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# How are distractibility and hazard prediction in driving related? Role of driving experience as moderating factor

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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.

## 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 et al., 2008; Louveton et al., 2006; Perlman et al., 2019), demonstrating the inability of drivers to successfully execute two tasks simultaneously (Regan et al., 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 et al., 2013; Klauer et al., 2006; NHTSA, 2009; Ranney, 2008; Regan et al., 2011; Stutts et al., 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 and Mouloua, 2019; Salmon et al., 2019; Sundfør et al., 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 and Divekar, 2016; Lee et al., 2016). Even the use of internal imagery can distract from hazard detection (Briggs et al., 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 and Horswill, 2004). This could be produced by distraction, which is understood to be what occurs when drivers no longer pay

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attention to the critical driving tasks but dedicate their attention to an alternative/simultaneous task that is competing with the prior one (Regan et al., 2011). For example, according to Thomas et al. (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 e al., 2004). 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 et al., 2010; Ledesma et al., 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 et al., 1990; Parker et al., 1995) and the Multidimensional Driving Style Inventory (MDSI; Taubman–Ben-Ari et al., 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 et al. (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 et al., 2015), the UK (Peña-Suarez et al., 2016) and the USA (Barragan et al., 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 succefully 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 et al., 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 et al., 2010; Crundall et al., 2012; McKenna and Crick, 1991; Pradhan and Crundall et al., 2017). Therefore, the worrying road accident figures could decrease if HP were improved through training.

As a first model of HP tests, Pelz and 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 and 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 et al., 2010; Regan et al., 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 et al., 2010; Chapman and Underwood, 1998; Sagberg and Bjørnskau, 2006; Underwood, Ngai & Underwood, 2013).

In order to avoid the above-mentioned Hazard Perception test weaknesses, Jackson et al. (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. Hovewer, 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).

## 2. 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).

## 3. Method

### 3.1. 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).

### 3.2. Materials

#### 3.2.1. 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 (see Table 1).

#### 3.2.2. 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 0.76 for the Manoeuvring Errors factor, 0.57 for the Control Errors factor and 0.67 for the Navigation Errors factor.

#### 3.2.3. 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 1920 × 1080 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 202 × 114cm was used, the projection size being 200 × 112.5 cm. This size is suitable for projections up to 4.5 m.

These situations depicted different obstacles on the road that could

**Table 1**
Demographics of participants by groups.

| | Novice<br>N = 35 | Experienced<br>N = 60 | Total<br>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*) |

**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. |

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 s. A short description of the videos is shown in Table 3.

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 $\alpha$ takes acceptable values of 0.82 for Detection, 0.83 for Cautiousness and 0.78 for Situation Awareness (see Horswill and McKenna, 2004).

### 3.3. Procedure

Participants completed the experiment in groups sitting at a distance of between 3 and 4.5 m 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 nº 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.

### 3.4. 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,

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

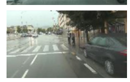
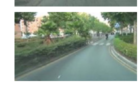
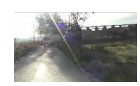
| Nº | Video clip content | *Time (sec)* | Last sketch prior to the clip occlusion | Nº | Video clip content | *Time (sec)* | Last sketch prior to the clip occlusion |
|---|---|---|---|---|---|---|---|
| **1** | In an urban street where the visibility is reduced, a car reverses towards an intersection (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 |  |

**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** | **Mean** | **15.20** | **.50** | .45 | .45 | .35 | **1.26** | **1.76** | 1.83 | 1.78 | 1.71 |
| **(N = 35)** | *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.

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 and Hochberg, 1995). All statistical analyses were performed using IBM SPSS Statistics v20 for Windows.

## 4. Results

### 4.1. 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 (0.50) than experienced drivers (0.68) and they obtained a lower score in Situation Awareness (Total = 1.26, What = 0.45 Where = 0.45, WHN = 0.35) than experienced drivers (Total = 1.49, What = 0.54 Where = 0.54, WHN = 0.43).

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.

### 4.2. 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 (−0.475), the WHN question (−0.396), and TOTAL Situation Awareness (−0.383). All of them correlates negatively with this ARDES Manoeuvering factor.

**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 coefficients | | Standardised coefficients | *T* | *p-value* |
|---|---|---|---|---|---|
| | *B* | SE | Beta | | |
| (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.

### 4.3. 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.

#### 4.3.1. 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 0.141. 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 0.202.

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 (Fig. 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 0.225, 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

**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.

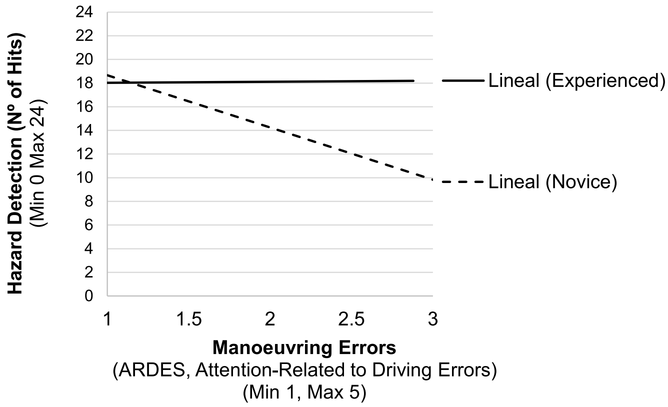



**Fig. 1.** Regression equation for novices and experienced drivers.

case of experienced drivers, on the other hand, the Manoeuvring Errors score obtained has no predictive value.

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 0.225, for experienced drivers is almost 0.

*4.3.2. 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 0.071 (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 signficant ($F$ (3,91) = 4.421, $p$ = .006), with an $R^2$ of 0.127.

The average score predicted for participants in Situation Awareness equalled 1.871, Specifically, −0.344* (Manoeuvring Errors) −0.546* (Driving Experience) + 0.439* (Manoeuvring Errors x Driving Experience). The effect of moderation means the regression equation for novices and experienced drivers is different (Fig. 2): in novices, Situation Awareness diminishes by −0.344 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 0.147, whereas this value for experienced drivers is 0.012.

Ultimately, self-reported proneness to Manoeuvring Errors

**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 coefficients | | Standardised coefficients | *T* | *p-value* |
|---|---|---|---|---|---|
| | *B* | SE | Beta | | |
| **(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.

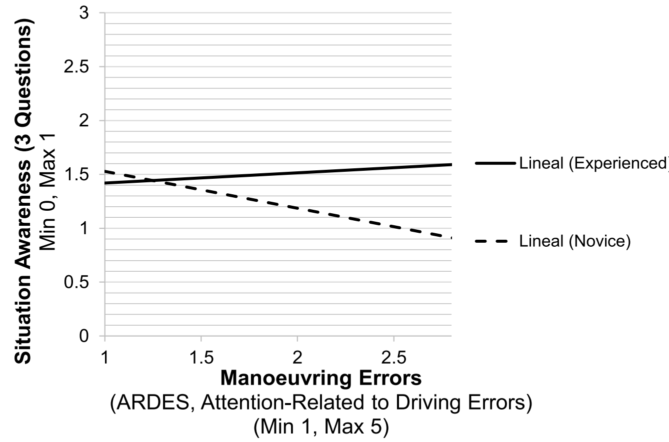



**Fig. 2.** Regression equation for novices and experienced drivers.

(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.

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

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 0.147, for experienced drivers is 0.012.

## 5. 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 inattentional errors than more experienced drivers. Novice drivers' processing capacity of selective attention is overloaded in numerous situations (Schneider and 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 et al., 2014; Crundall, 2016; Gugliotta et al., 2017; Ventsislavova et al., 2016, 2018; 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 upcoming 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 et al., 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 et al., 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 maintenanace training and/or teaching novice drivers to anticipate latent hazards, Yamani et al., 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 et al., 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 et al., 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.

## 6. 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, inexpert 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 et al., 2011; McKenzie and 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 and 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 automatisation 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 et al., 2008; 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 et al., 2014; Young et al., 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 and Crick, 1991; Mills et al., 1996). Recently, Hill et al. (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 and AuthorAnonymous, 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.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.apergo.2019.102886.

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