

How are Distractibility and Hazard Prediction in driving related?

Role of driving experience as moderating factor.

Candida Castro¹, Jose-Luis Padilla¹, Pablo Doncel¹, Pedro Garcia-Fernandez¹, Petya Ventsislavova², Eduardo Eisman¹, & David Crundall²

¹ CIMCYC, Mind, Brain and Behaviour Research Centre. Faculty of Psychology. University of Granada, Spain.

² Department of Psychology, School of Social Sciences, Nottingham Trent University, UK.

* Address for correspondence:

Candida Castro Ramírez

CIMCYC (Centro de Investigación Mente, Cerebro y Comportamiento)
Mind, Brain and Behaviour Research Centre

Departamento de Psicología Experimental
Experimental Psychology Department

Universidad de Granada
Campus Cartuja, s/n
18197Granada
SPAIN

Tlf: 958240663 Fax: 958246239 Móvil: 655-99 40 59

email: candida@ugr.es

Keywords: Distraction, hazard perception; hazard prediction; driving; road safety, inattention, novice, experienced drivers

ABSTRACT

Distraction constitute one of the ‘five fatal’ behaviours that contribute to road trauma, and some people may be more susceptible to it than others. It is also known that a greater ability to predict danger is related to a lower probability of suffering accidents. It could be hypothesised that drivers with a higher tendency to distraction are worse at predicting traffic hazards, but to what extent might driving experience serve to mitigate this tendency to distraction? The current study collected self-reported attentional errors from drivers by using the Attention-Related Driving Errors Scale (ARDES-Spain) in order to examine whether novice drivers suffered from inattention more than experienced drivers. The results demonstrated that novice drivers scored more highly on ARDES than experienced drivers. ARDES scores were then related to performance in a Hazard Prediction test, where participants had to report what hazard was about to happen in a series of video clips that occlude just as the hazard begins to develop. While experienced drivers were better at the Hazard Prediction test than novice drivers, those participants who reported fewer attention errors were also better able to detect the upcoming hazard following occlusion. In addition, our results demonstrate a relationship between self-reported attentional errors and the ability to predict upcoming hazards on the road, with driving experience having a moderating role. In the case of novice drivers, as their scores in the Manoeuvring Errors ARDES factor increase, their ability in Hazard Prediction diminishes, while for experienced drivers the increase is not significant. Guidance on how to improve training for drivers in order to mitigate the effects of inattention on driving safety can be addressed.

Keywords: Hazard Perception, Hazard Detection, Distraction, Inattention, Risk Estimation, Driving experience

HIGHLIGHTS

- Control ARDES scores were negatively correlated to performance in the Hazard Prediction (HP) test
- Driving experience plays a role in improving hazard prediction and moderating the negative effect of distraction while driving
- Proneness to distraction is more negative when it affects novice drivers.
- Only for novice drivers, higher scores in the Manoeuvring Errors factor predict a worse performance in the Hits and Situation Awareness

1. INTRODUCTION

Many recent works have approached the study of distraction in driving while carrying out dual tasks, for example, using smartphones or smartwatches (Caird, Willness, Steel, & Scialfa, 2008; Louveton et al; 2016; Perlman et al. 2019), demonstrating the inability of drivers to successfully execute two tasks simultaneously (Regan, Lee & Young, 2008). However, to what extent individual differences might predispose drivers to distraction or if this greater disposition could be related to poorer skills in traffic hazard prediction has been studied far less.

There is no lack of reasons for exploring the consequences of driver distraction while driving, which is considered one of the so-called “five fatal” driving behaviours (“driving under the influence of drink or drugs, distraction and inattention, speeding, fatigue, and failure to wear a seat belt”) that contribute to road accidents (Beanland, Fitzharris, Young & Lenné, 2013; Klauer, et al., 2006; NHTSA, 2009; Ranney, 2008; Regan, Hallett & Gordon, 2011; Stutts, Reinfurt, Staplin & Rodgman, 2001; Young et al., 2017). From Ergonomics, for validation and safety purposes, no effort should be spared in identifying which factors might influence these behaviours (Louie & Mouloua, 2019; Salmon et al. 2019; Sundfør, Sagberg & Høye, 2019).

Active involvement in distracting tasks will potentially have a negative impact on the ability to detect hazards. Distracting external visual and auditory stimuli have recently been noted to reduce the ability to spot and respond to hazards in studies of driver safety (Horrey & Divekar, 2016; Lee, Black, Lacherez & Wood, 2016). Even the use of internal imagery can distract from hazard detection (Briggs, Hole & Land, 2016). Therefore, it seems logical to think that a greater propensity to distraction could be related to a worse ability to detect obstacles that might be considered a hazard in driving, with hazard being defined as any obstacle that requires the driver to perform an evasive manoeuvre in order to avoid a collision (McKeenna & Horswill, 2004). This could be produced by distraction, which is understood to be what occurs when drivers no longer pay attention to the critical driving tasks but dedicate their attention to an alternative/simultaneous task that is competing with the prior one (Regan, Hallett & Gordon 2011). For example, according to Thomas, Morris, Talbot and Fagerlind (2013), 18% of all accidents are due to distraction, which can be broken down into 4% caused by the passenger, 8% due to an external competing activity, 5% to an internal competing activity, and 1% to other activities.

That said, it is possible that Hazard Perception skills and the propensity to distraction could be conceptually different and empirically separable; they might have different psychological origins and interventions might require different remedies. For this reason specifically, the current study aims to contribute in a pioneering way to the quantification of the relation between self-reported measures of attentional error and the ability to detect hazards, and, in particular, we hope to ascertain whether there is a moderating effect of driving experience in such a relation.

The distraction propensity could be associated with personality “traits” or driving styles (e.g. the Dissociative Driving Style, Taubman–Ben-Ari y Katz Ben-Ari, 2013). The Attention-Related Driving Errors Scale (ARDES-Spain, Roca et al. 2013) will allow us to obtain measures of the “propensity to distraction” construct. In addition, the skill of Hazard Perception in driving correlates negatively with the risk of suffering accidents (Wells et al, 2008). The skill of Hazard Perception, which could be considered “a state” of the road user, that’s, the driver (learner, novice or experienced) who would be susceptible to specific training programmes, and the practice of driving per se (Horswill and McKenna, 2004). The Hazard Perception test will be useful to measure the ability to detect hazards. This skill, for which training can be provided and that may be different in novice and experienced drivers (see Crundall, 2016 for a review), consists of being able to detect and respond to events on the road that have a high probability of producing a collision. In our previous works, we studied this skill with the Hazard Prediction test from the point of view of the car driver, adapted to the Spanish context, by evaluating different types of drivers (with different experience and reoffending profiles), analyzing the psychometric properties of the test, and by an experimental exploration using naturalistic driving videos (Castro et al, 2014; 2016; and Gugliotta et al. 2017; Ventsislavova et al. 2016).

1.1. The Attention-Related Driving Errors Scale (ARDES)

The ARDES is a self-report measurement developed with the aim of evaluating individual differences associated with the commission of attentional errors while driving (Ledesma, Montes, Poó, & López-Ramón, 2010; Ledesma, Montes & Martín, 2015). A series of items asks respondents to rate the frequency with which they notice the consequences of their own distraction (e.g. hitting something when reversing without previously being aware of its presence). This scale has its roots in the Driver Behaviour Questionnaire (DBQ; Reason, Manstead, Stradling, Baxter & Campbell, 1990; Parker, West, Stradling & Manstead, 1995) and

the Multidimensional Driving Style Inventory (MDSI; Taubman–Ben-Ari, Mikulincer & Gillath, 2004), being ARDES a purer though assessment of attentional errors than the other assessment instrument (Ledesma et al. (2010)), and including planning and execution errors.

Roca, Padilla, López-Ramón and Castro (2013) adapted ARDES to the Spanish language spoken in Spain and traffic norms and driving habits in that country, and found that the scale could successfully distinguish between safe and less-safe driver groups, classified based on self-reported collisions with material damage: drivers who were more prone to attentional errors while driving self-reported more collisions with material damage than those drivers who did not self-report these collisions (Roca et al., 2013). Similar validity evidence for ARDES measures has been found in China (Qu, Ge, Zhang, Zhao & Zhang, 2015), the UK (Peña-Suarez et al., 2016) and the USA (Barragan, Roberts & Baldwin, 2016). Such proneness to distraction is potentially a greater threat than temporary state-based distractions and needs to be assessed to gauge the impact on hazard perception.

In 2015, Ledesma, Montes and Martín conducted a validation study of the ARDES to perform a deeper analysis of individual differences in driver inattention. They found that ARDES scores fit better to a three-factor structure than the previously proposed unidimensional solution (Ledesma et al., 2010). ARDES items cover successfully three dimensions of the attentional errors in driving: *Control Errors*: errors in the execution of automatic actions such as braking (e.g. “I unintentionally shift gears incorrectly or shift to the wrong gear”); *Manoeuvring Errors*: errors in response patterns in traffic situations such as changing lanes (e.g.: “I fail to realise that the vehicle just in front of me has slowed down, and I have to brake abruptly to avoid a crash”); and *Navigation Errors*: errors in top-level driving tasks such as route planning and maintenance (e.g. “When driving somewhere, I make more turns than I have to”). This factorial structure has been replicated in a cross-cultural analysis looking for Equivalence of the ARDES, in which samples were gathered from 6 countries: Argentina, Spain, UK, USA, China and Brazil (Padilla et al., submitted)

1.2. The Hazard Prediction Test

Data exist supporting the idea that HP in driving is a factor that reduces the risk of suffering accidents (Horswill, Anstey, Hatherly & Wood, 2010; Wells et al, 2008). This skill consists in being able to detect and respond to events on the road that have a high probability of

producing a collision (Crundall, Andrews, van Loon, & Chapman, 2010; Crundall et al., 2012; McKenna & Crick, 1991; Pradhan & Crundall, 2016). Therefore, the worrying road accident figures could decrease if HP were improved through training.

As a first model of HP tests, Pelz & Krupat (1974) cited Spicer (1964). In the Spicer's study, participants watched a series of filmed videos of traffic scenes. After each situation, the participants completed a questionnaire (in the form of a checklist) in which they selected features they considered important to the situation. According to Spicer, young people and drivers who had been involved in accidents were less precise than drivers without an accident record at perceiving the essential features of traffic situations.

Pelz and Krupat (1974) asked the participants to watch videos of traffic filmed from the driver's perspective, for instance, a cyclist approaching head-on suddenly crossing in front of the driver. The participants had to indicate to what extent the developing situations were safe or unsafe by moving a lever to right or left according to whether they felt safe or not. It was found that drivers without an accident record or traffic fines responded more quickly. Quimby and Watts (1981) based their work on that of Pelz and Krupat and, using the same task, found a significant correlation between the perception and frequency of having suffered a road accident in the previous three years.

The traditional format of a Hazard Perception test entails a series of video clips filmed from the perspective of a driver (McKenna & Crick, 1991). The test-takers are asked to press a button as soon as they detect a developing hazard (e.g., a pedestrian stepping into the road, a car pulling out from a side street into your path, etc.). Faster responses to hazards are said to be indicative of safer or more experienced drivers (see Horswill, 2016 for a review). HP tests are now used as part of the licensing procedure in the UK and parts of Australia, and in training programmes for improving drivers' HP Ability (e. .g, Horswill, Kemala, Wetton, Scialfa, & Pachana, 2010; Regan,Triggs, & Godley 2000).

There is some concern among researchers about the influence of possible response biases in the hazard perception test measures. According to Horswill and McKenna (2004), individual differences in hazard prediction could be associated with different thresholds for classifying an incident as a hazard rather than with drivers' ability to detect that incident. Despite the wealth of studies demonstrating the discriminative success of Hazard Perception tests, there are also a number of less successful studies of Hazard Perception tests that may have suffered from these

confounding effects (e.g. Borowsky, Shinar & Oron-Gilad, 2010; Chapman & Underwood, 1998; Sagberg & Bjørnskau, 2006; Underwood, Ngai & Underwood, 2013).

In order to avoid the above-mentioned Hazard Perception test weaknesses, Jackson, Chapman and Crundall (2009) recommended using an occlusion technique, modelled on the Situation Awareness Global Assessment Technique (SAGAT; Endsley, 1987; 1995 p.p 162 and 163), understanding Situation Awareness (SA) as “the perception of environmental elements and events with respect to time or space, the comprehension of their meaning and the projection of their future status in the near future”. In other words, SA was described by Endsley as “the mental representation and comprehension of objects, events, people, their interactions, environmental conditions and any other factors that form part of a specific situation and affect the development of complex and dynamic human tasks”. SA means that we are aware of what is happening and can plan what must be done. SA can be defined as what is needed in order to avoid being taken by surprise. To have SA it is essential to answer these questions: What is happening? (Levels 1 and 2), Where is it happening? (Levels 1 and 2) and What can I do now? (Level 3). Endsley (1995) points out the importance of taking into account the variability of the information being processed, as an essential feature of driving. Many changes occur while we are driving, for example, in the environmental conditions. Drivers, therefore, find themselves in a continuous situation of decision-making on the basis of these variable conditions. To make the correct decision, the situation must be constantly evaluated and immediate changes anticipated.

According to Stanton et al. (2006, p. 1288), Situation Awareness can also be defined as “a dynamic and collaborative process binding agents together on tasks on a moment-by-moment basis”. Situation Awareness is essential to undertake complex tasks such as driving or aviation, which require making decisions. Different factors could influence the Situation Awareness of a driver or pilot, attention and working memory, among others, being considered critical and essential to interpret information (Endsley, 2015).

SA involves more than perceiving hazards, it requires Perception, Comprehension and Projection to the next situation. The Hazard the Prediction test is based on the SAGAT technique, is similar to the traditional Hazard Perception test, but instead of requiring participants to make a fast response to developing hazards, the screen simply occludes (i.e., cuts to black) as the hazard appears and participants are asked: What is the hazard?, Where was the hazard at the moment when the video was cut?, and What might happen next in the traffic scene? Responding does not require them to interpret the imminent hazard in terms of their own self-

perceived skill, but ensures that they have been looking at the right place at the right time in order to predict the upcoming hazard. For example, a highly experienced driver may spot a hazard much sooner than a novice driver, but then delay responding because they perceive their skill to be sufficient to cope with the hazard, at least in the early stages of the hazard's development. This could potentially result in safer drivers responding at the same time as less safe drivers, even though they had spotted and considered the hazard much sooner (Castro et al. 2016; Crundall, 2016; Gugliotta et al. 2017; Ventsislavova et al., 2016; 2018). The Hazard Prediction test better addresses the projection element of SA than the traditional Hazard Perception test. The outcome of the Hazard Perception test can be viewed as a domain-specific example of SA. However, this does not imply that SA is only about spotting hazards. In addition, the Hazard Perception test confuses SA processes with post SA processes (Ventsislavova et al. 2019).

RESEARCH PREDICTION

We predict that those drivers who report being prone to distraction in the ARDES will perform worse in the Hazard Prediction test than their more attentive peers. In addition, we expect experience level (i.e. being a novice or an experienced driver) to play a moderating role in this relation: the negative influence of distraction proneness in Hazard Prediction should be compensated for when a driver has a certain amount of experience. This prediction is predicated on the assumption that inattentive drivers are less likely to prioritise the hazardous precursors in the clips (i.e. those clues in the scene that provide evidence on the nature of the imminent hazard), and therefore they will not be looking at the right place at the right time when the hazard begins to develop and the screen is suddenly occluded (Crundall, 2016).

2. METHOD

2.1. Participants

One hundred participants were recruited from the University of Granada (students and staff) and from several driving schools of Granada (Spain). Five participants were excluded from data analysis based on their aberrant response patterns to ARDES (e. g., same answer for every item), resulting in a final sample of 95 participants (36.5% females and 63.5% males, with a mean age of 32.88). The participants were divided into two groups based on their driving experience: 1) Novice drivers had less than 8 years' driving experience and did not drive

frequently (less than twice a week); and 2) Experienced drivers were those with more than 8 years' driving experience, who drove frequently (at least twice a week).

Table 1. Demographics of participants by groups

	Novice N=35	Experienced N=60	Total N=95
Female Percentage	31.4%	5.1%	36.5%
Age Mean (SD)	21.71 (2.99)	39.51 (10.43)	32.88 (12.08)
Driving experience Mean (SD)	4.49 (3.18)	20.07 (10.48)	14.20 (11.37)

2.2. Materials

2.2.1. Demographics questionnaire

Using a questionnaire, we collected demographic data: gender, age and relevant driving-related variables, such as the number of years since passing the driving test, type of license, driving frequency and driving collision history.

2.2.2. Attention-Related Driving Errors Scale (ARDES)

The participants responded to the Attention-Related Driving Errors Scale (ARDES-Spain, Roca et al., 2013) (see Annex I). The scale consists of 19 Likert-type items with 5 response options scored from 1 to 5. It is intended to measure the different consequences of distraction (Table 2 presents an English version of the ARDES in order to make easier follow this study). According to a recent validation study (Ledesma et al., 2015), ARDES scores fit to a three-factor structure, with better fit indices than the previously proposed unidimensional solution (Ledesma, et al., 2010). As a consequence of this validation study, item 18 was removed from the scale, since it failed to show good psychometric properties. The three factors explain 34% of the items' total variance in our sample, the Cronbach's α value being .76 for the Manoeuvring Errors factor, .57 for the Control Errors factor and .67 for the Navigation Errors factor.

Table 2. Three factors of ARDES (Attention-Related Driving Errors Scale)

Manoeuvring Errors

-
1. Heading towards a known place, becoming distracted and then going several streets beyond it.
-
4. Suddenly realising that I'm lost or that I've taken the wrong road on a familiar route.
-
11. Forgetting for a brief moment where I'm driving to.
-
12. Taking a roundabout route to arrive at a place I know how to get to.
-
16. Leaving for one destination and suddenly realising I'm going somewhere else.
-

Control Errors

-
2. Signalling a manoeuvre but unintentionally making another (for example, switching on the indicator to turn one way but instead turning the other).
-
10. Forgetting my lights are on full beam until another driver flashes their lights to warn me.
-
14. Trying to drive off and realising I'm not in first gear.
-
15. Intending to use one device but using another instead (for example, meaning to switch on the windscreen wipers and instead switching on the lights).
-
19. Unintentionally crunching the gears or going into an unsuitable gear.
-

Navigation Errors

-
3. Being distracted when reaching a junction and as a result failing to see a car approaching the junction.
-
5. When arriving at a junction, instead of looking in the direction the traffic is coming from, looking in the other direction.
-
6. On arriving at a junction, not realising that a pedestrian is crossing the street.
-
7. Not realising there is an object or a car behind me and hitting it unintentionally.
-
8. Not realising that the vehicle in front has slowed down and having to brake sharply to avoid a collision.
-
9. Another driver sounding their horn because I'm distracted and haven't noticed that the traffic lights have changed to green.
-
13. Going through traffic lights when they've just turned red, not realising they had changed because I was blindly following the preceding traffic.
-
17. Due to distraction, realising that I haven't even noticed the traffic lights.
-

2.2.3. Hazard Prediction test

























Twenty-four video clips followed by 5 hazard prediction questions were used for the current study. All video clips contained real hazardous driving situations filmed from the driver's perspective. The recording resolution was 1920x1080 pixels 50fps (photograms per second) and the recording was done with a medium angle of vision of 107.1 degrees of diagonal FOV.

A projection screen of 92 pixels with dimensions of 202x114cm was used, the projection size being 200x112.5cm. This size is suitable for projections up to 4.5 metres.

These situations depicted different obstacles on the road that could be either real hazards or hazards not fully developed. All clips were edited so that the screen was occluded (cut to black) just as the hazard began to develop, though with sufficient clues to the impending hazard (the precursors) to allow the safest drivers to be able to predict what would happen following

occlusion. The selected videos lasted between 11 and 26 sec. A short description of the videos is shown in Table 3.

Table 3. Description of the Hazard Prediction clips used in the current study.

Nº	Video clip content	Time (sec)	Last sketch prior to the clip occlusion	Nº	Video clip content	Time (sec)	Last sketch prior to the clip occlusion
1	In an urban street where the visibility is reduced, a car reverses towards an intersection (from the left) forcing us to brake.	11.90		13	At a roundabout, a car is crossing our lane and will invade the right lane.	11.27	
2	In an urban street, a pedestrian is about to cross from behind vegetation, forcing us to brake.	19.27		14	In an urban street, a pedestrian hidden by vegetation, forces us to brake when he suddenly starts to cross the road.	21.30	
3	In an urban street where the visibility is reduced, a car suddenly joins the lane from the left, forcing us to brake.	15.30		15	In an urban street, a car which is reversing from the left joins our lane and forces us to brake.	24.27	
4	In an urban street, a pedestrian is about to cross from behind vegetation, but in the end changes his mind.	26.27		16	A van with its intermittent lights flashing, stops on the hard shoulder, forcing us to brake.	17.07	
5	In an urban street, a motorcycle appears at the exit of a car park and is trying to join the left lane of our road by invading our lane, forcing us to brake.	17.23		17	In an urban street, a car suddenly stops and tries to park on the left, forcing us to brake.	18.30	
6	In an urban street, hidden by the vehicle in front of us, a group of pedestrians crosses at the crossroads with enough time to pass.	25.27		18	In an urban street, a car approaches the intersection on the left, but finally brakes and gives way to us.	19.30	
7	On a backroad, a car is merging at an intersection with reduced visibility, forcing us to brake..	12.04		19	In an urban street, a pedestrian is approaching a crossroads obstructed by vegetation, and tries to cross the street, forcing us to brake.	19.27	
8	On an urban dual carriageway, a red car in the left lane suddenly invades our lane while trying to avoid another vehicle.	11.27		20	On a backroad, obstructed by other vehicles, an oncoming motorcycle is about to invade our lane, forcing us to brake.	18.57	
9	In an urban street, obstructed by urban equipment, a pedestrian is about to cross the street from the pavement but in the end decides to stop.	21.97		21	In an urban street, a car which was hidden by other vehicles appears abruptly on the right, trying to join our lane, but finally gives way to us.	20.53	
10	In an urban street, and hidden by other vehicles, a car is trying to join the lane while reversing, forcing us to brake.	19.63		22	On a dual carriageway, a car passes us on our left, while another car is trying to join the dual carriageway from the right, forcing us to slow down.	26.53	
11	On a dual carriageway, a car stops in the middle of a junction between two exits, then reverses and tries to change direction to the other exit, forcing us to brake.	16.17		23	On a backroad, an oncoming truck is approaching, invading our lane and forcing us to brake.	22.70	
12	In an urban street, a pedestrian on the right pavement is about to cross the street, but finally stops.	11.27		24	In an urban street, a car is trying to change lanes in front of us, forcing us to brake.	12.33	

After each hazard prediction clip, participants had to answer five questions about each clip in a booklet. Q1 (Detection): “Had you seen any hazard at the moment when the video was

cut?"; Q2 (Cautiousness): "What manoeuvre would you perform if you were the driver of the vehicle?"; Q3 (Where?): "Where was the hazard at the moment when the video was cut?"; Q4 (What): "What is the hazard?"; and Q5 (What happens next?, WHN?): "What might happen next in the traffic scene?" (see Annex II).

The Detection question was used to calculate Detection at the moment the hazard was predicted; if the participant responded affirmatively, this response was counted as a hit. When the answer for the Detection question was 'No', the following responses for Cautiousness, Where?, What and WHN? were coded as 0. Otherwise, these measures were used as follows.

The Cautiousness question was used as an indicator of Caution in decision-making. If the participant opted for the alternative "Perform an evasive action", s/he would score a 1, given that this response is always considered the most prudent, while those who opted for the alternative "Maintain the same speed and direction" would score 0. The mean of the Cautiousness question across all clips indicated participants' Caution in the decision-making measure.

Where?, What? and WHN? evaluated the participant's Situation Awareness of the hazardous situation. Where? explored participants' skill in locating the hazard. In this question, they were asked to draw a cross in the place they thought the hazard had appeared. To score Where?, a perimeter was defined, covering the area of the hazard plus 1 cm. If the cross was drawn within this perimeter, the participants scored 1; if the cross was drawn outside this perimeter, they scored 0. The What? question analysed their ability to recognise the hazard and the WHN? question explored their ability to predict how the potentially hazardous situation would conclude. The last two questions were multiple-choice. One point was awarded for selecting the correct option for each one. For the 24 hazard clips, the correct answers referred to the actual hazard or to a hazard that almost happened. The sum of Where?, What? and WHN? question scores was calculated for each clip, and the mean of sums across all clips provided participants' hazard prediction scores, a measure of their Situation Awareness. Additionally, the mean in Where?, What? and WHN? was calculated separately across all clips, in order to consider the 3 different aspects of Situation Awareness in further analysis.

The response options for the multiple-choice questions were developed from the most frequent responses given by the sample of participants that took part in our previous hazard prediction test study, when the same questions were presented in an open format (Castro, et al., 2014). The correct alternative was that which coincided with the way the potential hazard in the

traffic scene developed, while the distractors were selected from the most frequent incorrect answers given by the participants.

In addition, with the aim of ensuring that the measure of Hazard Prediction obtained in the test was the most reliable possible, a reliability analysis was made separately using the three main measures of the study: answers to Detection Q1 (Detection), Cautiousness Q2 (Caution in Decision Making) and the sum of Where? Q3, What? Q4, and WHN? Q5 (Situation Awareness: Location, Identification and Prediction of the situation). Cronbach's α takes acceptable values of .82 for Detection, .83 for Cautiousness and .78 for Situation Awareness (see Horswill and McKenna, 2004).

2.3. Procedure

Participants completed the experiment in groups sitting at a distance of between 3 and 4.5 metres from a projection screen. First, participants were asked to fill in a brief socio-demographic questionnaire. They were then presented with a practice block containing two videos plus two experimental blocks of 12 videos each. Participants recorded their answers to the 5 questions for each clip in a response booklet (Table 4). After the Hazard Prediction test, they responded to the ARDES (Annex I).

The University of Granada's Committee for Ethical Research with Humans awarded a favourable report n° 825/2013 to this investigation: "*Hazard perception, situation awareness and decision making whilst driving*". We undertake to guarantee that the investigation will be carried out following the ethical standards of the Helsinki Declaration. No risk is involved for participants in this study. Data protection and anonymity of participants are guaranteed. Participants take part in the research voluntarily. Before starting the experiment, information is given to them about the activity they are about to undertake. Afterwards, they voluntarily sign a form giving consent to their participation in the research. They receive no financial compensation for their participation.

2.4. Data Analysis

First, to compare the performance of novice and experienced drivers in the different measures of the hazard prediction test, several *t*-tests for independent samples were carried out. Second, to explore the relationships between the Hazard Prediction test and ARDES scores, Pearson correlations were calculated for novice and experienced drivers separately. Third, to study how experience could moderate the relation between ARDES scores and Hazard

Prediction measures, two moderation analyses were performed. Finally, Pearson correlations were used to study relations between self-assessment measures and the remaining measures.

For all the analyses, a check of the assumptions was carried out: for the *t*-test, we ensured compliance with normality and for the regression and moderation analyses, the suppositions of linearity, colinearity, normality, homoscedasticity and independence were verified, in addition to studying the possible existence of atypical and influential cases. All contrasts were corrected using the false discovery rate (Benjamini & Hochberg, 1995). All statistical analyses were performed using IBM SPSS Statistics v20 for Windows.

3. RESULTS

3.1. Analysis of ARDES measures and HP Test parameters by driver experience

Table 4 presents the score means of Detection, Cautiousness, Where?, What?, WHN? questions (Situation Awareness), and of ARDES scores, broken down by driver experience.

The contrasts for comparisons between means of novices and experienced drivers are significant for the following variables: Detection, Caution in decision-making, Where?, What?, WHN?, The Total Hazard Prediction (SA) scores and Control Errors ARDES factor.

The significant differences demonstrate that drivers with experience discriminate and predict hazards better than novice drivers (novice drivers' detection rate is 15.20, while experienced drivers' detection rate is 18.08). Novice drivers are less cautious (.50) than experienced drivers (.68) and they obtained a lower score in Situation Awareness (Total= 1.26, What=.45 Where=.45, WHN=.35) than experienced drivers (Total=1.49, What=.54 Where=.54, WHN=.43).

In addition, novice drivers obtain a significant higher average score (1.71) than experienced drivers (1.46) in the ARDES Control Errors Factor, that's, novices make more control errors in the execution of automatic actions such as braking. No significant differences are found for the ARDES total score, the Navigation Errors factor or the Manoeuvring Errors factor.

Table 4. Detection, Cautiousness, Situation Awareness and ARDES measures by experience

		Total	Mean	Situation Awareness (SA)			Situation Awareness TOTAL	ARDES TOTAL	ARDES (3 Factors) Attention-Related to Driving Errors		
		(Min 0 Max 24)	(Min =0 Max 1)	(Min 0. Max 1)			(Min 0 Max 3)	(Min 1 Max 5)	(Min 1 Max 5)		
		Detection	Cautiousness	Where?	What?	WHN?	SA	ARDES	Navigation Errors	Manoeuvring Errors	Control Errors
Novice drivers (N =35)	Mean	15.20	.50	.45	.45	.35	1.26	1.76	1.83	1.78	1.71
	SD	4.72	.19	.17	.17	.14	.45	.42	.64	.51	.48
Experienced drivers (N =60)	Mean	18.08	.68	.54	.54	.43	1.49	1.62	1.64	1.72	1.46
	SD	3.72	.18	.17	.15	.12	.41	.40	.48	.47	.45
Independent samples t-test results	t value (df)	-3.29 (93)	-4.42 (93)	-2.36 (90)	-2.69 (93)	-2.78 (93)	-2.51 (93)	1.68 (93)	1.67 (93)	.64 (93)	2.56 (93)
	P(value)	.005**	<.01**	.028*	.02*	.02*	.023*	.11	.11	.52	.023*
	Cohen's d	.68	.97	.53	.56	.61	.53	-	-	-	.54

* Statistically significant as P < .05

** Highly significant as P <.01

3.2. Relation between ARDES Scores and Hazard Prediction Test accuracy measures

A main hypothesis of this study is to examine to what extent propensity to distraction (evaluated by means of the ARDES scores) is related to hazard perception performance measures. In addition, this relation may vary from novice to experienced drivers. With the aim of exploring this relationship, correlations between ARDES scores and the different measures of hazard perception and prediction were calculated by level of experience (See **Table 5**).

All the significant correlations are found for novice drivers between the Manoeuvring Errors ARDES factor and the measures: Detection (-.475) , the WHN question (-.396), and TOTAL Situation Awareness (-.383). All of them correlates negatively with this ARDES Manoeuvring factor.

Table 5. Correlations between ARDES scores and measures of the Hazard Prediction Test by level of Experience

	TOTAL ARDES		Navigation Errors		Manoeuvring Errors		Control Errors	
	Novice	Experienced	Novice	Experienced	Novice	Experienced	Novice	Experienced
Detection	-.321	.050	-.205	.017	-.475*	.011	.031	.108
Cautiousness	-.186	-.055	-.159	-.046	-.291	-.056	.059	-.031
Where?	-.167	.170	-.095	-.015	-.335	.163	.168	.226
What	-.200	-.008	-.103	.009	-.359	-.003	.086	-.005
WHN?	-.296	.093	-.291	.009	-.396*	.112	.093	.099
TOTAL Situation Awareness	-.230	.086	-.165	-.051	-.383*	.110	.124	.125

* Statistically significant as $P < .05$

3.3. Experience as a moderating variable between distractibility and hazard prediction

On the basis of the significant correlations presented in the previous section, we decided to run two regression models, with ARDES Manoeuvring Errors factor as the predictor variable: a) a first model aimed at predicting number of Detection hits; and b) a second model aimed at predicting Situation Awareness. As we are interested in studying the possible role of driving experience as a moderating effect, an interaction effect between this variable and the ARDES Manoeuvring Errors factor was included in both models.

3.3.1. Regression model: Detection as dependent variable

First, a regression model including Detection as the dependent variable and Manoeuvring Errors factor and experience as independent variables was fitted. A significant regression equation was found ($F(2,92) = 7.451, p = .001$), with an R^2 of .141. Then, a second regression model was fitted, introducing interaction between Manoeuvring Errors and driving experience; this result was also significant, ($F(3,91) = 7.666, p < .001$), with an R^2 of .202.

In respect of the second and definitive model (Table 6), the average score predicted for participants in number of Detection hits equalled $23.078 - 4.420^*$ (Manoeuvring Errors) $- 5.141^*$ (Driving Experience) $+ 4.506^*$ (Manoeuvring Errors x Driving Experience). The effect of moderation means the regression equation for novices and experienced drivers is different (Figure 1): in novices, prediction by number of Detection hits diminishes by 4.420 points for each point that Manoeuvring Errors scores increase, while in experienced drivers this increase is not significant. If we consider groups of experience separately, linear regression R^2 for novices has a value of .225, whereas this value for experienced drivers is almost 0.

Ultimately, self-reported proneness to manoeuvring distraction (measured with ARDES) predicts the Detection average. For novice drivers, higher scores in the Manoeuvring Errors factor predict a worse performance in the response to the hazard Detection question. In the case of experienced drivers, on the other hand, the Manoeuvring Errors score obtained has no predictive value.

Table 6. Regression Coefficients for predicting the average score on number of Detection hits from Manoeuvring Errors scores (moderated by experience)

Dependent Variable: Score on Detection	Non-standardised		Standardised	<i>T</i>	<i>p-value</i>
	coefficients		coefficients		
	<i>B</i>	<i>SE</i>	<i>Beta</i>		
(Intercept)	23.078	2.457		9.392	<.001**
Manoeuvring errors	-4.420	1.327	-.496	-3.330	.001**
Driving experience	-5.141	3.117	-.576	-1.648	.103
Manoeuvring errors x Driving experience	4.506	1.710	.951	2.635	.010**

* Statistically significant as $P < .05$

** Highly significant as $P < .01$

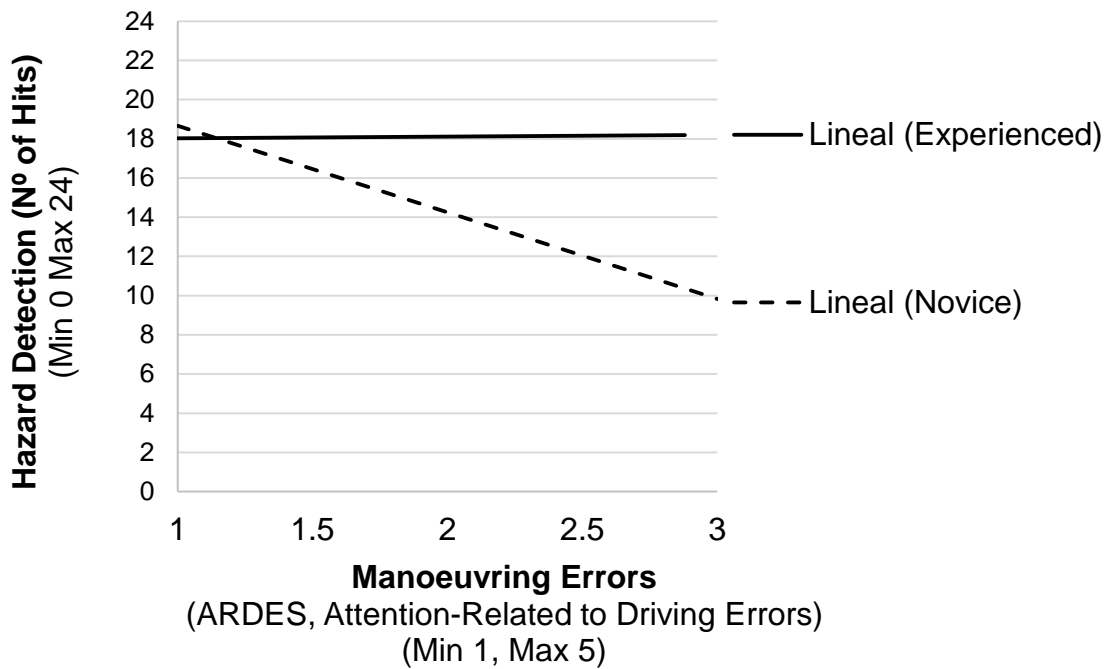


Figure 1. Regression equation for novices and experienced drivers.

For novice drivers, prediction of the number of hits diminishes by 4.420 points for each point that Manoeuvring Errors scores increase, while in experienced drivers this increase is not significant. Linear regression R^2 for novices has a value of .225, for experienced drivers is almost 0

3.3.2. Regression Model: Situation Awareness as dependent variable

For this model, the Situation Awareness measure was used as the dependent variable and the Manoeuvring Errors factor as the independent variable, as this is the factor most related to hazard prediction in novices (having a significant relation with What, WHN? and the sum of Where?, What, WHN?: Situation Awareness).

Thus, a regression model including Situation Awareness as the dependent variable, and Manoeuvring Errors factor and Experience as independent variables was fitted. A significant regression equation was found ($F(2,92) = 3.538, p = .033$), with an R^2 of .071 (Table 7). Then, to explore the aforementioned moderation effect, interaction between Manoeuvring Errors and experience was also included in a second regression model, the result also being significant ($F(3,91) = 4.421, p = .006$), with an R^2 of .127.

The average score predicted for participants in Situation Awareness equalled 1.871, Specifically, $-.344^*$ (Manoeuvring Errors) $-.546^*$ (Driving Experience) $+ .439^*$ (Manoeuvring Errors x Driving Experience). The effect of moderation means the regression equation for novices and experienced drivers is different (Figure 2): in novices, Situation Awareness diminishes by $-.344$ points for each point that Manoeuvring Errors scores increase, while in experienced drivers this increase is not significant. If we consider groups of experience separately, linear regression R^2 for novices has a value of $.147$, whereas this value for experienced drivers is $.012$.

Ultimately, self-reported proneness to Manoeuvring Errors (measured with ARDES) predicts the average score on Situation Awareness. For novice drivers, higher scores in the Manoeuvring Errors factor predict a worse performance in the response to Situation Awareness questions. In the case of experienced drivers, Manoeuvring Errors obtained has no predictive value.

Table 7. Regression coefficients for predicting the average score on Situation Awareness from Manoeuvring Errors (moderated by experience).

Dependent Variable: Score on Situation Awareness	Non-standardised		Standardised	<i>T</i>	<i>p-value</i>
	coefficients		coefficients		
	<i>B</i>	<i>SE</i>	<i>Beta</i>		
(Intercept)	1.871	.261		7.160	<.001**
Manoeuvring errors	-.344	.141	-.379	-2.434	.017**
Driving experience	-.546	.331	-.602	-1.648	.103
Manoeuvring errors x Experience	.439	.182	.910	2.412	.018**

* Statistically significant as $P < .05$

** Highly significant as $P < .01$

Only for novice drivers, higher scores in the Manoeuvring Errors factor predict a worse performance in the response to Situation Awareness questions.

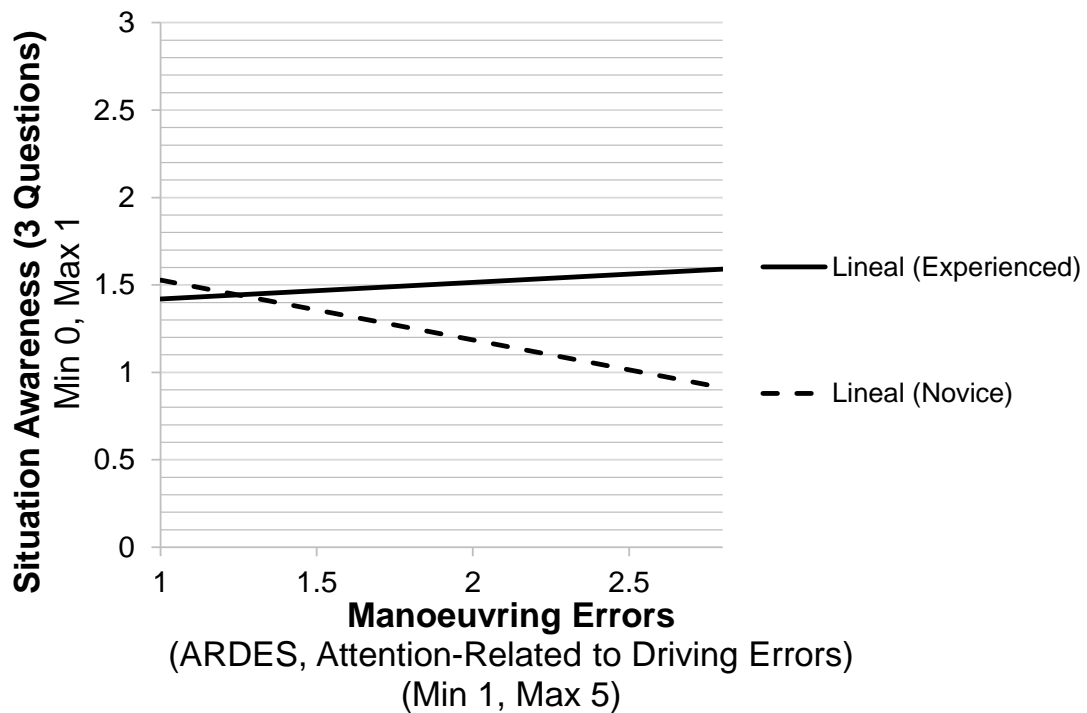


Figure 2. Regression equation for novices and experienced drivers.

For novice drivers, Situation Awareness diminishes by -0.344 points for each point that Manoeuvring Errors scores increase, while in experienced drivers this increase is not significant. Linear regression R^2 for novices has a value of $.147$, for experienced drivers is $.012$.

4. Discussion

The study suggests that proneness to distraction, as measured by ARDES, can distinguish to some extent between drivers based on their driving experience. Novice drivers report greater frequency of inattentive errors than more experienced drivers. Novice drivers' processing capacity of selective attention is overloaded in numerous situations (Schneider & Shiffrin, 1977). For example, while experienced drivers may make conscious decisions to engage in risky and violating behaviour (e.g. jumping a red light because they cannot see any opposing traffic), novice drivers may be more likely to contravene the rules unintentionally (e.g. jumping a red light because they fail to notice that the light has change or unintentionally shift gears incorrectly or shift to the wrong gear). This could have important ramifications for the re-education of drivers

who have been caught contravening the law on the road. Not only might it be appropriate to focus on risk-taking for novice drivers; they may also benefit more from a focus on visual-skill development in relation to driving.

However, the results also demonstrate support for the Hazard Prediction test as a diagnostic measure of hazard prediction skill. The hazard prediction task is a relatively recent development compared to the more traditional Hazard Perception test, though evidence is accumulating to support its superiority over existing methods of assessing this complex skill (e.g. Jackson et al., 2009; Castro et al., 2014, 2016; Lim, Sheppard & Crundall, 2014; Crundall, 2016; Gugliotta, et al., 2017; Ventsislavova et al., 2016; 2017; 2019). The current data show that experienced drivers have greater sensitivity to reporting whether or not they had seen the hazard begin to develop, what is supported by the subsequent finding that they can also identify the developing hazard and predict what will happen next in the driving setting.

In addition, a link was found between self-reported distraction errors and performance in the hazard perception test. Those who scored low on ARDES demonstrated greater sensitivity to the detection of up-coming hazards, greater ability to report the location and nature of the imminent hazard and to predict the incoming traffic situation. As the Hazard Prediction test requires participants to be looking at the right place at the right time to spot the start of the hazard, any form of distraction is likely to increase the chances that the participant is looking elsewhere when the occlusion occurs. According to Schneider and Shiffrin (1977), a possible strategy for training is to identify consistent task components and to design training for these components. The only way to ensure that one is looking at the right place at the right time is to extract information from hazardous precursors, which then allow one to prioritise different areas of the driving scene for further inspection according to their probability of producing a hazard.

Thus, distraction does not have to coincide exactly with the point of occlusion to degrade predictive accuracy; any distraction from safety-relevant information at any time during the clip may impair one's awareness of the precursors, with a concomitant effect upon hazard prediction accuracy. These results accord with those found by Padilla et al. (submitted), which show a positive correlation between two self-report measures, the Dissociative Driving Style of the MDSI (Multi Driving Styles Inventory, Taubman–Ben-Ari, Mikulincer & Gillath, 2004) and the Lapses and Errors subscale measures of the DBQ (Driver Behaviour Questionnaire). In our current study, the relation between a self-report measure (ARDES) and a behavioural measure (Hazard Prediction test) is established.

Finally, it is worth noting the role that driving experience plays in improving hazard perception and moderating the negative effect of distraction while driving. Proneness to distraction is more negative when it affects novice drivers. We have found that as their distractibility increases, their ability in Hazard Prediction diminishes, while in experienced drivers the effect of distractibility on Hazard Prediction is non-significant. So, can we overcome distractibility? In order to overcome attentional errors in driving we must understand the source of those errors (i.e. manoeuvring errors mainly). A completely stable trait is perhaps more likely to be immune to modification, though the evidence provided here suggests that one's proneness to distraction can change over time.

One possible reason for this change is the improvement in visual search skills that is noted as drivers move from novice status to become more experienced road users (Underwood, 2007). According to him, drivers develop schemata that help guide their search for hazards on different roadways, though several studies have demonstrated that these schemata may take some time to develop, even post-licensure; hence the over-representation of novice drivers in the collision statistics. These schemata help prioritise areas of the visual scene that are most likely to produce hazards (e.g. look for pedestrians on the pavement when approaching a crossing). These preferred areas of the scene ('scene priors'; Torralba, Oliva, Castelhana & Henderson, 2006) modify a bottom-up saliency map, ensuring that highly salient but completely irrelevant stimuli are less likely to grab attention. If, however, these schemata are still under development in novice drivers, then this would increase the possibility that highly salient objects may capture attention regardless of their relevance to task goals.

The obligatory and automatic nature of orientation processes can be compensated for by an increase in driving experience, although for both novice drivers and those with experience, the appearance of invalid signals (invalid signals are those that occur in a location where nothing relevant is going to happen; Posner, 1980) had an adverse effect (Muela et al, submitted). Klein (2000) observed the need to engage and disengage the attention in order to constantly update information from our visual world. However, it is possible that the ability to disengage the attention from stimuli that capture our attention increases with a higher degree of driving experience (Underwood et al, 2003), given the even greater necessity to do so in a traffic environment (Klein 2000).

If this is indeed the case, this strengthens the argument for more visual training for learner drivers prior to their driving tests (i.e., attention maintenance training and/or teaching novice

drivers to anticipate latent hazards, Yamani, Samuel, Knodler & Fisher, 2016, p. 135). According to these authors teaching novice drivers is worthy: “Trained groups are more likely to anticipate hazards, quicker and more effective at responding to hazards and more likely to maintain glance duration under critical threshold compared to drivers in placebo-trained group”. If drivers learn what cues to look for and where they are likely to be found in the scene, then this should constrain visual attention to more safety-relevant areas and reduce the risk of bottom-up distraction. It is possible that the safety benefit gained in the UK from their introduction of the Hazard Perception test in 2002 (Wells, Tong, Sexton, Grayson & Jones, 2008) derives from the need for instructors to train their students in how to look for and spot hazards in order to pass the test. It is possible that this benefit could be achieved in other countries with the inclusion of a similar or improved test (though see Ventsislavova et al., 2019, for an explanation of why the Hazard Prediction test is a better measure of skill for the global market than the traditional Hazard Perception test).

The revealing finding that attentional errors diminish with experience suggests that drivers can change. This should motivate us to employ means of exploring and creating effective training programmes that speed up the process by which novice drivers can learn to survey the road situation as if “through the eyes of an experienced driver.” It would be possible to improve this ability to “read the road” and anticipate hazards, guided by their prior experience, using short training programmes (for example, Castro 2016; Horswill, et al. 2010; Horswill, Garth, Hill & Watson, 2017), thus freeing resources to carry out competing tasks that may be required at the same time. We could arrange tasks that are difficult to perform simultaneously so that they are executed in sequence, thus achieving a synchronisation that would make a perfect choreography of our driving.

5. Conclusion, further research and limitations

In conclusion, the data suggest that ARDES has identified a strand of distractibility that is particularly pertinent to novice drivers and that this may have an impact on their ability to successfully detect on-road hazards. Fortunately there are training options available (e.g. Horswill, 2016) that could be used to mitigate the effects of this ‘trait’.

It is possible that the over-representation of novice drivers in the accident statistics could be due in part to the fact that strategies to guide their visual search for hazards have not yet been developed. Such strategies take time to emerge, which means that young, inexperienced drivers have not yet had sufficient time or experience to develop them (e.g. Underwood, 2007). We believe that with proactive instructive commentaries, it is possible to train drivers, guiding their visual search

for hazards on different types of road (Castro et al., 2016). We would also recommend analysing the pattern of visual search by registering ocular movements during the visualisation of hazard prediction videos, with the correct demarcation of regions of interest over time, in order to obtain measures of the position and duration of fixation and withdrawal during the performance of the task (Underwood, Crundall & Chapman, 2011; McKenzie & Harris, 2015, 2017). Hazard Prediction Models can be based on the data obtained testing the ability of experienced drivers. These data could be used to plan new evaluation strategies and promote training that would improve the visual search of novice or unsafe drivers, and to improve the adaptability of automated driving systems to the hazardous nature of driving environments, providing knowledge that might guide the road “scan” they perform so as to resemble that of experienced drivers.

At the same time, it would be possible for drivers with experience to improve their Hazard Prediction since, when the attentional resources of the experienced driver have to be shared with other tasks, their Hazard Prediction skill is reduced to the level of novice drivers (McKenna & Farrand, 1999). Rowe (1997) found that drivers with experience suffered more interference when they had to carry out dual tasks. More recently, McKenzie and Harris (2015) compared the ocular movements of participants while they carried out the Hazard Prediction task only (i.e., in passive form) and while they drove in a simulator at the same time. In the latter case, Hazard Prediction (i.e., in active form) was more cognitively demanding, the participants were left with fewer resources and they scanned the road to a lesser extent. The authors argue that increased driving experience would have a beneficial effect on the scanning of the traffic scene because to a certain extent the process of controlling the vehicle becomes automatic, freeing resources that could be used to attend to other areas of the road. The execution of the Hazard Prediction task (active) would be more detrimental to the performance of novice drivers. In short, we can establish that the problem of young drivers could be due to the lack of automatization of the perceptual-motor skills required for driving, to the dearth of previous knowledge and the lack of mental strategies to guide the visual search, more than to the problem of distraction.

However, the fact that the participants were not driving or interacting with any vehicle controls should be acknowledged as a limitation. This might also include a discussion of the weaknesses of a SAGAT-style approach (e.g., new perception-action cycle models of situation awareness have been proposed, Salmon et al., 2008). In any case, novice drivers require exposure to more driving scenarios involving potential hazards prior to their driving tests. The video training might help (Castro et al. 2016; Isler, Starkey & Williamson, 2009; Wetton, Hill & Horswill 2013). The load of the driving task might interfere and commentary training under

conditions of live commentary may not be beneficial (Young, Chapman & Crundall, 2014; Young, Crundall & Chapman, 2017).

Nevertheless, we should continue to analyse the possible generalisation of these results to real driving. It was shown some time ago that training in Hazard Prediction in real driving situations corresponds to a better performance in the Hazard Prediction test with videos and that training with the videos of the Hazard Prediction test also correspond to a better performance in the real world (McKenna & Crick, 1991; Mills, Hall, McDonald & Rolls, 1998). Recently, Hill, Horswill, Whiting and Watson (2019) demonstrated that Hazard Perception, measured with a test installed on a computer, is negatively associated with sudden braking in real driving. In the current investigation as in some previous ones (i.e. Crundall, 2016; McGowan & Banbury, 2004; and Ventsislavova et al. 2019). We are defending the use of Hazard Prediction tests to measure the Situation Awareness of drivers as a way of avoiding the response bias of traditional Hazard Perception tests. For example, in Ventsislavova et al., (2019) it was shown that the Hazard Prediction test is capable of differentiating between novice and experienced drivers in different countries (Spain, UK and China) independently of the different hazard thresholds assumed in driving in these countries.

Finally, as a limitation, it must be said that R-square values of the regression models are quite low, except for the one found in the case of novice drivers. Further research will explore other potential predictors that could explain part of the variance. Nevertheless, the differences shown between novice and experienced drivers have practical significance, since they vary from moderate to large.

6. Acknowledgments

We would like to thank the Spanish participants who volunteered for the studies as well as our English reviewer Barbara Lamplugh for revising and improving the English. We are also indebted to the Spanish Government, MICINN (PSI2016-75086), whom gave us financial support and the three driving schools in Granada (Autoescuelas la Victoria, Luna and Genil) from whom we obtained our sample of participants. We much appreciate their contribution to the study.. The study design, data collection, analysis and interpretation were carried out independently of the funding bodies, as were the writing up of the experiment and the decision to seek publication.

7. References

- Barragan, D., Roberts, D.M., & Baldwin, C.L. (2016). Validation of the Attention-Related Driving Errors Scale (ARDES) in an English-Speaking Sample. *Human Factors*, 58(8):1262-1274. DOI: 10.1177/0018720816657927
- Beanland, V., Fitzharris, M., Young, K.L., Lenne, M.G., (2013). Driver inattention and driver distraction in serious casualty crashes: data from the Australian National Crash in-depth study. *Accident Analysis & Prevention*, 54, 99–10. DOI: 10.1016/j.aap.2012.12.043
- Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society. Series B*, 57(1), 289-300. Retrieved from <http://www.jstor.org/stable/2346101>
- Borowsky, A., Shinar, D., & Oron-Gilad, T. (2010). Age, skill and hazard perception in driving. *Accident, Analysis and Prevention*, 42(4), 1240-1249 DOI: 10.1016/j.aap.2010.02.001
- Briggs, G.F., Hole, G.J., & Land, M.F., (2016). Imagery-inducing distraction leads to cognitive tunnelling and deteriorated driving performance. *Transportation Research Part F*, 38, 106-117. DOI: 10.1016/j.trf.2016.01.007
- Caird, J. K., Willness, C., Steel, P., Scialfa, C. (2008). A meta-analysis of cell phone use on driver performance. *Accident Analysis & Prevention*, 40, 1282–1293. DOI: 10.1016/j.aap.2008.01.009
- Castro, C., Padilla, J.L., Roca, J., Benítez, I., García-Fernández, P., Estévez, B., López-Ramón, M.F., & Crundall, D., (2014). Development and validation of the Spanish hazard perception test. *Traffic Injury and Prevention*, 15(8), 817–826. DOI: 10.1080/15389588.2013.879125
- Castro, C., Ventsislavova, P., Peña-Suárez, E., Gugliotta, A., García-Fernández, P., Eisman, E., & Crundall, D., (2016). Proactive listening to a training commentary improves hazard prediction. *Safety Science*, 82, 144–154. DOI: 10.1016/j.ssci.2015.09.018.
- Chapman, P., & Underwood, G. (1998). Visual search of driving situations: Danger and experience. *Perception*, 27, 951–964. DOI: 10.1068/p270951
- Chapman, P., Ismail, R., & Underwood, G.J. (1999). Waking up at the wheel: accidents, attention and the time-gap experience. *Vision in vehicles*, 7, 131-138.
- Crundall, D. (2016). Hazard prediction discriminates between novice and experienced drivers. *Accident Analysis and Prevention*, 86, 47-58. DOI: 10.1016/j.aap.2015.10.006.

- Crundall, D., Andrews, B., Van Loon, E., & Chapman, P. (2010). Commentary training improves responsiveness to hazards in a driving simulator. *Accid. Anal. Prev.* 42, 2117-2124.
- Crundall, D., Chapman, P., Trawley, S., Collins, L, Van Loon, E., Andrews, B., & Underwood, G. (2012). Some hazards are more attractive than others: Drivers of varying experience respond differently to different types of hazard. *Accid. Anal. Prev.* 45, 600-609.
- Crundall, D., Van Loon, E., & Underwood, G. (2006). Attraction and distraction of attention with outdoor media. *Accident Analysis and Prevention*, 38, 671-677. DOI: 10.1016/j.aap.2005.12.012
- Endsley, M.R. (1995). Toward a theory of situation awareness in dynamic-systems. *Human Factors*, 37(1), 32-64. DOI: 10.1518/001872095779049543
- Endsley, M.R. (2015). Situation Awareness Misconceptions and Misunderstandings. *Journal of Cognitive Engineering and Decision Making*, 9(1) 4-32 DOI: 10.1177/1555343415572631
- Endsley, M.R., (1987). *SAGAT: A methodology for the measurement of Situation Awareness* (No. NORDOC 87–83). Hawthorne, CA: Northrop Corporation.
- Engström, J., Monk, C.A., Hanowski, R.J., Horrey, W.J., Lee, J.D., McGehee, D.V., & Yang, C.Y.D. (2013). *A conceptual framework and taxonomy for understanding and categorizing driver inattention*. Brussels, Belgium: European Commission.
- European Commission (2015). Study on good practices for reducing road safety risks caused by road user distractions. Final report. Directorate-General for Mobility and Transport by TRL; TNO, RAPPTnas –Luxembourg Publications Office of the European Union, 2015-193 p. N° Doc EL4420.
- Gugliotta, A, Peña-Suárez, E., Ventsislavova, P., Garcia-Fernandez, P., Eisman, E., Crundall, D., & Castro, C. (2017). Are Situation Awareness and Decision-Making in driving totally conscious processes? Results of a Hazard Prediction task. *Transportation Research, Part F.*, 44, 168-179 DOI: 10.1016/j.trf.2016.11.005
- Hill, A., Horswill, M.S., Whiting, J., & Watson, M.O. (2019). Computer-based hazard perception test scores are associated with the frequency of heavy braking in everyday driving. *Accident Analysis & Prevention*, 122 207-214. DOI:10.1016/j.aap.2018.08.030
- Horn, J.L. (1965). A rationale and test for the number of factors in factor analysis. *Psychometrika*, 30, 179-185 DOI: <https://doi.org/10.1007/BF02289447>

- Horrey, W.J., & Divekar, G. (2016). Attention allocation and Maintenance in Novice and Teen Drivers. In Fisher, D. L., Caird, J., Horrey, W. and Trick L. (Eds.). (2016). *Handbook of Teen and Novice Drivers: Research, Practice, Policy, and Directions*. CRC Press: Boca Raton, FL.
- Horswill, M.S. (2016). Hazard perception tests. In Fisher, D. L., Caird, J., Horrey, W. and Trick L. (Eds.). (2016). *Handbook of teen and novice drivers: Research, Practice, Policy and Directions*. CRC Press: Boca Raton, FL.
- Horswill, M.S., & McKenna, F.P. (2004). Drivers' Hazard Perception Ability: Situation Awareness. In S. Banbury & S. Tremblay, *A Cognitive Approach to Situation Awareness*. Burlington, VT: Ashgate
- Horswill, M.S., Garth, M. Hill, A., & Watson, M.O. (2017). The effect of performance feedback on drivers' hazard perception ability and self-ratings. *Accident, Analysis and Prevention; 101*, 135-142. DOI: 10.1016/j.aap.2017.02.009.
- Horswill, M.S., Kemala, C.N., Wetton, M., Scialfa, C.T., & Pachana, N.A. (2010). Improving older drivers' hazard perception ability. *Psychology of Aging, 25(2)*, 464-469. DOI: 10.1037/a0017306
- Isler, R.B., Starkey, N.J., & Williamson, A.R. (2008). Video-based road commentary training improves hazard perception of young drivers in a dual task. *Accid. Anal. Prev. 41*, 445-452. DOI: 10.1016/j.aap.2008.12.016
- Jackson, L., Chapman, P., & Crundall, D. (2009). What happens next? Predicting other road users' behaviour as a function of driving experience and processing time. *Ergonomics, 52(2)*, 154–164. DOI: 10.1080/00140130802030714
- Klauer, S.G., Dingus, T.A., Neale, V. L., Sudweeks, J.D., & Ramsey, D.J. (2006). *The impact of driver inattention on near-crash/crash risk: An analysis using the 100-car naturalistic driving study data*. Blacksburg, Virginia: Virginia Tech Transportation Institute.
- Klein, R.M. (2000). Inhibition of return. *Trends in cognitive sciences, 4(4)*, 138–147. DOI:10.1016/S1364-6613(00)01452-2
- Ledesma, R.D., Montes, S.A., Poó, F.M., & López-Ramón, M.F. (2010). Individual differences in driver inattention: The attention-related to driving errors scale. *Traffic Injury Prevention, 11(2)*, 142–150. DOI: 10.1080/15389580903497139

- Ledesma, R.D, Montes, S.A., & Martín, F.M. (2015). Measuring individual differences in driver inattention. Further validation of the Attention-Related Driving Errors Scale, *Human Factors*, 2, 193-207. DOI: 10.1177/0018720814546530
- Lee, S.S.Y., Black. A. A., Lacherez, P., & Wood, J.M., (2016). Eye movements and road hazard detection: effects of blur and distractors. *Optometry and Vision Science*, 93, 9, 1137-1146. DOI: 10.1097/OPX.0000000000000903
- Lim, P.C., Sheppard, E., & Crundall, D. (2014). A predictive hazard perception paradigm differentiates driving experience cross-culturally. *Transportation Research Part F*, 26, 210–217. DOI: 10.1016/j.trf.2014.07.010
- Louie, J.F & Mouloua, M. (2019). Predicting distracted driving: The role of individual differences in working memory. *Applied Ergonomics*, 74, 154-161. DOI: 10.1016/j.apergo.2018.07.004
- Louveton, N., Koenig, V., Avanesov, T., & Engel, T. (2006). Driving while using a smartphone-based mobility application: evaluating the impact of three multi-choice user interfaces on visual-manual distraction. *Applied Ergonomics*. 54, 196–204 DOI: 10.1016/j.apergo.2015.11.012 7,
- Mackenzie, A.K., y Harris, J.M. (2015). Eye movements and hazard perception in active and passive driving. *Visual Cognition*, 3; 23(6), 736-757. DOI: 10.1080/13506285.2015.1079583
- Mackenzie, A.K., y Harris, J.M. (2017). A link between attentional function, effective eye movements, and driving ability. *Journal of Experimental Psychology: Human Perception and Performance*, 43(2), 381-394. DOI:10.1037/xhp0000297
- McGowan, A.M. y Banbury, S.P. (2004). Evaluating Interruption-Based Techniques using Embedded Measures of Driver Anticipation. En Banbury, S., y Tremblay, S. (Eds.). (2004). *A cognitive approach to situation awareness: theory and application*. Gower Publishing, Ltd.
- McKenna, F.P., & Crick, J.L. (1991). *Hazard perception in drivers: a methodology for testing and training*. Crowthorne, UK: Transport and Road Research Laboratory. CR313 Downloaded from: <https://trl.co.uk/reports/CR313>
- McKenna, F.P., y Farrand, P. (1999). The role of automaticity in driving. In *Behavioural Research In Road Safety IX*. PA3524/99.

- Mills, K.L., Hall, R.D., McDonald, M., y Rolls, G.W.P. (1996). The effects of hazard perception training on the development of novice driver skills. En *Roadsafe'96. Influences Affecting Road User Behaviour. International Conference, London 24th And 25th July 1996*. Conference Report.
- Muela, I., Chica, A., García-Fernández, P., & Castro, C. (submitted). Visual attention in naturalistic driving situations.
- NHTSA (2009). *Distracted Driving*. Research Note: Traffic Safety Facts. <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811379>
- Parker, D., West, R., Stradling, S., & Manstead, A. S. R. (1995). Behavioural characteristics and involvement in different types of traffic accident. *Accident Analysis and Prevention* ,27 , 571–581. DOI: 10.1016/0001-4575(95)00005-K
- Pelz, D. C., & Krupat, E. (1974). Caution profile and driving record of undergraduate males. *Accident, Analysis and Prevention*, 6, 45-58. DOI: 10.1016/0001-4575(74)90015-3
- Peña-Suarez, E., Padilla, J.L., Ventsislavova, P., Gugliotta, A., Roca, J., López-Ramón, M.F., & Castro, C. (2016) Assessment of proneness to distraction: English adaptation and validation of the Attention-Related Driving Errors Scale (ARDES) and cross-cultural equivalence. *Transportation Research Part F*, 43, 357–365. DOI: 10.1016/j.trf.2016.09.004
- Perlman, D., Samost, A., Domel, G., Mehler, B., Dobres, J.& Reymer, B. (2019). The relative impact of smartwatch and smartphone use while driving on workload, attention, and driving performance. *Applied Ergonomics*, 75, 8-16 DOI: 10.1177/1541931215591347
- Posner, M.I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*. 1980, 32 (1): 3–25. DOI: 10.1080/00335558008248231.
- Pradhan, A.K., & Crundall, D. (2017). Hazard avoidance in young novice drivers: definitions and a framework. In D. L. Fisher et al. (Ed.s) *Handbook of teen and novice drivers: Research, Practice, Policy and Directions*. Boca Raton, FL: CRC Press.
- Qu, W., Ge, Y., Zhang, Q., Zhao, W., & Zhang, K. (2015). Assessing dangerous driving behaviour during driving inattention: Psychometric adaptation and validation of the Attention-Related Driving Errors Scale in China. *Accident Analysis and Prevention*, 80, 172–177. DOI: 10.1016/j.aap.2015.04.009

- Quimby, A.R., & Watts, G.R., (1981). *Human Factors and Driving Performance*. Transport and Road Research Laboratory, Crowthorne, UK. LR1004. Downloaded from: <https://trl.co.uk/reports/LR1004>
- Ranney, T.A. (2008). *Driver distraction: A review of the current state-of knowledge DOT HS 810 787*. Washington, USA: National Highway Traffic Safety Administration.
- Reason, J.T., Manstead, A., Stradling, S., Baxter, J.S., & Campbell, K. (1990). Errors and violations on the roads: A real distinction? *Ergonomics*, 33, 1315–1332. DOI: 10.1080/00140139008925335
- Regan, M.A., Lee, J.D., & Young, K.L. (2008), *Driver Distraction: Theory, Effects, and Mitigation* (pp. 135-165). Boca Raton, FL: CRC Press Taylor & Francis Group.
- Regan, M.A., Hallett, C., & Gordon, C.P. (2011). Driver distraction and driver inattention: Definition, relationship and taxonomy. *Accident Analysis & Prevention*, 43(5), 1771-1781. DOI: 10.1016/j.aap.2011.04.008
- Regan, M., Triggs, T. J., & Godley, S. T. (2000). Evaluation of a novice driver CD-ROM based training program: A simulator study. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 44(11), 334-337. DOI:10.1177/154193120004401101
- Roca, J., Padilla, J. L., López-Ramón, M. F., & Castro, C. (2013). Assessing individual differences in driving inattention: Adaptation and validation of the attention-related to driving errors scale to Spain. *Transportation Research, Part F: Traffic Psychology and Behaviour*, 21, 42–51. DOI: 10.1016/j.trf.2013.09.001
- Rowe, R. M. (1997). *Anticipation in skilled performance*. Doctoral dissertation, University of Reading.
- Sagberg, F., & Bjørnskay, T. (2006). Hazard perception and driving experience among novice drivers. *Accident Analysis and Prevention*, 28(2), 407–414. DOI: 10.1016/j.aap.2005.10.014
- Salmon, P.M., Stanton, N.A., Walker, G.H., Baber, C., Jenkins, McMaster, R., & Young, M.S. (2008). What really is going on? Review of situation awareness models for individuals and teams. *Theoretical Issues in Ergonomics Science* 9(4):297-323 DOI: 10.1080/14639220701561775
- Salmon, P.M., Read, G.J.M., Beanland, V., Thompson, J., Filtness, A.J., Hulme, A., McClure, R., & Johnston, I. (2019). Bad behaviour or societal failure? Perceptions of the factors

- contributing to drivers' engagement in the fatal five driving behaviours. *Applied Ergonomics*, 74, 162-171; DOI: 10.1016/j.apergo.2018.08.008
- Schneider, W., & Shiffrin, R.M. (1977). Controlled and automatic human information processing: 1. Detection, search, and attention. *Psychological Review*, 84, 1-66. DOI: 10.1037/0033-295X.84.1.1
- Sundfør, H:B., Sagberg, F., & Høye, A. (2019). Inattention and distraction in fatal road crashes—Results from in-depth crash investigations in Norway. *Accident Analysis & Prevention*, 124, 152-157. DOI: 10.1016/j.aap.2019.02.004
- Stanton, N. A., Stewart, R., Harris, D., Houghton, R. J., Baber, C., McMaster, R., Green, D. (2006). Distributed Situation Awareness in dynamic systems: theoretical development and application of an ergonomics methodology. *Ergonomics*, 49, 12-13, 1288-1311. DOI: 10.1080/00140130600612762
- Stutts, J.C., Reinfurt, D.W., Staplin, L., & Rodgman, E.A. (2001). The role of driver distraction in traffic crashes. Downloaded from: [https://www.aaafoundation.org/sites/default/files/distraction%20\(1\).pdf](https://www.aaafoundation.org/sites/default/files/distraction%20(1).pdf)
- Taubman–Ben-Ari, O., Mikulincer, M., & Gillath, O. (2004). The multidimensional driving style inventory—scale construct and validation. *Accident Analysis & Prevention*, 36(3), 323-332.
- Thomas, P., Morris, A., Talbot, R., & Fagerlind, H. (2013). *Identifying the causes of road crashes in Europe*. In: Annals of the Association for Automotive Medicine, Annual Scientific Conference, 57, pp.1-10.
- Torralba, A., Oliva, A., Castelhana, M., & Henderson, J. (2006). Contextual guidance of eye movements and attention in real-world scenes: the role of global features in object search. *Psychological review*, 4(113), 766–786. DOI: 10.1037/0033-295X.113.4.766
- Underwood, G. (2007). Visual attention and the transition from novice to advanced driver. *Ergonomics*, 50, 8, 1235-1249. DOI: 10.1080/00140130701318707
- Underwood, G., Chapman, P., Brocklehurst, N., Underwood, J., & Crundall, D. (2003) Visual attention while driving: sequences of eye fixations made by experienced and novice drivers. *Ergonomics*; 46(6): 629–646. DOI:10.1080/0014013031000090116

- Underwood, G., Chapman, P., y Crundall, D. (2011). Driving simulator validation with hazard perception. *Transportation Research Part F: Traffic Psychology and Behaviour*, 14, 435-446. DOI: 10.1016/j.trf.2011.04.008
- Underwood, G.,A., & Underwood, J. (2013). Driving experience and Situation Awareness in hazard detection. *Safety Science*, 56, 29-35. DOI: 10.1016/j.ssci.2012.05.025
- Ventsislavova, P., Crundall, D., Baguely, T, Castro, C., Gugliotta, A., Garcia-Fernandez, P., Qiucheng, L., Ba, Y., & Zhang, W. (2019). A cross-cultural comparison of hazard perception and hazard prediction tests. *Accident Analysis and Prevention*, 122, 268-286 DOI: 10.1016/j.aap.2018.10.010
- Ventsislavova, P. & Crundall, D. (2018). The hazard prediction test: a comparison of free-response and multiple-choice formats. *Safety Science*, 109, 246-255. DOI: 10.1016/j.ssci.2018.06.004
- Ventsislavova, P., Gugliotta, A., Peña-Suarez, E., Garcia-Fernandez, P., Eisman, E., Crundall, D, & Castro, C. (2016). What happens when drivers face hazards on the road? *Accident Analysis and Prevention*, 91, 43-54. DOI: 10.1016/j.aap.2016.02.013
- Wells, P., Tong, S., Sexton, B., Grayson, G., & Jones, E., (2008). *Cohort II: A Study of Learner and New Drivers*. Department of Transport, DOT. London, UK. Young, K., Stephens, A.N., Logan, D.B & Lenné, M.G. (2017). Investigating the impact of static roadside advertising on drivers' situation awareness. *Applied Ergonomics*, 60, 136-145 DOI: 10.1016/j.apergo.2016.11.009
- Wetton, M. A. Hill, A., & Horswill, M. S. (2013). Are what happen next exercises and self-generated commentaries useful additions to hazard perception training for novice drivers. *Accident Analysis and Prevention*, 54, 57-66. DOI: 10.1016/j.aap.2013.02.013
- Yamani, Y., Samuel, S., Knodler, M.A., & Fisher, D.L: (2016) Evaluation of the effectiveness of a multi-skill program for training younger drivers on higher cognitive skills. *Applied Ergonomics*, 52, 135-141 Doi:10.1016/j.apergo.2015.07.005
- Young, A.H., Chapman, P. & Crundall, D. (2014). Producing a commentary slows concurrent hazard perception responses. *Journal of Experimental Psychology: Applied*, 20 (3),. 285-294. DOI: 10.1037/xap0000016
- Young, A.H., Crundall, D., & Chapman, P. (2017). Commentary driver training: effects of commentary exposure, practice and production on hazard perception and eye movements. *Accident Analysis & Prevention*, 101, 1-10. DOI: 10.1016/j.aap.2017.01.007

Young, K.L, Stephens, A.N, Logan, D.B., & Lenne, M.G. (2017). Investigating the impact of static roadside advertising on drivers' situation awareness. *Applied Ergonomics*, 60, 136-145. DOI: 10.1016/j.apergo.2016.11.009

ANNEX 1. ARDES (Attention-Related Driving Error Scale). Example of the 19 Likert-type items of the ARDES-UK* (Peña-Suárez, et al., 2016)

The following questionnaire describes situations that can happen unintentionally while a person is driving a vehicle. We ask you to indicate to what extent these things happen to you as a driver. To answer, mark with a cross (X) the number that fits your response in each situation using the scale below.

1=never or almost never; 2=Rarely; 3 Sometimes; 4 Often; 5 Always or almost always

1. Heading towards a known place, becoming distracted and then going several streets beyond it.	1 2 3 4 5
2. Signalling a manoeuvre but unintentionally making another (for example, switching on the indicator to turn one way but instead turning the other).	1 2 3 4 5
3. Being distracted when reaching a junction and as a result failing to see a car approaching the junction.	1 2 3 4 5
4. Suddenly realising that I'm lost or that I've taken the wrong road on a familiar route.	1 2 3 4 5
5. When arriving at a junction, instead of looking in the direction the traffic is coming from, looking in the other direction.	1 2 3 4 5
6. On arriving at a junction, not realising that a pedestrian is crossing the street.	1 2 3 4 5
7. Not realising there is an object or a car behind me and hitting it unintentionally.	1 2 3 4 5
8. Not realising that the vehicle in front has slowed down and having to brake sharply to avoid a collision.	1 2 3 4 5
9. Another driver sounding their horn because I'm distracted and haven't noticed that the traffic lights have changed to green.	1 2 3 4 5
10. Forgetting my lights are on full beam until another driver flashes their lights to warn me.	1 2 3 4 5
11. Forgetting for a brief moment Where I'm driving to.	1 2 3 4 5
12. Taking a roundabout route to arrive at a place I know how to get to.	1 2 3 4 5
13. Going through traffic lights when they've just turned red, not realising they had changed because I was blindly following the preceding traffic.	1 2 3 4 5
14. Trying to drive off and realising I'm not in first gear.	1 2 3 4 5
15. Intending to use one device but using another instead (for example, meaning to switch on the windscreen wipers and instead switching on the lights).	1 2 3 4 5
16. Leaving for one destination and suddenly realising I'm going somewhere else.	1 2 3 4 5
17. Due to distraction, realising that I haven't even noticed the traffic lights.	1 2 3 4 5
18. Unintentionally turning in the wrong place or going in the wrong direction	1 2 3 4 5
19. Unintentionally crunching the gears or going into an unsuitable gear.	1 2 3 4 5

Note: ARDES factors:

ARDES -Navigation Errors: Items, 3, 5, 6, 7, 8, 9, 13, 17

ARDES- Manoeuvring Errors : Items 1, 4, 11, 12, 16

ARDES- Control Errors: Items 2, 10, 14, 15, 19

Item excluded: 18

ANNEX II.. Detection, Caution in Decision Making and the three Hazard Prediction test Questions: Where?, What? and WHN?

HAZARD DETECTION QUESTION TO 24 HAZARDS

Question 1: Detection

Had you seen any hazard at the moment when the video was cut?
 No / Yes

CAUTION IN DECISION MAKING

Question 2: Cautiousness

What manoeuvre would you perform if you were the driver of the vehicle?
 Maintain same speed and direction
 Perform an evasive action
 (e. g. brake gradually)

3 HAZARD PREDICTION QUESTIONS: SITUATION AWARENESS

Question 3;Where?

Where was the hazard at the moment when the video was cut?
 Please use the photograph below to draw a cross (X) in the place where you consider the hazard appeared

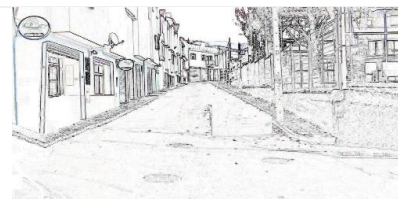


Figure 3. Clip 1 sketch example.

Question 4; What?

What is the hazard?

- A. The white pickup on the right
- B. The car that appears on the left
- C. Intersection with poor visibility

Question 5: WHN?

What might happen next in the traffic scene?

- A. The car would reverse
- B. The white pickup would reverse
- C. The car would continue forward