results regarding whether Malaysian drivers attend more to objects located in the background compared to UK drivers have yielded mixed results. When choosing where to look, some cultural differences emerged with Malaysian drivers choosing more background regions than UK drivers (Chapter 4). However this finding was not replicated in the change blindness studies described in Chapter 5, where there were no cross-cultural differences in detecting changes in either focal or background regions. These findings therefore offer mixed support for with past research suggesting that Westerners should attend more to focal objects, whilst Easterners should attend more to the background (e.g. Chua et al., 2005; Masuda & Nisbett, 2001; Masuda & Nisbett, 2006).

As previously discussed in Chapter 5, it could be the case that the driving task itself overshadows cultural differences in visual attention since the task itself demands that attention be allocated in a certain way. In linking this to the model previously described in Chapter 2 (section 2.2.3.3) from Trick et al. (2004), it could be the case that the task presented to participants in Chapter 5 led to attention being allocated in an automatic manner influenced by either external cues (reflexes), or formed habits. In contrast, when participants were free to choose where they would look (as they were in the study presented in Chapter 4), attention is allocated in a more controlled manner which seems to have the potential to differ by culture.

Based on these past findings, it was necessary to explore whether there are cross-cultural differences in visual search in situations when driving where a driver can allocate their attention in a more controlled manner and actively choose where to look. One aspect of driving where this would be possible is when stopped at a junction. Whilst driving continuously along a road requires attention to be allocated mostly in an automatic way to ensure you are following the road, keeping a safe distance from the car ahead, and avoiding hazards, however it is possible to freely explore the environment when stopped in a vehicle. Whilst this could be the case for stopping at any junction, this is particularly true when stopping at a traffic light controlled junction when waiting for a red light to turn green. It may be the case that in these situations, cultural differences in visual attention begin to emerge as they are no longer supressed by the attentional demands of the driving task.

To explore this possibility, participants were presented with three driving tasks in the current study; driving continuously following a vehicle, stopping at a junction with a give-way sign and approaching traffic, and stopping at a traffic light controlled junction showing a red light. If it is the case that these cross-cultural differences in visual search only emerge in situations where a driver is free to allocate their attention in a controlled manner, a cross-cultural effect should be found when drivers are stopped at a traffic light, but not when they are driving continuously, or when stopped at a junction requiring active visual search.

In addition to exploring potential cultural differences in how attention is allocated to focal and background objects in each of these tasks, the current study also once again compared general visual search between UK and Malaysian drivers as was previously investigated in Chapter 6. Whilst past studies have explored visual attention at junctions, the focus of this research is typically on right of way violation crashes such as those involving bicycles or motorcycles (e.g. Robbins & Chapman, 2018; Summala et al., 1996). So far, no research has explored differences in general visual search at junctions between drivers from different nationalities. Therefore this will also be addressed in the current study.

Several hypotheses are being tested in this final study. First, it is hypothesised that there will be a cross-cultural interaction between nationality and object region when waiting at a traffic light such that UK drivers attend to more focal objects than Malaysians, and Malaysians attend to more background objects than UK drivers. However this interaction will not emerge when participants are driving continuously, or when stopped at a give-way junction.

Second, it is hypothesised that when driving on a Malaysian road compared to a UK road, that participants will have a wider spread of search, more fixations and a shorter mean fixation duration. It is also hypothesised that participants will fixate on more background objects when driving on Malaysian roads (particularly context irrelevant background objects), and more focal objects when driving on UK roads. As this is related to exposure to a particular environment leading to differences, it is hypothesised that self-construal will not be related to any of the above measures.

Finally, it is hypothesised that there will be a main effect of driving task on the total number of fixations, mean fixation duration, and spread of search in both the horizontal and vertical axes.

7.2 Method

7.2.1 Design

This study once again used a 2 x 2 x 3 mixed design. The between groups variable was the nationality of the participant (either UK or Malaysian). The within groups variables were the driving task (Task A: driving straight ahead, Task B: stopping at a give-way junction (with approaching traffic), or Task C: stopping at a traffic light controlled junction), and the road country (UK or Malaysia). UK and Malaysian roads were presented in two separate blocks with half of the participants completing each block first. Within the block the order of the trials was fully counterbalanced, the same counterbalanced order was then used for the second block of trials.

The dependent variables for eye tracking measures were the number of fixations, mean fixation duration (ms), spread of search in the horizontal and vertical axes (as calculated by the standard deviation of fixation locations in each axis), proportion of total fixations in focal objects, proportion of total fixations of background relevant objects, and the proportion of total fixations on background irrelevant objects.

Similar to previous studies (Chapters 4 & 5), focal objects were defined as any object within the driver's lane including lead vehicles, and the roadway itself. Background relevant objects were defined as objects outside of the driver's lane which are still relevant to the driving task, this includes objects such as other vehicles, road signs, and traffic lights. Finally, background irrelevant objects are those outside of the driver's lane which are not directly relevant to the driving task such as buildings, trees, and other background objects.

7.2.2 Participants

Participants were UK and Malaysian drivers at the University of Nottingham, with Malaysian participants being international students studying abroad in the UK. The eligibility criteria for the study were the same as described in Chapter 6, section 6.2.2; a full UK or Malaysian driver's licence, no experience of driving in the other country and minimal experience driving abroad, lived in your home country for the majority of your lifetime, and for Malaysian participants not living in the UK for over one year.

This study was pre-registered (osf.io/7y9c5) with a total sample size of 76 participants (38 per nationality) which would be needed to detect a medium effect size (d = .25) with a power of 0.8. Initially 89 participants took part in the study (43 UK, 46 Malaysian), however 13 were excluded (5 UK, 8 Malaysian). Nine participants were excluded for experiencing simulator sickness, 2 participants were excluded as the eye tracker failed to record at least 75% of fixations, and 2 participants reporting living abroad for more than half of their lifetime. This gave a final sample of 76 participants (38 UK, 38 Malaysian). Additional demographics and inferential statistics can be found in Table 7.1.

None of the UK participants had lived abroad for a prolonged period of time and had no experience driving in another country. Malaysian participants had been living in the UK between 1 and 7 months (M = 4.18 months, SD = 1.98) and had no experience driving outside of Malaysia.

Table 7.1: Demographic data

Nationality	UK (n=38)		Malaysian (n=38)		t-test		
	Range	*M* (SD)	*Range*	*M* (SD)	*t*	*P*	*d*
Age	18-31	20.55 (3.22)	18-23	21.45 (1.08)	1.62	.11	.37
Driving experience (years)	0.25-11.58	2.86 (3.06)	1.75-5.25	3.58 (0.96)	1.37	.18	.31
Annual mileage*	0-20,000	4810.02 (4714.23)	12.43-17,398	4945.23 (4762.06)	0.12	.91	.03
Hours driven per week	0-20	3.86 (4.82)	1-28	8.51 (5.87)	3.72	<.001	.87
SCS Independence	2.13-5.80	4.48 (0.70)	3.33-6.0	4.69 (0.66)	1.39	.17	.68
SCS Interdependence	3.67-6.33	4.61 (0.50)	2.80-6.33	5.01 (0.76)	2.66	.01	.64

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

All participants either received a £5 inconvenience allowance, or course credit for taking part in the study, however course credit was only received by a subsection of participants in the UK sample.

7.2.3 Apparatus and materials

As with the previous study in Chapter 6, testing took place in the Nottingham Integrated Transport and Environment Simulation facility's high fidelity driving simulator (NITES1) (see section 6.2.3 for a technical description of the simulator).

The trials consisted of 6 different key scenarios (3 for each road country), and one additional scenario which was not used for analysis purposes. All trials involved participants driving through the same suburban area within the simulator, stills from each of the 6 trials can be seen in Figure 7.1

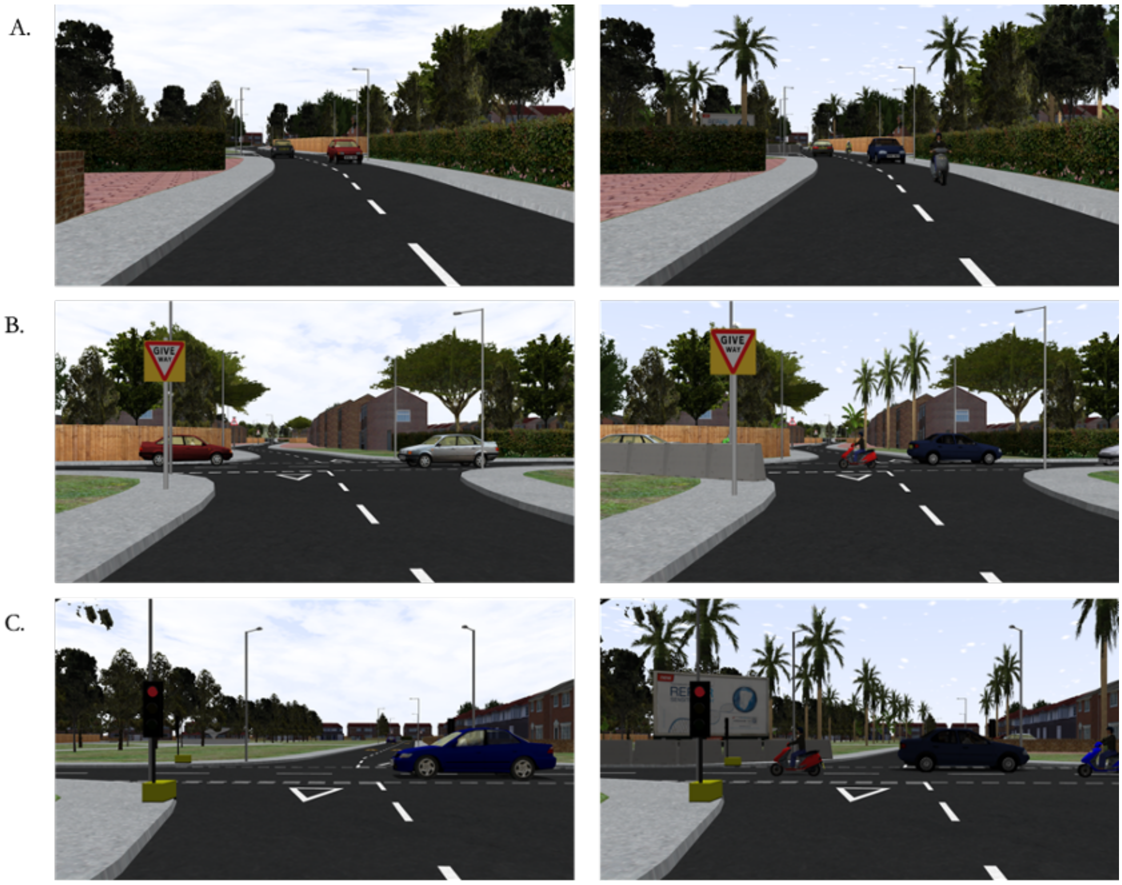

Figure 7.1: Roads used for each of the 3 trials, A) driving continuously, B) a give-way junction, C) a traffic light controlled junction. Resembling both the UK (left) and Malaysia (right)

Trial A involved participants driving straight along a road where they were following a car ahead which travelled at a speed of 25mph. Other vehicles were present on the road in the opposite lane.

Trial B involved participants driving towards a junction with a give-way sign, with traffic approaching from both directions. Traffic was heavy enough such that participants were forced to wait at the junction for approximately 30 seconds before it became clear enough for them to safely cross and drive straight ahead.

Finally, trial C involved participants driving towards a different junction which had a temporary traffic light showing a red light. Participants should wait at the red light for the remainder of the trial which lasted approximately 30 seconds. It was not possible to turn the red-light green, so after all vehicles had passed the scenario was terminated. In order to ensure that participants did not assume that this junction would only involve a red light with no option to drive further, an additional trial was added where the traffic light showed a green-light which participants were able to drive through. This was a short drive and was not included in the analysis.

Each of these 3 scenarios were created to look like both a UK and Malaysian road. For the UK versions, no additional objects were added to the scenarios, and the traffic consisted of mostly cars. In contrast, on Malaysian roads foliage was changed to better represent Malaysian roads, roadside objects such as concrete barriers and roadside advertisements were added, and traffic consisted of a larger proportion of PTWs to represent Malaysian traffic more accurately. These were checked by a Malaysian driver to ensure they accurately represented a Malaysian road.

Eye tracking was once again recorded using Tobii Pro Glasses 2, in the same manner as described in Chapter 6 (section 6.2.3).

7.2.4 Procedure

Before the experiment, participants were sent an information sheet and consent form to be completed online, as well as the background questionnaire and SCS used in the previous study. On the day of the study participants visited the simulator lab and were reminded of the instructions for the experiment, if they were happy to continue, they were then taken to the simulator and were provided with eye tracking glasses which were calibrated before starting the recording. Participants were also asked to review the SSQ before starting the experiment.

Before the experimental trials participants were given a two short practice drives to allow them to become familiar with driving the simulator, and to check for any signs of simulator sickness. The first practice drive involved driving along a straight road containing no other traffic, whilst the second involved approaching a junction, stopping, and then driving straight ahead with no traffic present. Following the practice drives participants once again received the SSQ and any participants showing signs of simulator sickness were removed from the study.

7.2.5 Data analysis

Eye tracking data were extracted using Tobii pro analyser software. Fixations were classified using the Tobii I-VT fixation gaze filter which classified a fixation as a point in which the participants' gaze was within 0.5° for a minimum of 60ms.

As with the previous study, the number of fixations per minute are reported as opposed to fixation count to account for any differences in speed and time spent completing each trial.

In order to determine which objects participants fixated on, each fixation was coded as either falling on a focal object, context relevant object, or context irrelevant object as defined above (section 7.2.1). As background objects could be context relevant or irrelevant, the proportion of fixations across these regions was summed for follow up analyses.

When calculating the spread of search, the x and y coordinates for each fixation were taken (with a fixation directly ahead being classified as 0°), the standard deviation of these fixation locations within each trial was then calculated as a measure of spread.

All data met the assumptions of normality and homogeneity of variance. All data were analysed using SPSS v28.

7.3 Results

7.3.1 Number of fixations per minute and mean fixation duration

Number of fixations per minute and mean fixation duration (MFD) were subject to a 2 (nationality) x 2 (road country) x 3 (driving task) analysis of variance. Descriptive statistics from both ANOVAs can be seen in Table 7.2.

Table 7.2: Descriptive statistics for fixations per minute and mean fixation duration

	UK (n=38)		Malaysian (n=38)	
	M	SD	M	SD
Fixations per minute				
UK A	151.79	24.38	140.58	26.33
UK B	118.51	16.10	118.79	16.56
UK C	138.45	23.30	129.75	21.94
Malaysia A	153.84	23.95	143.05	24.75
Malaysia B	123.08	15.12	122.02	15.96
Malaysia C	129.98	28.27	134.02	22.35
Mean fixation duration				
UK A	288.00	106.42	344.11	104.98
UK B	229.65	60.47	248.05	56.36
UK C	249.63	89.25	272.34	77.48
Malaysia A	285.42	99.32	331.38	94.07
Malaysia B	223.52	46.39	245.03	53.05
Malaysia C	249.17	116.61	257.90	65.40

7.3.1.1 Number of fixations and mean fixation duration

In terms of number of fixations per minute, there was no main effect of nationality (F(1, 74) = 1.72, p = .19, η_p^2 = .02), however there was a marginally significant interaction between nationality and road country (F(1, 74) = 2.95, p = .09, η_p^2 = .04) (see Figure 7.2).

Post hoc pairwise comparisons showed that for UK participants the number of fixations per minute did not change between road counties (MD = .62, p = .70), however Malaysian participants made more fixations per minute when driving on Malaysian roads compared to UK roads (MD = 3.32, p = .04).

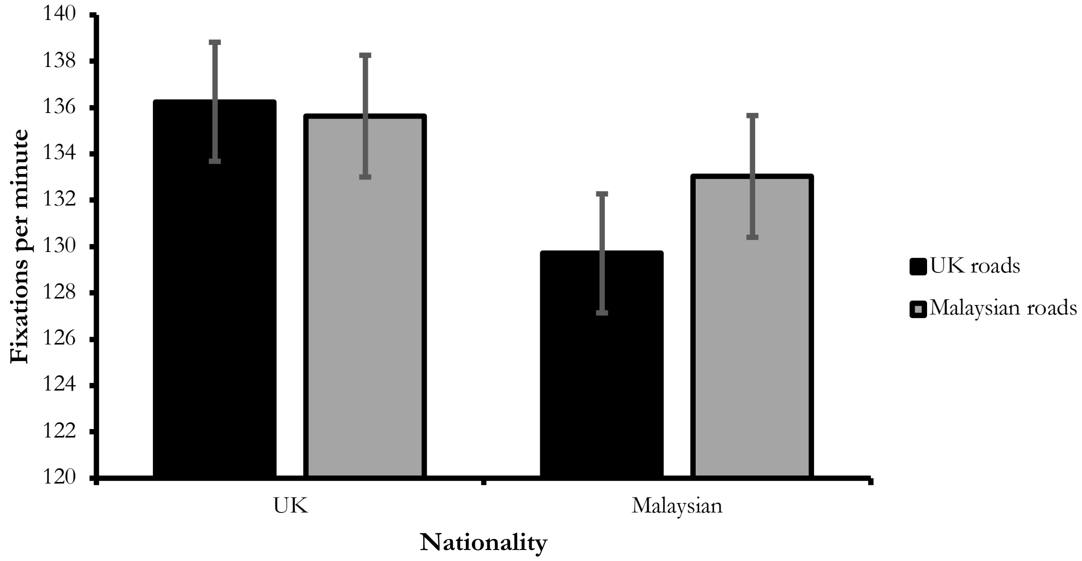

Figure 7.2: Interaction between participant nationality and road country (± 1 SEM)

There was a significant main effect of task (F(2, 148) = 52.11, p<.001, η_p^2 = .41). Planned helmert contrasts first compared Task A (driving continuously) to the average of Tasks B and C (stopping at a junction), whilst the second contrast compared the two junction conditions. The first orthogonal contrast showed that participants made more fixations when driving continuously (M = 147.32, SE = 2.71) compared being at a junction (M = 126.82, SE = 2.04) (F(1, 74) = 65.72, p<.001, η_p^2 = .47). Whilst the second contrast showed a higher number of fixations when stopped at a traffic light controlled junction (M = 133.05, SE = 2.44) compared to a give-way junction (M = 120.60, SE = 1.64) (F(1, 74) = 29.80, p<.001, η_p^2 = .29).

There was also a significant three-way interaction between nationality, road country, and task (F(2, 128) = 2.24, p = .04, η_p^2 = .04) (see Figure 7.3. Post hoc analyses revealed that the nationality x country interaction was only significant for Task C (F(1, 74) =5.99, p = .02, η_p^2 = .08), such that participants from the UK made more fixations per minute on UK roads compared to Malaysian roads (MD = 8.47, p = .02), however there was no difference for Malaysian participants (MD = 4.27, p = .25). All other main effects and interactions were non-significant.

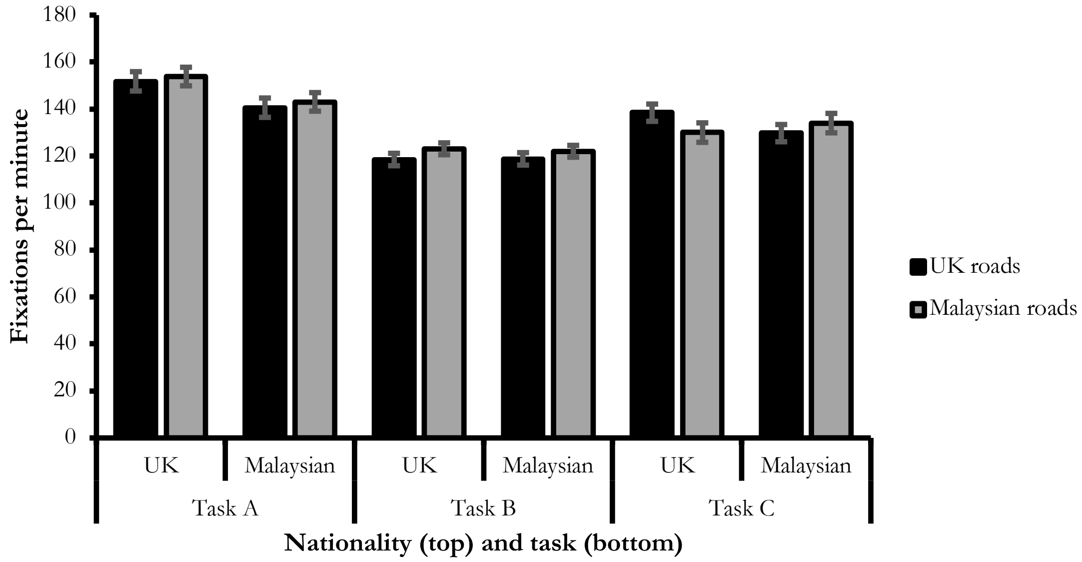

Figure 7.3: Interaction between nationality and country across the three tasks (± 1 SEM)

For MFD there was a marginally significant effect of nationality ($F(1, 74) = 3.23$, $p = .08$, $\eta_p^2 = .04$) with Malaysian participants having slightly longer fixations (M = 283.14ms, SE = 11.38) compared to UK drivers (M = 254.23ms, SE = 11.38). There was once again a marginally significant effect of road country such that fixations were slightly longer on UK roads (M = 271.96ms, SE = 8.45) compared to Malaysian roads (M = 265.40, SE = 8.01) ($F(1, 74) = 3.55$, $p = .06$, $\eta_p^2 = .05$), however there was no interaction between nationality and road country ($F(1, 74) = 1.01$, $p = .32$, $\eta_p^2 = .01$).

There was a main effect of task on MFD ($F(2, 148) = 54.20$, $p<.001$, $\eta_p^2 = .42$) with orthogonal contrasts showing longer fixations when driving continuously (M = 312.23ms, SE = 11.20) compared to being at a junction (M = 246.91ms SE = 5.89) ($F(1, 74) = 91.20$, $p<.001$, $\eta_p^2 = .55$), and longer fixations when stopped at a traffic light controlled junction (M = 257.26ms, SE = 9.55) compared to stopping at a give-way junction (M = 236.56ms, SE = 5.84).

There was a significant interaction between task and nationality ($F(2, 148) = 3.30$, $p = .04$, $\eta_p^2 = .04$) (see Figure 7.4). Bonferroni corrected pairwise comparisons revealed that Malaysian drivers had longer fixations (M = 337.75ms, SE = 15.84) compared to UK drivers (M = 286.71ms, SE = 15.84) when driving continuously (MD = 51.04, $p = .03$). However, there was no difference between groups when stopped at a give-way junction (MD = 19.96, $p = .09$) or a traffic light controlled junction (MD = 15.72, $p = .41$).

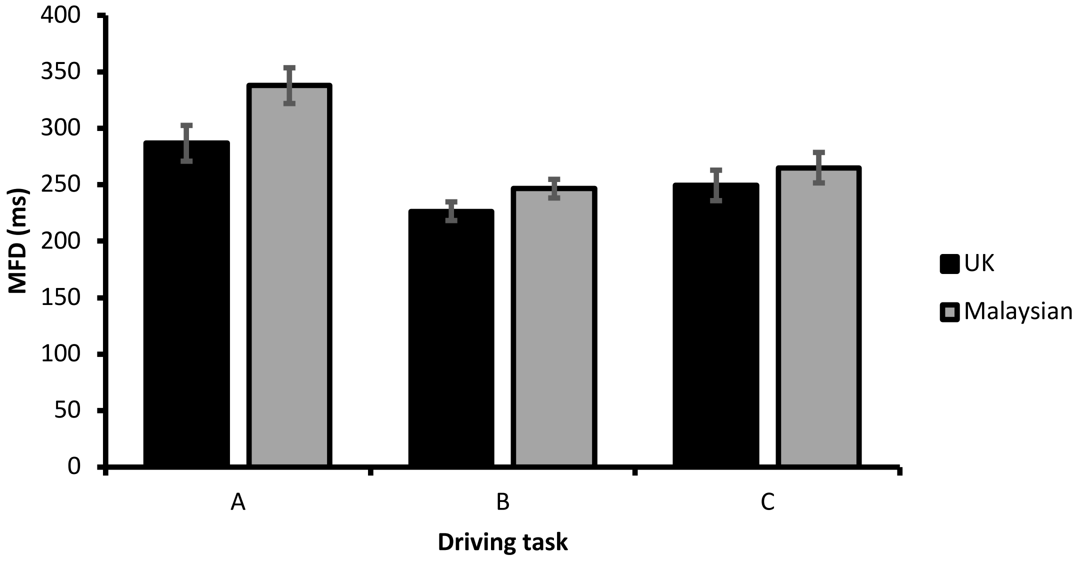

Figure 7.4: Interaction between participant nationality and driving task (± 1 SEM)

7.3.2 Spread of search

Spread of search in both the horizontal and vertical axes were also subject to a 2 (nationality) x 2 (road country) x 3 (driving task) analysis of variance. Descriptive statistics from both ANOVAs can be seen in Table 7.3

Table 7.3: Descriptive statistics for spread of search in the horizontal and vertical axes

	UK (n=38)		Malaysian (n=38)	
	M	SD	M	SD
Horizontal spread				
UK A	6.48	1.54	6.12	1.67
UK B	20.03	3.64	19.01	3.39
UK C	13.19	2.83	13.47	3.16
Malaysia A	5.87	1.44	6.17	1.53
Malaysia B	19.27	3.99	18.42	3.70
Malaysia C	13.18	3.21	13.04	2.88
Vertical spread				
UK A	7.08	3.24	4.21	2.19
UK B	6.60	1.78	5.27	1.35
UK C	6.60	1.60	6.62	1.66
Malaysia A	6.43	3.13	3.88	2.11
Malaysia B	6.81	1.78	5.40	1.25
Malaysia C	6.72	1.96	6.53	1.77

For spread of search in the horizontal axis there was no main effect of nationality ($F(1, 74) = .54$, $p = .47$, $\eta_p^2 = .01$). There was a main effect of country such that participants had a wider spread of search on UK roads (M = 13.05, SE = .23) compared to Malaysian roads

(M = 12.66, SE = .22) (F(1, 74) = 5.16, p = .03, η_p^2 = .07), however there was no interaction between nationality and country (F(1, 74) = .15, p = .70, η_p^2 = .002).

There was once again a main effect of task (F(2, 73) = 642.18, p<.001, η_p^2 = .90). The first orthogonal contrast showed that spread of search in the X axis was wider when waiting at a junction (M = 16.20, SE = .34) compared to driving continuously (M = 6.16, SE = .15) (F(1, 74) = 1240.33, p<.001, η_p^2 = .94). The second contrast revealed a wider spread when waiting at a give-way junction (M = 19.19, SE = .39) compared to waiting at a traffic light controlled junction (M = 13.22, SE = .29) (F(1, 74) = 227.51, p<.001, η_p^2 = .76).

Finally for spread of search in the vertical axis, there was a main effect of nationality such that UK drivers showed a wider spread of search (M = 6.06, SE = .18) compared to Malaysian drivers (M = 5.96, SE = .19) (F(1, 74) = 1220.96, p<.001, η_p^2 = .94). There was no effect of country, nor a significant interaction between nationality and country (F(1, 74) = .00, p = .95, η_p^2 <.001).

There was a main effect of task (F(2, 73) = 14.17, p<.001, η_p^2 = .16), with contrasts revealing a wider spread of search whilst waiting at a junction (M = 6.32, SE = .17) compared to driving continuously (M = 5.40, SE = .29) (F(1, 74) = 14.69, p<.001, η_p^2 = .17), and a wider spread when waiting at a traffic light (M = 6.62, SE = .17) compared to a give-way junction (M = 6.02, SE = .16) (F(1, 74) = 12.74, p<.001, η_p^2 = .15).

There was also an interaction between nationality and task (F(2, 148) = 16.46, p<.001, η_p^2 = .18) (see Figure 7.5) Bonferroni corrected pairwise comparisons revealed that UK drivers had a wider spread of search when driving continuously (MD = 2.71, p<.001) and when stopped at a give-way junction (MD = 1.37, p<.001), however there was no difference when stopped at a traffic light controlled junction (MD = .08, p = .35).

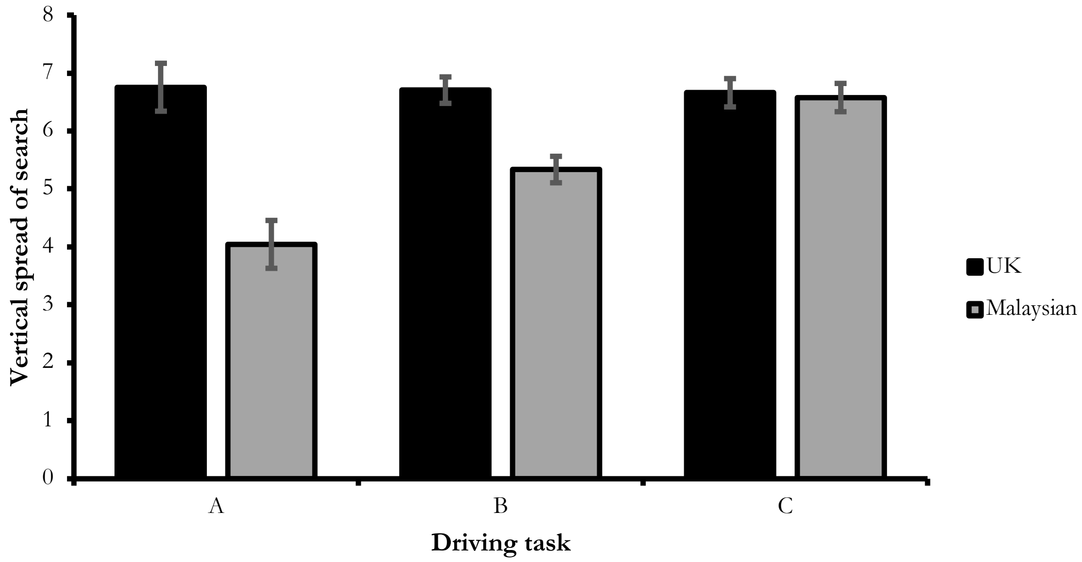

Figure 7.5: Interaction between participant nationality and driving task (± 1 SEM)

Finally there was a significant interaction between road country and task ($F(1, 148) = 3.14$, $p = .05$, $\eta_p^2 = .04$) (see Figure 7.6). Bonferroni corrected pairwise comparisons revealed that when driving continuously spread of search in the vertical axis was wider on the UK road compared to the Malaysian road (MD = .49, $p = .03$) however there was no effect of country when stopped at either a give-way (MD = .17, $p = .28$) or traffic light controlled junction (MD = .02, $p = .92$).

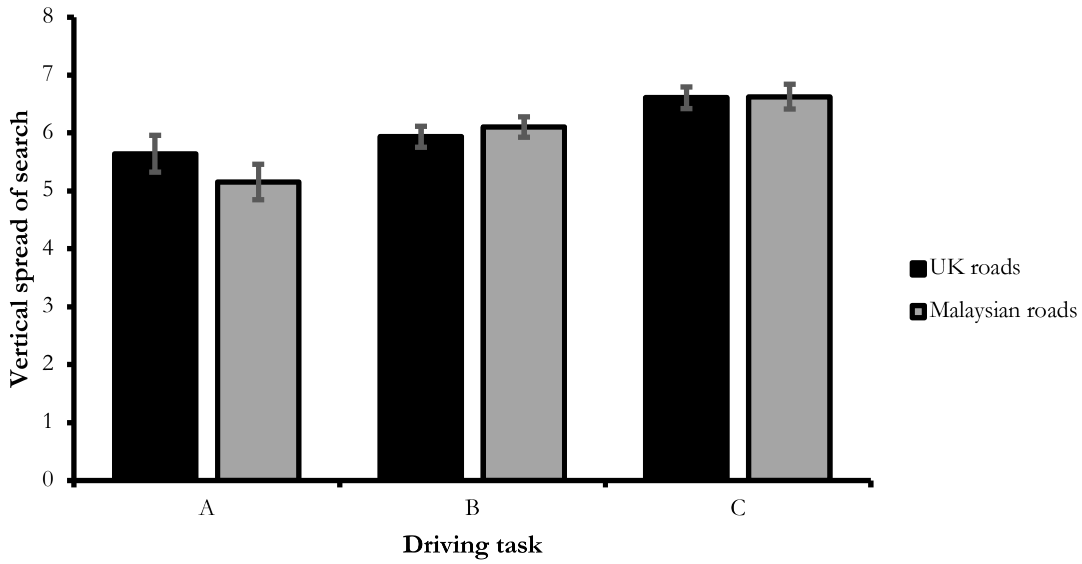

Figure 7.6: Interaction between road country and driving task on vertical spread of search (± 1 SEM)

7.3.3 Proportion of fixations in focal and background regions

In order to explore how participants allocated their attention across focal and background regions in each of the three driving tasks, an initial 2 (nationality) x 2 (country) x 3 (driving task) x 3 (region: focal, context relevant, context irrelevant) ANOVA was conducted. Descriptive statistics can be seen in Table 7.4.

There was an overall main effect of region, ($F(2, 148) = 79.72$, $p<.001$, $\eta_p^2 = .52$). Post hoc analyses revealed that overall participants had a higher proportion of fixations in background regions (M = 56. 94%, SE = 1.26) compared to focal regions (M = 43.02%, SE = 1.26) ($F(1, 74) = 30.45$, $p<.001$, $\eta_p^2 = .29$), whilst in the background participants allocated a larger proportion of fixations on context irrelevant regions (M = 38.74%, SE = 1.47) compared to context relevant regions (M = 18.20%, SE = .82).

This analysis also revealed a significant interaction between region and driving task ($F(4, 296) = 92.74$, $p<.001$, $\eta_p^2 = .56$) suggesting that the allocation of fixations between regions differs between the three tasks (see Figure 7.7). There were also significant interactions between region, nationality, and driving task ($F(4, 296) = 2.88$, $p = .02$, $\eta_p^2 = .04$), region, country, and driving task ($F(4, 296) = 3.70$, $p = .01$, $\eta_p^2 = .05$), and a marginally significant four-way interaction between region, nationality country, and driving task ($F(4, 296) = 2.09$, $p = .08$, $\eta_p^2 = .03$).

Given the number of interactions involving the factor of driving task, further analyses were conducted to specifically test the hypothesis that an interaction between nationality and region would only occur during Task C (stopping at a traffic light controlled junction). For each of the three driving tasks, a 2 (nationality) x 2 (country) x 3 (region: focal, context relevant, context irrelevant) ANOVA was ran (see Table 7.4).

Table 7.4: Descriptive statistics for the proportion of fixations in each region across the three driving tasks

	UK (n=38)		Malaysian (n=38)	
	M	SD	M	SD
Task A				
UK Focal	59.57%	14.56	55.58%	17.79
UK Context Relevant	20.62%	10.36	16.90%	9.84
UK Context Irrelevant	19.82%	14.83	27.52%	22.20
Malaysia Focal	56.98%	15.07	49.76%	17.74
Malaysia Context Relevant	19.68%	10.42	19.30%	12.96
Malaysia Context Irrelevant	23.23%	18.10	30.94%	22.67
Task B				
UK Focal	35.14%	10.23	35.01%	11.99
UK Context Relevant	20.14%	9.48	20.27%	8.56
UK Context Irrelevant	44.72%	10.59	44.72%	14.81
Malaysia Focal	32.93%	10.64	33.03%	10.63
Malaysia Context Relevant	17.99%	9.24	17.76%	6.49

Malaysia Context Irrelevant	48.89%	11.69	49.21%	12.53
Task C				
UK Focal	47.47%	16.45	38.04%	15.05
UK Context Relevant	16.38%	10.50	17.82%	8.47
UK Context Irrelevant	36.14%	13.87	44.11%	17.71
Malaysia Focal	38.81%	13.40	33.90%	12.42
Malaysia Context Relevant	14.89%	8.46	16.70%	8.62
Malaysia Context Irrelevant	46.17%	13.16	49.37%	14.80

When driving continuously (Task A) there was a main effect of region (F(2, 148) = 78.46, p < .001, η_p^2 = .51), post hoc analyses revealed that overall participants made more fixations in focal regions (M = 55.47%, SE = 1.82) compared to background regions (M = 44.50%, SE = 1.82) (F(1, 74) = 9.06, *p* = .004, η_p^2 = .11). Within the background regions, participants made more fixations on context irrelevant objects (M = 25.38%, SE = 2.21), compared to context relevant objects (M = 19.12, SE = 1.19 (F(1, 74) = 4.21, *p* = .04, η_p^2 = .05).

There was also a significant interaction between region and road country (F(2, 148) = 12.77, *p*<.001, η_p^2 = .15) (see Figure 7.7 top row, Task A). Bonferroni corrected pairwise comparisons found that participants attended to more focal objects on UK roads compared to Malaysian roads (MD = 4.20%, *p*<.001), and attended to more context irrelevant objects on Malaysian roads compared to UK roads (MD = 3.42, *p*<.001).

The interaction between nationality and region was marginally significant (F(2, 148) = 2.46, *p* = .09, ηp2 = .03)) (see Figure 7.7 bottom row, Task A), with pairwise comparisons showing that Malaysian participants fixate on marginally more context irrelevant objects than UK participants (MD = 7.70%, *p* = .09) however there were no differences for the other regions. There were no other significant main effects or interactions.

When stopped at a give-way junction (Task B) there was once again a main effect of region (F(2, 148) = 101.40, *p*<.001, η_p^2 = .58). Participants fixated on more background objects (M = 65.92%, SE = 1.15) compared to focal objects (M = 34.03%, SE = 1.14) (F(1, 74) = 193.55, *p*<.001, η_p^2 = .72). within the background participants allocated more attention to context irrelevant objects (M = 46.89%, SE = 1.31) compared to context relevant objects (M = 19.04%, SE = .90) (F(1, 74) = 208.04, *p*<.001, η_p^2 = .74).

There was also once again a significant interaction between region and round country (F(2, 148) = 9.62, *p*<.001, η_p^2 = .11) (see Figure 7.7 top row, Task B). As was seen in the previous analysis, participants attended to more focal objects on UK roads compared to

Malaysian roads (MD = 2.10%, p = .04), and attended to more context irrelevant objects on Malaysian roads compared to UK roads (MD = 4.33, p<.001). Participants also attended to more context relevant objects on UK roads compared to Malaysian roads (M = 2.32%, p = .004). There were no other significant main effects or interactions.

Finally when stopping at a traffic light controlled junction (Task C), there was a main effect of region ($F(2, 148) = 80.23$, p<.001, $\eta_p^2 = .52$). Participants made more fixations on background objects (M = 60.40%, SE = 1.49), compared to focal objects (M = 39.56%, SE = 1.49) ($F(1, 74) = 48.70$, p<.001, $\eta_p2 = .40$). In the background participants fixated more on context irrelevant objects (M = 43.95%, SE = 1.55) compared to context relevant objects (M = 16.45%, SE = .90) ($F(1, 74) = 180.16$, p<.001, $\eta_p^2 = .71$).

As with the previous two tasks there was a significant interaction between region and round country ($F(2, 148) = 19.07$, p<.001, $\eta p2 = .20$) (see Figure 7.7 top row, Task C). Pairwise comparisons once again revealed that participants attended to more focal objects on UK roads compared to Malaysian roads (MD = 6.40%, p<.001), and attended to more context irrelevant objects on Malaysian roads compared to UK roads (MD = 7.65%, p<.001).

There was a significant interaction between nationality and region ($F(2, 148) = 3.92$, p = .02, $\eta p2 = .05$), with pairwise comparisons showing that UK participants attended to more focal objects than Malaysian participants (MD = 7.18%, p = .02), whilst Malaysian participants attended to marginally more context irrelevant objects than UK participants (MD = 5.58%, p = .08). (see Figure 7.7 bottom row, Task C).

7.3.4 Relationship to self-construal

For the final analysis, a series of bivariate correlations were run to explore whether any of the dependent variables correlated with either independence or interdependence as measured by the self-construal scale. These analyses revealed no significant relationships (see Table 7.5).

Table 7.5: Pearson's r correlations between self-construal with each of the dependent variables

Variables	Fixations per minute	MFD	Horizontal spread	Vertical spread	% FO	% CR	% CI
Independence	0.14	0.13	0.19	0.08	0.07	0.08	0.11
Interdependence	0.13	0.10	0.07	0.04	0.01	0.18	0.11

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

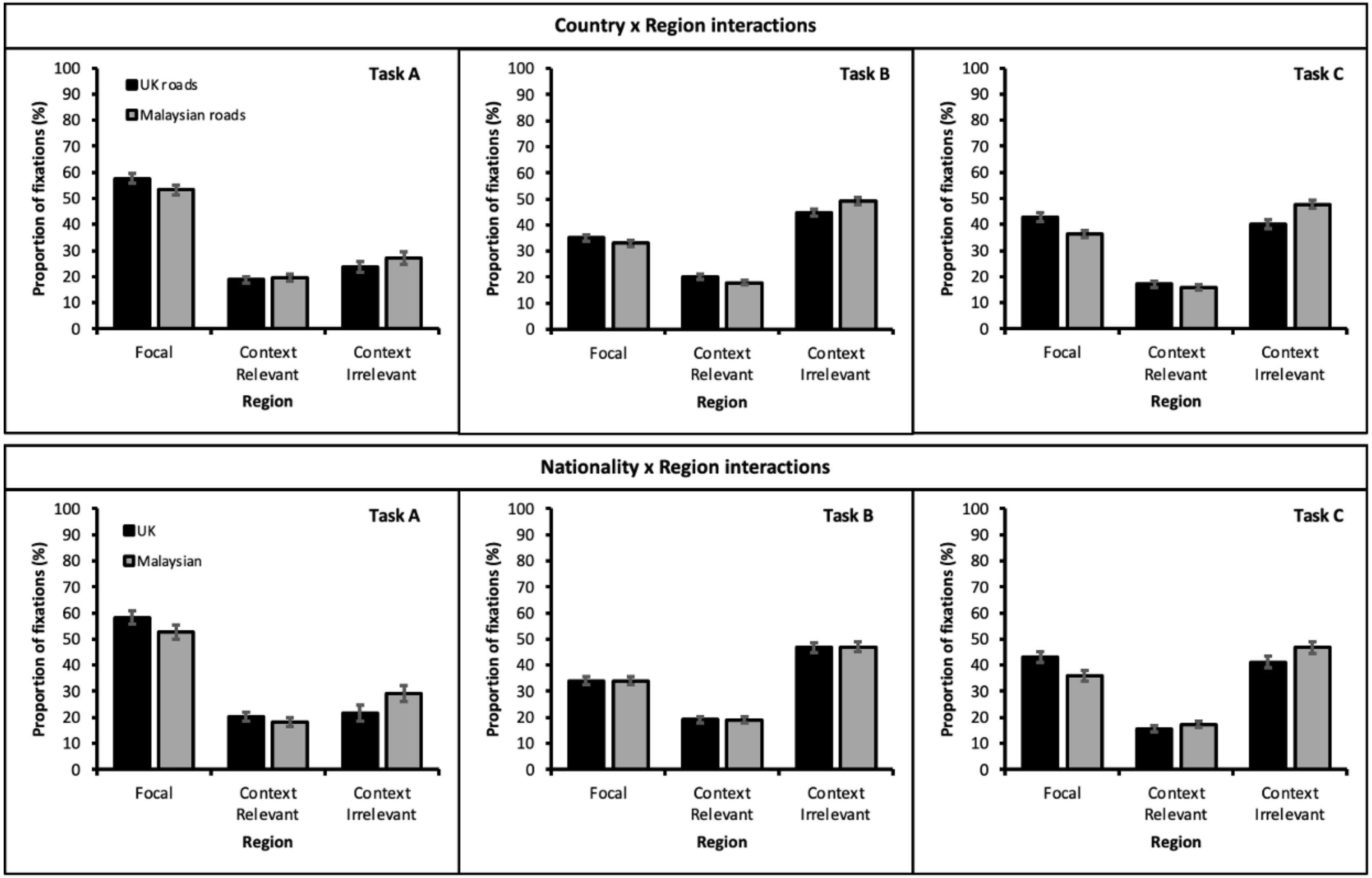

Figure 7.7: Interactions between road country and region (top row) and participant nationality and region (bottom row) for each of the three driving tasks (± 1 SEM)

7.4 Discussion

The aim of the final study in this thesis was to investigate whether the proposed cross-cultural differences in visual search are present in tasks where a driver is free to allocate their attention in a more controlled manner. This was investigated across three driving tasks, driving continuously, stopping at a give-way junction, and stopping at a traffic light controlled junction.

7.4.1 Differences in visual search across the three driving tasks

For both the number of fixations per minute, and mean fixation duration (MFD), there was a significant main effect of driving task. Participants made more fixations per minute and had longer fixation durations when driving continuously compared to when stopped at a junction (with both the number of fixations per minute and MFD being similar to those observed in the previous study). In contrast, at junctions, participants made more fixations and had longer fixation durations at a traffic light controlled junction compared to a give-way junction.

When stopped at a junction (particularly the give-way junction with a heavy flow of approaching traffic) it might have been expected that people would make a larger number of fixations as they are actively scanning the environment to either find a gap or to explore the environment, however this was not the case. In addition, it is not the case that the lower number of fixations compared to driving continuously was due to the fact that participants were making longer fixations on objects such as tracking approaching vehicles, as the MFD in these trials was lower than the other two tasks. Instead, it is likely the case that participants were making many more saccades and head movements during the task and therefore made less fixations per minute overall.

When stopped at a traffic light controlled junction, participants did make more fixations and for a longer duration than when waiting at a give-way junction. This suggests that they were exploring the environment more since the demands of the driving task itself had been reduced. As will be discussed later, it is possible that this increase in fixation count and duration us due to the fact that participants were free to explore the environment when stopped at a traffic light junction compared to a give-way junction. As such participants were able to look at a variety of different objects in the scene, and spend a longer time looking as they did not have a particular goal such as finding a suitable gap to enable them to cross the junction.

In terms of cultural differences in number of fixations, as with the previous study there was no overall cross-cultural difference, therefore suggesting that the number of overall fixations made when driving may not differ as a result of culture overall. This finding does not support the past cross-cultural literature which has suggested that East Asians make more fixations than Westerners when viewing a scene, and have a shorter fixation duration (Chua et al., 2005; Goh et al., 2009).

However, there was a marginally significant interaction between nationality and country on the number of fixations per minute, alongside a three-way interaction between nationality, country, and task. This showed that the nationality country interaction was only significant in Task C (waiting at a traffic light controlled junction) with participants from both nationalities making more fixations on their home road country.

The analysis of fixation duration did reveal a marginally significant effect of nationality, with Malaysian drivers showing a longer fixation duration contrary to the initial hypothesis. This analysis also revealed an interaction between task and nationality. When stopped at either of the junctions there were no differences in MFD between UK and Malaysian participants. However when driving continuously, Malaysian drivers showed a longer fixation duration. A possible explanation for this difference could be related to the perceived complexity of the task. As is seen in the driving literature, fixations are typically longer when driving on low complexity roads such as those in rural environments (e.g. Chapman & Underwood, 1998). If this is a result of the low complexity of these rural environments, it might be the case that the Malaysian participants in the current study did not consider the driving task to be particularly complex, so therefore were more comfortable making longer fixations than their UK counterparts. However when approaching a junction, the task increased in complexity leading to participants from both nationalities showing similar fixation durations.

As with the previous study, the average fixation durations observed in the current study are smaller than those found elsewhere in the literature. As discussed in section 6.4 this is likely due to the short duration of the tasks meaning that participants are less able to make long fixations as they would on a longer drive. In addition, similar research exploring visual attention at simulated junctions (also using Tobii eye tracking glasses) has shown mean fixation durations of approximately 200-300ms which are similar to those obtained in the current research (Robbins, Allen, Miller, et al., 2019). Additional factors which may influence fixation durations are discussed in section 6.4.1.

When looking at spread of search, whilst the previous study showed a wider spread of search in the horizontal axis amongst UK drivers, the current study found no cross-cultural differences in horizontal spread of search. This finding does not support the initial hypothesis or the past literature as it was expected that Malaysian drivers would show a wider spread of search in the horizontal axis.

However as with the previous study, there was a main effect of road country, with a wider spread of search being observed on UK roads compared to Malaysian. As with the previous study, whilst it was predicted that spread of search would be wider on Malaysian roads due to their increased visual clutter and complexity, it may be the case that this increased complexity led to attentional narrowing in the current research.

As predicted, there was a main effect of task on spread of search in the horizontal axis, with a wider spread of search being observed when stopped at a junction (particularly a give-way junction) compared to driving continuously. Whilst this finding is to be expected due to the fact that the nature of scanning a junction requires an increased spread of search, the lack of interaction between task and nationality suggests that these differences between driving tasks are likely universal and do not differ as a result of exposure to a particular driving environment.

In the vertical axis, results were similar to those observed in Chapter 6. There was once again a main effect of nationality with UK participants having a wider spread of search than Malaysians. As previously discussed in Chapter 6, it is likely that this difference is not the result of a strong cross-cultural difference in how drivers allocate their attention in the vertical axis, but instead a result of UK drivers making more fixations in the vehicle on the speedometer compared to Malaysians. However the significant interaction between nationality and task shows that this difference was only present in Tasks A and B, however in Task C this cultural difference was not present.

The current study did find a main effect of task on vertical spread of search, with spread once again being wider when stopped at a junction compared to driving continuously, particularly when stopped at a traffic light controlled junction. This is most likely another indication that when stopped at a traffic light participants felt more able to explore the environment (and attend to irrelevant objects as discussed below) due to the reduced demands of the task. Despite some studies showing differences in vertical spread of search as a result of driving experience, the recent meta-analysis from Robbins and Chapman (2019) instead suggested that vertical spread does not vary between drivers of different levels of experience. This is not surprising as vertical spread of search is arguably less important than horizontal search in terms of scanning the environment for hazards. Instead, vertical search begins to increase when participants are suddenly free to explore the environment as they wish. The lack of cultural difference in vertical spread of search in

Task C also suggests that this increased ability to scan the environment was utilised by participants from both nationalities.

7.4.2 The proportion of fixations on focal or background regions

It was hypothesised that there would be a cross-cultural interaction between nationality and the proportion of fixations in either focal or background regions when participants were waiting at a red light (Task C), but not when they were driving continuously or stopped at a give-way junction.

The results supported this hypothesis and showed that when stopped at a traffic light, there was a significant interaction such that UK participants allocated more attention to focal objects than their Malaysian counterparts, whilst Malaysians allocated more attention to context irrelevant background objects than UK participants.

When driving straight ahead, there was a marginal interaction between nationality and region, with Malaysian participants attending to marginally more context irrelevant objects than UK participants. However, for all participants the majority of fixations were on focal objects or regions such as lead vehicles, the road straight ahead, and the focus of expansion. Similarly when stopped at a give-way junction there was no interaction, with the proportion of fixations in each of the three regions being similar for participants of both nationalities (although a larger proportion of fixations were allocated to context irrelevant objects).

This finding suggests that the previously observed cross-cultural differences between Westerners and East Asians, showing Westerners attending to more focal objects and East Asians attending to more background objects (e.g. Chua et al., 2005; Masuda & Nisbett, 2001; Masuda & Nisbett, 2006), are present in driving tasks, but only under specific circumstances where drivers are free to explore the environment, and additional demands are reduced, including the demands of the driving task itself or completing a specific task such as hazard detection.

In linking to the model from Trick et al. (2004) it can be argued that attention was allocated in a more controlled manner during this trial, allowing differences between cultures to emerge which were previously not present. This finding has been seen earlier in this thesis, with the results presented in Chapter 4 suggesting that when free to choose where they would allocate their attention when driving, Malaysian participants selected more background objects than UK participants.

Whilst it has been argued that these cross-cultural differences emerge when stopped at a red traffic light due to the fact that the attentional demands of the driving tasks have been reduced so participants are free to allocate their attention in a more controlled manner, there are still reasons why understanding the differences in visual search when stopped at a traffic light are important.

First, although stopped drivers should still be aware of their surroundings and monitor the environment as hazards can still emerge. If it is the case that Malaysian drivers are attending to less relevant aspects of the road environment, they may be more likely to miss task and safety critical information which may have emerged whilst waiting for the red light to change. This might include vehicles entering the roadway, or pedestrians crossing the street in front of a driver. This is particularly important when driving in Malaysia as the number of potential hazards on the road is higher than those seen in the UK, meaning there is a need to be more vigilant and attend to relevant objects when waiting at a traffic light.

Second, if a driver is attending to irrelevant aspects of the scene when a critical change happens such as a red light turning green, they may be more likely to be involved in a collision as a result of missing this new information. This also has implications for the design of autonomous vehicles, as a key questions for psychologists in the design of these vehicles is "how do drivers regain control and attention during autonomous driving". If decreased task demands lead to drivers attending to irrelevant objects, this could prove problematic if a future autonomous vehicle requires a participant to regain control of the vehicle when they have been attending to task irrelevant objects and are not fully aware of their surroundings. If this is more prevalent amongst Malaysian drivers, there may be a case for culturally specific autonomous vehicle systems which help to bring the driver back into the loop during takeover requests.

As well as demonstrating a cross-cultural interaction in Task C, the current study also revealed interactions between road country and region. In all 3 tasks, there was an interaction such that participants attended to more focal objects on UK roads compared to Malaysian roads, with the reverse being true for context irrelevant objects.

This finding therefore suggests that exposure to a particular environment can lead to differences in visual search. In the case of the current study, the increased proportion of fixations to context irrelevant objects on Malaysian roads suggests that when driving in a visually cluttered environment, all participants begin to attend more to this irrelevant visual clutter. This finding, combined with the lack of correlation between proportion of fixations in either region and self-construal, provides support for the environmental affordance theory described by Miyamoto et al. (2006) suggesting that exposure to a particular cultural environment can lead to a cultural specific style of perception being used.

Whilst this does provide further evidence for cross-cultural theories, this finding also has implications for the traffic and transport psychology literature. When driving on the more visually cluttered Malaysian roads, the increased proportion of fixations on irrelevant objects meant that less attention was being allocated to relevant aspects of the road scene including focal objects. Whilst drivers do have some capacity for attending to irrelevant items on the road, it may be the case that on certain roads this is actually reducing how much attention is paid to relevant aspects of the roadway, thus having a potential safety implication. For example, in the real world if a British driver were to drive in Malaysia, this increased attention on irrelevant aspects of the scene could lead to important information being missed and a crash occurring.

7.4.3 Limitations

As with the previous study, the primary limitation in the current study is the fact that the drivers taking part in this research could be said to be inexperienced compared to the typical driving population. Although groups were matched for driving experience, a cautious approach should be taken when applying the current findings to drivers of different levels of experience.

7.4.4 Summary and conclusions

In conclusion, the final study in this thesis demonstrated that the hypothesised cross-cultural differences in allocating attention to focal or background objects may only emerge in driving tasks where people are free to allocate their attention in a controlled manner, thus resolving some of the discrepancies in results across the previous chapters in this thesis. With this, it was also found that how attention is allocated to focal or background objects can vary as a result of the road country itself, with participants attending to more context irrelevant objects when driving on Malaysian roads compared to UK roads.

Finally, this research has demonstrated general differences in visual search when driving continuously, stopping at a give-way junction, and stopping at a traffic light controlled junction. However broadly speaking, these differences are consistent across nationalities.

Chapter 8: Discussion

This thesis explored the cross-cultural differences in visual attention between drivers from the UK and Malaysia. Previously, the majority of research exploring where drivers looked focused on drivers from Western countries such as the UK where driving is relatively safe, much less research looked at visual search amongst drivers from non-Western countries where crash rates are significantly higher.

The question of whether visual attention differs between drivers of different nationalities arose out of the combination of several streams of research. First, within the traffic and transport psychology literature, it has been shown that increased experience leads to differences in visual search due to the fact that drivers develop a mental model over time based on their experience (Crundall & Underwood, 1998; Mourant & Rockwell, 1972; Underwood et al., 2002). The cross-cultural literature has shown differences in visual attention between Westerners and East Asians (e.g. Masuda & Nisbett, 2001) which likely come about as a result of exposure to the increased visual clutter in East Asian environment (Miyamoto et al., 2006).

This thesis combined these two areas of research to explore the cross-cultural differences in visual attention between UK and Malaysian drivers using a combination of methods including focus groups, online data collection, driving simulation, and eye tracking. This final chapter will discuss and combine the findings from each of these individual studies linking them to the past literature and the research questions, consider the potential implications of this research, before finally discussing the limitations of this research and suggestion possibilities for further research.

8.1 Summary of the findings

In initially exploring the views of Malaysians drivers on the experience of driving in Malaysia and how this might influence their visual attention (Chapter 3) it was clear that drivers viewed the Malaysian road environment as chaotic and requiring attention to be allocated across the environment. This was said to be due to the increase in visual clutter, including other road users such as motorcyclists, billboards, and irrelevant clutter in and around the roadway. This was combined with the view that road users in Malaysia themselves may drive in a more dangerous, less predictable manner meaning that drivers have to pay particular attention to the behaviour of others in order to drive safely.

In Chapter 4, UK and Malaysian drivers were asked to self-report where they would look across a series of images from the perspective of a driver. Overall, there were some similarities between participants in where they reported choosing to look, with no differences emerging in the distribution of locations across the horizontal axis, and participants from both nationalities selecting to attend to more background objects compared to focal objects. The overall proportion of focal objects selected by participants from both groups was similar (~30%), however cultural differences emerged in the types of background objects attended to. Compared to Malaysian participants, the UK participants selected more relevant objects, whereas the Malaysian participants selected more irrelevant objects. This provided some experimental evidence that where we look on the road may differ as a result of culture and exposure to particular environments.

This finding was expanded upon in Chapter 5 using a change blindness paradigm. In the first study, participants were presented with a change blindness task involving driving scenes where the change occurred either in a focal, background relevant, or background irrelevant region (as well as manipulating the safety relevance of the change). Based on previous cross-cultural studies using change blindness (e.g. Masuda & Nisbett, 2006) it was hypothesised that UK drivers would be better at detecting focal changes, whilst Malaysian drivers should be better at detecting background changes, however this was not the case. Instead, there was a large main effect of safety relevance, but no cross-cultural differences.

A second change blindness study aimed to explore the possibility that this lack of cross-cultural difference was due to the large effect of safety relevance masking any cultural differences in visual attention. The second study involved participants detecting changes in both driving and non-driving related stimuli, to explore whether the hypothesised differences only occurred in non-driving tasks. However as with Study 1 there were no cross-cultural effects to suggest that Malaysian participants were better able to detect background changes in visual scenes, contrary to both the hypothesis and past literature.

Whilst the experiments presented in Chapters 4 and 5 measured visual attention in a non-direct manner using online data collection, the final two experiments measured visual attention more directly by recording eye movements whilst driving through a simulated environment. In Chapter 6, general measures of visual attention as previously investigated mostly amongst Western drivers (number of fixations, mean fixation duration, and spread of search; see Robbins and Chapman (2019) for a review) were compared between drivers from the UK and Malaysia. Contrary to hypothesis Malaysian participants did not have a wider spread of search, with more fixations and shorter fixation durations. Instead UK drivers were found to have a wider spread of search, and no cultural differences in fixation count or duration were found. There were however effects of road type with urban roads leading to wider spread of search, more fixations, and shorter fixation durations as seen in previous studies.

Finally, the data presented in Chapter 7 once again explored whether there are differences in how attention is allocated to focal and background objects, but across different driving tasks where the participant is either moving or stopped. As hypothesised, there was an interaction between nationality and object region when participants were stopped at a traffic light such that UK drivers allocated more attention to Focal objects than Malaysians, whilst Malaysians allocated more attention to background irrelevant objects than UK drivers. Similarly, all participants fixated on more focal objects when driving on UK roads compared to Malaysian roads, and fixated on more background irrelevant objects on Malaysian roads compared to UK roads, across each driving task.

Combined, these results suggest that there are some cases where drivers from the UK and Malaysia attend to different aspects of the visual environment whilst driving, however the findings are not as clear cut as first predicted. The findings will now be combined across studies and discussed in relation to the research questions outlined at the start of this thesis.

8.1.1 What are the cross-cultural differences in widely used measures of visual search between drivers from the UK and Malaysia?

Across several studies it was hypothesised that there would be cross-cultural differences in commonly reported measures of drivers' visual attention (spread of search, number of fixations, and fixation duration), such that Malaysian drivers would have a wider spread of search, with a high fixation count and short fixation duration.

Overall the results did not support this hypothesis and were not consistent with past cross-cultural research suggesting that East Asians distribute their attention across a wider area (Boduroglu et al., 2009), or make a series of short fixations across a visual scene (Chua et al., 2005). In terms of spread of search, the current research found some evidence of a wider spread of search in the horizontal axis amongst Malaysian participants when choosing where they would allocate their attention (Chapter 3), whilst eye tracking data revealed a wider spread of search amongst UK participants (Chapter 6), or no difference between nationalities (Chapter 7). These inconsistent findings could suggest that spread of search does not differ between drivers as a result of culture or prolonged exposure to a particular environment in the same way that driving experience in terms of length of licensure leads to differences in spread of search. When controlling for experience, it may simply be the case that spread of search is similar across all drivers and only changes as a result of the road type in that particular moment (as shown in Chapter 6).

An alternative explanation for this could be related to the trials used in the driving simulator studies. Although each drive in the simulator had some level of complexity such as following a vehicle or having a large amount of traffic present, they were not as complex as real Malaysian roads. It may be the case that Malaysian drivers would exhibit a wider spread of search when driving in their own country, but viewed the roads in the current research as too simple to warrant a wider spread of search, similar to how spread of search decreases when driving along less complex roads (Crundall & Underwood, 1998; Underwood et al., 2002). In contrast, the roads may have been more complex than those encountered by UK drivers thus leading them to increase their spread of search in order to drive safely. However, whether or not this is the case is not clear from the current data, and further research should be conducted using a variety of road types (discussed further in section 8.6).

Across the thesis there was no evidence to suggest that Malaysian drivers made more fixations or had a shorter fixation duration than UK drivers. Instead, differences were found between driving tasks such as driving on urban vs rural roads as has been shown in previous studies (e.g. Crundall & Underwood, 1998; Underwood et al., 2002), however this was consistent across nationalities. This is inconsistent with past cross-cultural findings (e.g. Chua et al., 2005) and seemingly inconsistent with some of the past driving literature (e.g. Chapman & Underwood, 1998; Crundall et al., 2003; Konstantopoulos et al., 2010). However, although past studies have found differences in fixation count and duration as a result of experience within a nationality, the recent meta-analysis from Robbins and Chapman (2019) found no overall differences in the number of fixations or fixation duration between drivers of different experience levels. It may be the case that experience (or in the case of the current research experience in the form of prolonged exposure to a particular driving environment) does not lead to differences in fixation count and duration during driving, and these measures may instead be universal.

8.1.2 Do Malaysian drivers attend more to background information on the roads?

Across most of the studies in this thesis, the differences in the allocation of attention to either focal or background objects was investigated. In most of the cross-cultural studies described throughout this thesis there is a clear difference such that Westerners attend more to focal objects, whereas East Asians attend more to the background (Chua et al., 2005; Masuda et al., 2016; Masuda & Nisbett, 2001; Masuda & Nisbett, 2006). In part, the current research has supported these findings, however it seems to be the case that this cross-cultural difference is only present under certain circumstances when driving. In situations where the demands of the task itself are higher, there was no cross-cultural effect, however in cases where the demands were lower a cross-cultural difference emerged. This applies to both the demands of the driving task such as navigating traffic in active driving (Chapter 7), but also non-driving tasks such as detecting visual changes in an environment which is not related to driving (Chapter 5, Study 2). Both of these tasks may override any differences in visual attention observed between culture.

Linking this back to the model proposed by Trick et al. (2004) (see section 2.2.3.3) the results presented in this thesis suggest that cultural differences may only emerge when attention can be allocated in a controlled manner. When attention is allocated in an automatic manner, the demands of the driving task itself may be the main determinant of where a driver looks on the road due to the fact that driving does require a large amount of visual attention. In contrast, when drivers are free to decide where to look the potential for cultural differences to emerge opens up.

As no previous studies have applied the cross-cultural differences in visual attention to tasks in which visual attention is critical (such as safety relevant tasks) little is known about how other factors may supress cross-cultural differences in visual attention. The current research suggests that other factors more directly related to the driving task such as vehicle guidance or safety may be prioritised over cultural differences in general visual search. When these demands of the driving task are reduced, drivers are free to control their attention and cultural differences can emerge.

8.1.3 If there are cross-cultural differences, are these a result of cultural social differences or exposure to a particular environment?

Although the cross-cultural differences in visual attention were not as clear as first predicted, there are still differences present through the research in this thesis. If it was the case that these differences were a result of social and cultural differences between the two nationalities, a correlation between visual search and self-construal would be expected such that a higher interdependent self-construal should correlate with a more global attentional style with more attention being allocated to background objects.

Across all experimental studies presented in this thesis there were differences in self-construal between UK and Malaysian participants. As one might expect, on average Malaysian participants had a more interdependent self-construal than UK participants. As described in the literature review (section 2.3.2.1) individuals from Eastern countries tend to have a more interdependent self-construal in which emphasis is placed on relationships between individuals and your role within a larger social network, as opposed to the more Western independent self-construal (Markus & Kitayama, 1991).

Surprisingly, there was no difference between UK and Malaysian participants on independent self-construal (with one study even showing higher independence scores for Malaysian participants). Whilst this seems incompatible with the differences in interdependence it is worth remembering that these are separate orthogonal dimensions as opposed to representing separate ends of a spectrum, therefore individuals can score high or low on both scales independently, suggesting that people can possess both independent and interdependent qualities to varying degrees. In the case of the current research, it is possible that exposure to Western influences such as studying at a Western university and studying abroad in the UK led to this particular sample of Malaysian drivers being more independent than the average Malaysian population. In addition, globalisation more broadly may have contributed to this difference, particularly as the participants in this research were mostly younger adults. This may come about due to the wider influence of Western media, as well as education and cultural exchange as previously discussed. These effects of globalisation may lead to independent traits being more universally valued or expressed than previously thought.

Despite the similarities in independence between participants from both countries, Malaysian participants were still significantly more interdependent in all the experimental studies conducted. With this, it would be sensible to assume that any correlations between self-construal (particularly interdependent self-construal) and measures of visual attention in this research would indicate a relationship between cultural social differences and visual attention.

In each of the studies conducted, there were no significant correlations between self-construal and measures of visual attention, therefore suggesting that any cross-cultural differences are actually the result of exposure to a particular environment as opposed to differences in self-construal.

This interpretation of the results supports the environmental affordances theory described by Miyamoto et al. (2006), which suggests that differences in visual search come about as a result of the increased visual clutter in Asian scenes, which subsequently leads to a more global attentional style in order to attend to all necessary information. This does make sense in linking to the driving literature as repeated exposure to an environment does lead to changes in visual search amongst drivers within a culture such as increases in scanning (Chapman & Underwood, 1998; Underwood et al., 2002), different search patterns when driving in novel environments (Shinohara & Nishizaki, 2017a, 2017b), or failures to attend to road signs (Martens & Fox, 2007a, 2007b).

Within the cross-cultural literature it has been shown that when presented with East Asian scenes Western participants tend to show a more global perceptual style (e.g. Miyamoto et al., 2006) (see section 2.3.2.2). This was not found in all studies in this thesis, and in many cases it was not possible to sufficiently match driving stimuli between the two countries. However, in the final simulator study described in Chapter 7 there was a consistent effect such that participants attended to more focal objects on UK roads vs Malaysian roads, and more background irrelevant objects on Malaysian vs UK roads. However, in other studies (namely Chapter 6) there was a main effect of country but with UK roads leading to a wider spread and more global style, so whilst this does suggest that driving in a particular environment can lead to differences in visual attention, the direction of this is not always consistent.

8.2 Utility of the Trick et al. (2004) model

This thesis has made of use of the two-dimensional model of attention proposed by Trick et al. (2004) to interpret the findings. In evaluating the use of this model in the current research it served three key purposes.

First, by considering the influence of both exogeneous and endogenous factors the model accounts for differences in visual attention which may arise as a result of experience and past exposure to a particular environment and the subsequent mental model which would emerge as a result of this, as well as differences which arise as a result of current exposure to a particular environment. This became clear in Chapter 7 (particularly in section 7.3.3) where allocation of attention to the focal vs background objects was found to differ as a result of both cultural background, and the current driving environment.

Second, although other models consider the influences of exogeneous and endogenous factors (or top-down and bottom-up factors) the Trick model takes this a step further by also considering the role of automatic vs controlled attention. The ways in which cultural differences in attention vary on this dimension can be seen throughout the thesis. When drivers are free to decide where to look (Chapter 4) cross-cultural differences emerge in how attention is allocated to background objects. The same could also be said for describing where they would look (Chapter 3) in which participants described a visual attention pattern which would involve attention to the background and a wide spread of search. However, in tasks where attention is allocated in a more automatic manner (Chapters 5 & 6) cross-cultural differences were not present. This aspect of the Trick et al. model was tested in Chapter 7 in which results showed that cross-cultural differences do not emerge in tasks where attention is more likely to be automatically allocated, but they do emerge when participants are free to decide where to look.

Combined these findings demonstrate the model's relevance by showing how automatic processes, which are generally consistent across cultures due to their reflexive nature, contrast with controlled attentional processes that are more susceptible to cultural variability. The model demonstrates that in scenarios where attention is not constrained by task demands and can be deliberately allocated, drivers from different cultural backgrounds exhibit distinct attentional strategies. This aligns with the model's suggestion that controlled (endogenous) attention is modulated by internal goals and knowledge, which can emerge from culture or the development of a mental model as a result of increased exposure to a particular driving environment.

Finally, by understanding which modes of attention are consistent and which modes have the potential to differ between cultures, the model can serve as a foundation for developing tailored interventions and training which target the modes of attention which differ between cultures. By acknowledging that controlled attention is susceptible to cross-cultural differences, the current research can provide pathways for these interventions to be developed as well as opening up avenues for further research.

8.3 Contributions to knowledge

This thesis has contributed to the scientific literature and knowledge in several ways. First, within the field of traffic and transport psychology the findings have shown that whilst some aspects of visual attention are similar between drivers from different countries, some do differ dependent on the driving task. This provides further support for the idea that there are differences in driver cognition most likely as a result of exposure to a particular environment. This also provides further support for the research showing the influence of experience on drivers' visual search, however in this case experience comes in the form of exposure to a particular driving environment.

Second, the current research has taken the findings from the previous cross-cultural literature and applied them to a real-world scenario where visual attention is essential. Whilst the previous literature demonstrated cross-cultural differences in visual attention, this has been in simple lab-based tasks which could be said to have less importance in terms of visual search in the real world. Whilst some studies have applied previous findings to specific visual attention tasks such as searching web pages (e.g. Baughan et al., 2021; Dong & Lee, 2008) or face perception (Blais et al., 2008; Chuk et al., 2017) the current research is the first to thoroughly explore how cross-cultural differences in attention apply to a safety critical real world task in which visual search is essential.

The results of this thesis have shown that although there are differences in visual search which support the previous cross-cultural findings, the differences are not as clear cut as previous research would suggest, with other factors such as driver safety playing a more prominent role in influencing visual search. With that, it has been suggested that any differences in visual attention between drivers from different countries come about as a result of exposure to a particular environment as opposed to more social cultural differences such as self-construal.

The fact that the cross-cultural differences observed in the current research were limited to certain tasks where drivers were free to control their attention opens up questions regarding the ecological validity and relevance of past research. The earlier research on cross-cultural differences in visual attention often made use of artificial settings and stimuli which may not fully represent the complexity of everyday scenes. For example, studies often presented participants with one focal object against a background, whereas identifying a single focal object against a background is less clear in natural scene perception, especially when driving. With that, previous research has failed to find cross-cultural differences in visual search in scenes with multiple focal objects (Rayner et al., 2007). The lack of ecological validity in these past studies may misrepresent the nature of visual attention across cultures by only exploring differences in more simplistic tasks.

The current work increased ecological validity by using more realistic stimuli even when using static images (images of real roads), and by making use of a highly ecologically valid and immersive methodology (driving simulation). From this, it has been shown that in situations which more closely resemble real life visual environments, cross-cultural differences do not emerge as strongly as previous research has suggested and instead only emerge in situations where drivers are free to control their attention. This finding calls into question the relevance and applicability of past findings to real world settings, where multiple cognitive processes are at play (particularly related to safety on the road).

8.4 Implications

As well as contributions to knowledge within the traffic and transport and cross-cultural psychology literature, it is also worth considering the implications of this research and how the findings could be used in policy and practice to improve driver safety. There are several potential implications of the current work, however this section will focus on three in particular.

8.4.1 Road design

First, under the assumption that differences in drivers' visual attention are a result of differences within the environment, there may be a need to reduce visual clutter on the road to ensure that drivers are attending to more relevant information. Although the Malaysian road environment is more visually cluttered than the UK, the need to reduce visual clutter applies to both countries, with drivers from both attending to context irrelevant information when it was present in the driving task. As such, policy makes may wish to place an emphasis on reducing visual clutter on the roads and may wish to consider driver training to ensure that drivers are not distracted by visual clutter (discussed below).

Similarly, steps can be taken to ensure that key aspects of the road environment such as road signs are clearly visible and understandable, particularly when considering a road environment which may be used by drivers from different countries facing diverse traffic environments (Jamson & Mrozek, 2017).

8.4.2 Driver training

A second implication of the current work relates to driver training, particularly training in relation to visual search. Previous research has demonstrated that offering training to novice drivers with a goal of improving their visual search can effectively lead to a more suitable visual search strategy being used (Chapman et al., 2002; Pradhan et al., 2011). The findings of the current research suggest that there could be shortcomings in the visual search strategies used by drivers, mainly in fixating on context irrelevant objects at the expense of attending to the road straight ahead. In addition, the Malaysian drivers involved in the focus groups described areas of the roadway where they believe they should allocate their attention in the case of emerging hazards or to help predict the behaviour or other road users, which may not be commonly considered as relevant amongst UK drivers.

Any training interventions should consider the strengths of the visual search approach used by drivers from both countries and use tailored approaches to improve visual search amongst a particular group of drivers. By offering training to drivers, they can adopt optimal strategies which combine the strengths of drivers from both countries. It is possible that this would then lead to a more suitable visual search strategy being used which would lead to safer driving in the future.

8.4.3 Development of autonomous vehicles

A final important implication to consider in relation to this research is its relation to autonomous driving. Currently, an important topic within autonomous vehicle research and development is takeover requests. These are moments where a driver needs to regain control of a semi-autonomous vehicle due to factors such as system limitations, issues with sensors, or navigating complex driving situations. In these moments, it is essentially for the driver to be brought back into the loop in order to regain control and drive safely. A growing body of research is investigating this by testing different ways to bring the driver back into the loop (Gold et al., 2013; Huang et al., 2019; Large et al., 2018).

One important aspect of these takeover requests is the drivers' attention and situational awareness. In order to successfully execute a takeover request, a driver needs to be aware of their surroundings as if they were continuously driving the vehicle, however prior to this request the demands of the driving task are low and drivers are free to allocate their attention in a controlled manner. Based on the findings in this thesis, it may be the case that drivers from different countries are attending to different areas of the roadway when a takeover request is initiated, and may therefore have different levels of situational awareness and knowledge of the road environment. Recent research has suggested that there is a need for autonomous vehicles to reflect individual differences between users in terms of their driving style (Peng et al., 2022; Rodak et al., 2020), with some research highlighting the need to reflect differences in driving styles across cultures (Sun et al., 2023) however there may also be a need to consider the differences in attention and other cognitive processes when designing autonomous vehicle systems particularly with regards to takeover requests.

8.5 Limitations

The limitations for individual studies in this thesis have been discussed in their relevant chapters, however this section will discuss some limitations which apply to the research presented in this thesis as a whole. First, the drivers who took part in this research were predominantly younger with less driving experience. Although the study presented in Chapter 4 included drivers with slightly more experience as a result of using online data collection and recruitment, for the majority of the research in this thesis drivers were in their early 20s with an average length of licensure of 2-3 years. As has been described earlier in this thesis, visual attention when driving is known to change as a result of increased driving experience. The definition of what constitutes a novice driver differs within the literature, for example Mayhew et al. (2003) describes a drastic drop in accident rates after the first 6 months of driving, however studies exploring drivers' visual attention have considered those with less than 3 years driving experience to be novices (Robbins & Chapman, 2019).

In the current research, it may be the case that the patterns of visual attention exhibited by participants were those of novice drivers who have not yet fully developed the mental models needed to sufficiently scan the environment compared to more experienced drivers. Whilst this does limit the generalisability of the current findings, they are still highly applicable to novice drivers who would arguably benefit the most from training to improve visual search as described above. However, future work may wish to expand the current research by exploring differences in visual search amongst drivers with more experience, or investigating how visual attention changes over time between drivers from different countries.

Also related to the sample, another limitation of the current research is that the focus was on visual search amongst car drivers. Whilst car drivers make up the majority of road users in the UK (93%), they represent approximately half of Malaysian road users (World Health Organization, 2018). Arguably, there would be a benefit to examining visual search across other road users, in order to gain a better understanding of the differences in visual search amongst the most vulnerable road users who are overrepresented in crash statistics. Whilst this was not possible within the context of the current research, it may be an avenue for future research.

Another limitation of the current research is that it is not possible to infer which peripheral information was attended to by drivers during eye tracking studies. One limitation of using wearable eye trackers is their inability to measure attention being allocated to objects in the periphery as the data is based on fixations in which an individual is required to move their head and fixate on an object. Whilst this information is useful and drivers are able to make head movements to fixate on objects which are not directly ahead of them, drivers still make use of peripheral vision in order to drive safely (see Vater et al. (2022) for a review). If it is the case that Malaysian drivers attend more to background and contextual information, it may be the case that they also make more use of peripheral information when driving. This has been demonstrated in cross-cultural studies using simple stimuli such as coloured blocks (Boduroglu et al., 2009), however there is scope to further investigate this in driving.

A final limitation of the current research is related to this point. Although the current study used a mixture of trials and scenarios depicting roads from both the UK and Malaysia, it was not possible to fully reflect the hazardousness of the Malaysian road environment. Similarly, none of the tasks used in the current research explored attention in specific hazardous situations (discussed below in the context of further research). In linking this to peripheral attention, it may be worth investigating visual attention in situations where hazards emerge in the periphery leading to drivers having to make a response once a hazard has been detected.

8.6 Next steps and future research

The research presented in this thesis opens several avenues for further research. First, although the differences in visual search between UK and Malaysian drivers were only present in certain situations, the current research only presented participants with a limited number of driving tasks (particularly in the simulator). Based on the results from the focus groups presented in Chapter 3, it is clear that Malaysian drivers believe they need to allocate their attention in a particular way in order to drive safely, Future research may wish to explore the potential differences in visual attention across further driving tasks. One such example would be when encountering a hazard on the road, dependent on the action being performed by the driver (i.e. stopping or following a vehicle) and where the hazard occurs (in a focal or background region) there may be differences in how drivers attend to these hazards. Although some studies have explored the cross-cultural differences in hazard perception between UK and Malaysian drivers (Lee et al., 2020; Lim et al., 2013, 2014) this has not yet been explored in a highly complex visual environment with a large visual angle (such as a driving simulator).

The results of the focus groups in Chapter 3 also provide a good starting point for several other investigations into the cross-cultural differences between drivers. One aspects of driving which was discussed in the focus groups was Malaysian drivers' ability to predict the behaviour of other road users due to the fact that more explicit cues commonly used in Western countries (the UK) are not used as consistently in Malaysia. This has been explored in one study in which UK and Malaysian drivers were asked to judge the intended manoeuvre of approaching vehicles at junctions either using an indictor or not (Sheppard et al., 2023). It was found that UK drivers were more reliant on the use of the explicit cues compared to Malaysians, however this research was only conducted using videos. Future research should explore this in more natural environments such as simulator or using real world observations in order to understand the consequences of interpreting the behaviour of other road users. Future work should also examine differences in visual attention as well as behaviour during these tasks.

As well as further research into cross-cultural differences between drivers, it may also be interesting to further investigate cross-cultural differences in visual search outside of the driving domain. The results presented in this thesis show that the previous cross-cultural findings may not be as applicable to real world tasks, or situations in which it is difficult to define a singular focal object. Further research should explore the differences in visual search between Western and Eastern participants in more naturalistic large-scale environments (as opposed to just using computer-based tasks). In addition, it would be interesting to explore whether differences are present in real world tasks in which visual attention is critical or may have links to safety.

8.7 Conclusion

To conclude, this thesis explored the cross-cultural differences in visual attention between drivers from the UK and Malaysia using a combination of different methodological approaches. This was driven by the recognition that the majority of research into drivers' visual attention focuses on drivers from Western countries, such as the UK, while relatively little was known about to visual attention among drivers from non-Western countries like Malaysia, where crash rates are significantly higher. This research has combined insights from traffic and transport psychology with those from the cross-cultural psychology literature to investigate whether visual attention does differ between drivers from different countries.

The findings presented paint a nuanced picture of cross-cultural differences in drivers' visual attention. The initial hypothesis that cultural factors would significantly shape visual search patterns did not find consistent support across all studies. Instead, it was shown that certain aspects of visual attention were influenced more by specific driving tasks and environmental factors, such safety relevance, road type, or country, than by nationality or culture.

Whilst this research did identify some cross-cultural differences in visual attention, particularly related to the allocation of attention to focal and background objects, these differences were only apparent in certain driving tasks. Differences emerged in situations where the demands of the driving task were lower and attention allocation was more under their control. However, in other driving situations, attention allocation was primarily driven by the task itself, overshadowing any potential cultural differences.

This research contributed to the literature highlighting the role of environmental factors, such as exposure to a country's driving environment, in shaping visual attention among drivers. The current findings also have several practical implications. In terms of road design, it may be beneficial to reduce visual clutter in both countries' road environments at this seems to attract drivers' attention, driver training could also be used to encourage drivers (particularly newer drivers) to allocate their attention in a more appropriate manner. There are also implications for the design of autonomous vehicles particularly in relation to takeover requests, which may want to consider the potential differences in where drivers from different countries may be looking when they are required to regain control of a semi-autonomous vehicle.

This research is not without its limitations. The studies have primarily focused on younger, less experienced drivers, and the generalizability of our findings to more experienced or older drivers remains a question for future research. There is also the need for additional studies exploring the cross-cultural differences in visual attention in hazardous situations and among vulnerable road users to gain a more comprehensive understanding of these cross-cultural differences. However, this thesis does serve as a valuable contribution to our understanding of drivers' visual attention, and cross-cultural differences in attention particularly in a real-world safety critical task.

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Appendix A: Focus group question guide

Introduction

- Welcome and thanks for volunteering
- Introduction and overview of the session
- Encourage discussion and talking to each other
- All information provided will be confidential
- Can I record the discussion?

Driving in Malaysia

- How would you describe driving in Malaysia?
- What sort of things would you encounter on Malaysian roads?
    - Hazards
    - Road users
- Do you encounter a lot of motorcycles/ scooters? How do you deal with these?
    - Do you ever ride one yourself?
- How do you interact with other drivers on the road?
- What sort of things frustrate you on the road?
    - How would you respond to this?

Comparison to the UK

- How does driving in the UK compare to Malaysia? Have you noticed any differences?
    - If you haven't driven in the UK, what about as a passenger, cyclist, or pedestrian?
- Are there any differences in the way you would perform certain manoeuvres? i.e. pulling out of a junction?
- If you do drive in the UK, have you encountered any difficulties as a result of a different driving style?
- What do you think causes any differences?

Unwritten rules

- Are there any unwritten rules when driving in Malaysia?
    - That is, any common practices that people engage in which are not written into a highway code
- Could you give me some examples of these?
- How common are these unwritten rules?
- Do you know of any unwritten rules in the UK? How do the unwritten rules in Malaysia compare?

Violations

- Do people violate the rules when driving in Malaysia? If so, in what ways?
    - Prompts: Speeding, indicating
- What ways do *you* violate the rules?
- What ways do *others* violate the rules?

Visual attention

- How would you describe the roadway in Malaysia?
    - What sort of things do you see on the road, or by the side of the road etc?
- What sort of things do you look at when you're driving?
- Are there any visual distractions which are unique to Malaysia? Any things that you have to look out for that a UK driver wouldn't have to look out for?
- What things do you *need* to look at to stay safe when driving?
    - Does this differ in the UK?

Driver training in Malaysia

- Could you describe driver training in Malaysia?
    - i.e. driving lessons, tests etc.
- How effective do you think this is?
- Do you receive any training on where to look when you're driving?

Back up questions

- What sort of differences do you notice between novice and experienced drivers in Malaysia?

Closing

- Do you have any other comments, or questions you would like to ask?

Appendix B: Change detection trials, Chapter 5 Study 1

Trial	Country	Region	Complexity	Relevance	Type
1	UK	Focal	High	Relevant	Appear
2	UK	Context Relevant	High	Relevant	Change
3	UK	Context Irrelevant	High	Irrelevant	Change
4	Malaysia	Focal	High	Relevant	Appear
5	Malaysia	Context Relevant	High	Relevant	Change
6	Malaysia	Context Irrelevant	High	Irrelevant	Disappear
7	UK	Focal	Low	Relevant	Appear
8	UK	Context Relevant	Low	Relevant	Change
9	UK	Context Irrelevant	Low	Irrelevant	Appear
10	Malaysia	Focal	Low	Relevant	Disappear
11	Malaysia	Context Relevant	Low	Relevant	Appear
12	Malaysia	Context Irrelevant	Low	Irrelevant	Change
13	UK	Focal	High	Irrelevant	Appear
14	UK	Context Relevant	High	Irrelevant	Change
15	UK	Context Irrelevant	High	Irrelevant	Disappear
16	Malaysia	Focal	High	Irrelevant	Change
17	Malaysia	Context Relevant	High	Irrelevant	Disappear
18	Malaysia	Context Irrelevant	High	Irrelevant	Change
19	UK	Focal	Low	Irrelevant	Change
20	UK	Context Relevant	Low	Irrelevant	Disappear
21	UK	Context Irrelevant	Low	Irrelevant	Appear
22	Malaysia	Focal	Low	Irrelevant	Change
23	Malaysia	Context Relevant	Low	Irrelevant	Appear
24	Malaysia	Context Irrelevant	Low	Irrelevant	Change
25	UK	Focal	High	Relevant	Disappear
26	UK	Context Relevant	High	Relevant	Change
27	UK	Context Irrelevant	High	Irrelevant	Disappear
28	Malaysia	Focal	High	Relevant	Change
29	Malaysia	Context Relevant	High	Relevant	Appear
30	Malaysia	Context Irrelevant	High	Irrelevant	Change
31	UK	Focal	Low	Relevant	Change
32	UK	Context Relevant	Low	Relevant	Change
33	UK	Context Irrelevant	Low	Irrelevant	Disappear
34	Malaysia	Focal	Low	Relevant	Appear
35	Malaysia	Context Relevant	Low	Relevant	Change
36	Malaysia	Context Irrelevant	Low	Irrelevant	Appear
37	UK	Focal	High	Irrelevant	Disappear
38	UK	Context Relevant	High	Irrelevant	Change
39	UK	Context Irrelevant	High	Irrelevant	Disappear
40	Malaysia	Focal	High	Irrelevant	Disappear
41	Malaysia	Context Relevant	High	Irrelevant	Appear
42	Malaysia	Context Irrelevant	High	Irrelevant	Change
43	UK	Focal	Low	Irrelevant	Disappear
44	UK	Context Relevant	Low	Irrelevant	Change
45	UK	Context Irrelevant	Low	Irrelevant	Appear

46	Malaysia	Focal	Low	Irrelevant	Change
47	Malaysia	Context Relevant	Low	Irrelevant	Change
48	Malaysia	Context Irrelevant	Low	Irrelevant	Appear
49	UK	No Change	High		
50	UK	No Change	High		
51	UK	No Change	High		
52	UK	No Change	Low		
53	UK	No Change	Low		
54	UK	No Change	Low		
55	Malaysia	No Change	High		
56	Malaysia	No Change	High		
57	Malaysia	No Change	High		
58	Malaysia	No Change	Low		
59	Malaysia	No Change	Low		
60	Malaysia	No Change	Low		

Trial 1:

Trial 2:

Trial 3:

Trial 4:

Trial 5:

Trial 6:

Trial 7:

Trial 8:

Trial 9:

Trial 10:

Trial 11:

Trial 12:

Trial 13:

Trial 14:

Trial 15:

Trial 16:

Trial 17:

Trial 18:

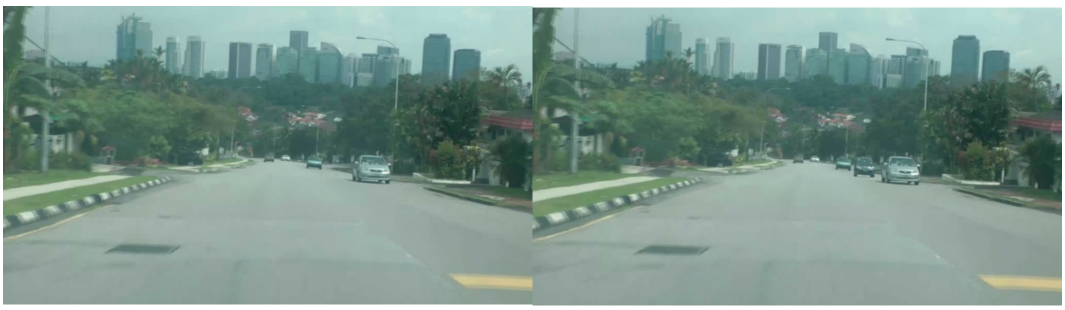
Trial 19:

Trial 20:

Trial 21:

Trial 22:

Trial 23:



Trial 24:

Trial 25:

Trial 26:

Trial 27:

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Trial 31:

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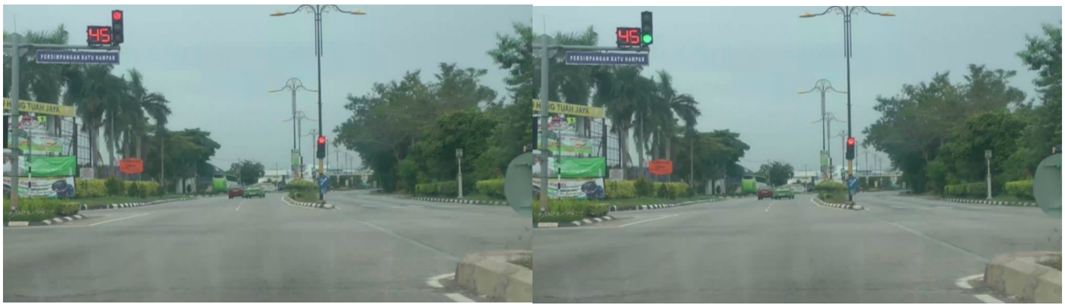
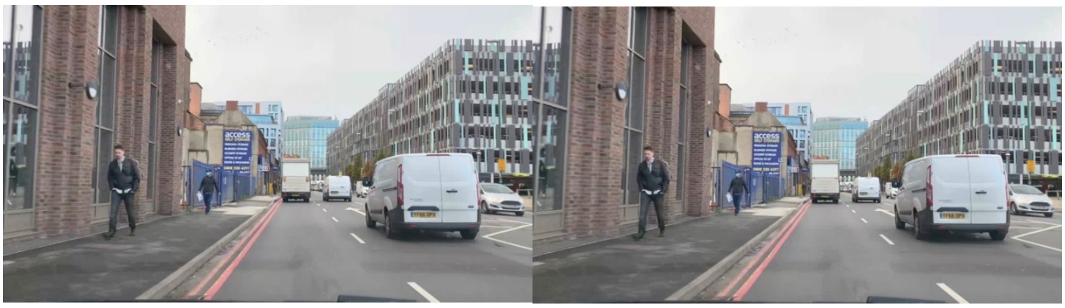
Trial 34:

Trial 35:



Trial 36:

Trial 37:



Trial 38:

Trial 39:

Trial 40:

Trial 41:

Trial 42:

Trial 43:

Trial 44:

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Trial 49:

Trial 50:

Trial 51:

Trial 52:

Trial 53:

Trial 54:

Trial 55:

Trial 56:

Trial 57:

Trial 58:

Trial 59:

Trial 60:

Appendix C: Change detection trials, Chapter 5 Study 2

Trial	Task	Country	Region	Relevance	Type
1	Driving	UK	Focal	Relevant	Appear
2	Driving	UK	Focal	Irrelevant	Change
3	Driving	UK	Background	Relevant	Change
4	Driving	UK	Background	Irrelevant	Disappear
5	Driving	Malaysia	Focal	Relevant	Appear
6	Driving	Malaysia	Focal	Irrelevant	Change
7	Driving	Malaysia	Background	Relevant	Appear
8	Driving	Malaysia	Background	Irrelevant	Change
9	Driving	UK	Focal	Relevant	Change
10	Driving	UK	Focal	Irrelevant	Disappear
11	Driving	UK	Background	Relevant	Change
12	Driving	UK	Background	Irrelevant	Disappear
13	Driving	Malaysia	Focal	Relevant	Change
14	Driving	Malaysia	Focal	Irrelevant	Disappear
15	Driving	Malaysia	Background	Relevant	Appear
16	Driving	Malaysia	Background	Irrelevant	Disappear
17	Driving	UK	No change		
18	Driving	UK	No change		
19	Driving	Malaysia	No change		
20	Driving	Malaysia	No change		
21	Non-driving	UK	Focal		Disappear
22	Non-driving	UK	Background		Disappear
23	Non-driving	Malaysia	Focal		Appear
24	Non-driving	Malaysia	Background		Disappear
25	Non-driving	UK	Focal		Disappear
26	Non-driving	UK	Background		Appear
27	Non-driving	Malaysia	Focal		Disappear
28	Non-driving	Malaysia	Background		Disappear
29	Non-driving	UK	Focal		Change
30	Non-driving	UK	Background		Disappear
31	Non-driving	Malaysia	Focal		Disappear
32	Non-driving	Malaysia	Background		Appear
33	Non-driving	UK	Focal		Disappear
34	Non-driving	UK	Background		Change
35	Non-driving	Malaysia	Focal		Disappear
36	Non-driving	Malaysia	Background		Disappear
37	Non-driving	UK	No change		
38	Non-driving	UK	No change		
39	Non-driving	Malaysia	No change		
40	Non-driving	Malaysia	No change		

Trial 1:

Trial 2:

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Trial 38:

Trial 39:

Trial 40: