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Motorcycle rider error and engagement in distracting activities: A study using the Attention-Related Driving Errors Scale (ARDES-M)

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A R T I C L E I N F O

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A B S T R A C T

Research on motorcycle rider distraction and inattention is limited, especially when compared to that on car drivers. This study examines motorcycle rider error and its relationship with engagement in distracting activities. Additionally, it provides an adaptation of the Attention-Related Driving Errors Scale for use with motorcycle riders (ARDES-M). A sample of 418 motorcyclists responded to a web questionnaire consisting of the ARDES-M, a self-report measure of Involvement in Distracting Activities (IDA), a measure of everyday inattention (ARCES, Attention Related Cognitive Errors Scale) and socio-demographic and riding-related questions. Riding errors were associated with a higher level of engagement in distracting activities and a greater propensity for inattention in daily life. ARDES-M scores were associated with various types of self-reported traffic crashes and near-crashes, while self-reported distractions (IDA) were only linked with near-crashes. The most widely self-reported distracting activities were using map navigation, listening to the radio or to music and adjusting vehicle devices. The various uses of cell phones were relatively minor. Young riders reported higher levels of engagement in distracting activities and committing more riding errors. The ARDES-M showed good psychometric properties for the sample in Spain.

1. Introduction

Among road users, motorcyclists are one of the most vulnerable groups, representing 28% of all road incident fatalities worldwide (WHO, 2018). In Spain, the involvement of motorcyclists in road crashes resulting in fatalities and hospitalizations increased steadily between 2011 and 2020, from 22% to 31% (DGT, 2021). In 2020, although motorcyclists made up just 10% of the vehicular fleet, they were involved in 27% of the road crashes with victims ($n = 20050$) (DGT, 2021). In Spain, the majority of motorcycle users are men (85%) and adults between the ages of 30 and 54; motorcycle users under the age of 20 represent less than 2% of all motorcyclists (DGT, 2022). The minimum age to obtain a license is 15 for mopeds and 16 for lightweight motorcycles. Lightweight motorcycles (75 to 125 cc) are the most popular in the country, especially the scooter type. In 2022, the five best-selling models were of this type (Anesdor, 2022). Because of their growing use and their involvement in road crashes, national plans have been developed specifically for motorcyclists (DGT, 2019), including actions focused on education, social communication, law enforcement, improvements in vehicles and protective equipment, infrastructure and research.

Research to better understand the behaviour of motorcyclists is critical to the design and evaluation of interventions specifically targeted to this population (Sakashita et al., 2014). Psychological research has provided results in diverse areas of road safety for motorcyclists, including helmet use, speeding, conspicuity and visibility, alcohol and alertness (Yousif et al., 2020). Specific lines have also been developed on risky behaviours; for example, the studies based on the Motorcycle Rider Behaviour Questionnaire (Bui et al., 2020; Chouhan et al., 2021; Coelho et al., 2012; Elliott et al., 2007; Motevalian et al., 2011; Sakashita et al., 2014; Stephens et al., 2017; Sumit et al., 2021; Uttra et al., 2020). Nonetheless, the broad consensus is that research on motorcyclists remains scarce and is comparatively much less than that on car drivers. Of course, driving a car and a motorcycle are significantly different, and

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this is the reason why specific research and methodologies adapted to this population are needed.

Driver distraction and inattention has been a growing area of study in recent decades due in part to the increased use of in-vehicle information systems and communication technologies. Distractions negatively impact driving performance, thus contributing to road crashes (Beanland et al., 2013; Guo et al., 2017; Sundfør et al., 2019; Wundersitz, 2019). A distracted driver can neither adequately operate a vehicle nor adjust to changing traffic conditions. Degraded lane keeping performance, speed control, reaction time, situational awareness and visual scanning are some of the documented effects of distractions (Cunningham and Regan, 2018). Although the negative impact of distractions on driving is well known, it continues to be a road safety problem. According to DGT (2021) data, over the past six years, distractions have been the leading human factor in crashes resulting in fatalities (e.g., in 2021, they were present in 32% of all cases, above both alcohol consumption and speeding).

Research has focused mainly on identifying the sources of distraction, their effects on driving performance and mitigation strategies for car drivers (Cunningham and Regan, 2018; Stutts et al., 2005). Motorcyclists have been studied to a lesser extent, and it is clear they have significant differences with car drivers. For example, some common distractions in cars are improbable on motorcycles, such as adjusting music or controls, applying makeup, handling children or pets, conversing with a passenger, eating or drinking, etc. Additionally, in-vehicle information is less developed for motorcycles. Studies on the effects of distractions on motorcyclists focus mainly on cellphone use, its prevalence, and associated factors (e.g., Gupta et al., 2022; Nguyen et al., 2020; Pérez-Núñez et al., 2014; Rusli et al., 2020; Truong et al., 2019; Widyanti et al., 2020). It is interesting to note that even for this specific behaviour, the associated factors also seem to differ between motorcyclists and car drivers. For example, one study in Vietnam analyzed the factors associated with a mobile phone while driving/riding (Nguyen-Phuoc et al., 2020). It found that problematic cellphone use was the main predictor among drivers, while attitudes and beliefs was the main predictor among riders.

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

A specific line of research on driver distraction and inattention has been developed based on the Attention-Related Driving Errors Scale (ARDES) (Ledesma et al., 2010). ARDES is a self-report instrument that assesses driving errors associated primarily or secondarily with a lack of attention. The construct is essentially conceived as unidimensional (only one latent factor), and the responses to the items are summed into a global score, with higher scores reflecting a greater propensity for error. Some studies (Barragán et al., 2016; Gresham et al., 2021; Ledesma et al., 2015) suggested that ARDES's items could be grouped according to the level of the driving task where they occur (i.e., navigation, manoeuvring and control level) (Michon, 1985), indicating that a three-factor structure fits well with the data. But even in these studies, unidimensionality is considered a plausible internal structure. Currently, researchers are undertaking a systematic, transcultural analysis of the ARDES' factorial structure and its invariance across different countries (Castro et al., 2022).

Evidence of validity for the ARDES has been obtained for populations of car drivers in several countries, including Argentina (Ledesma, et al., 2010; Ledesma et al., 2015), Spain (Castro et al., 2019; Roca et al., 2013), China (Qu et al., 2015), the UK (Peña-Suárez et al., 2016) and the USA (Barragán et al., 2016; Gresham et al., 2021). Overall, results from the validation studies indicate that ARDES measures have good psychometric properties and theoretical appropriate correlation patterns with external criteria. Although in a differentiated manner for each country, ARDES scores have been associated with several types of self-reported traffic crashes (e.g., Ledesma et al., 2010; Peña-Suárez et al., 2016; Qu et al., 2015; Roca et al., 2013), traffic tickets (Barragán et al., 2016; Ledesma et al., 2010), and measures of risky driving behaviours, such as the Driving Behaviour Questionnaire in a USA study (Gresham et al., 2021), and the Dula Dangerous Driving Index (Dula and Balard, 2003) in China (Qu et al., 2015). This evidence suggests that the ARDES evaluates attention-related driving errors as a factor that is capable of impacting driving safety.

Previous studies with ARDES reported evidence of validity based on relationships with other variables. For example, the ARDES was correlated with the Attention Related Cognitive Errors Scale (ARCES, Cheyne et al., 2006), a measure of everyday cognitive failures that result from attention lapses. This correlation has been consistent across various studies, with *r* values of 0.73 in Argentina (Ledesma et al., 2010), 0.60 in China (Qu et al., 2015), 0.59 in Spain (Valero-Mora et al., 2015), 0.55 in an adult population and 0.29 in an adolescent population in the USA (Barragán et al., 2016; Gresham et al., 2021). Correlations with other theoretically related measures were also obtained. For example, the ARDES has been correlated with mindfulness measures (e.g., Gresham et al., 2021; Knight, 2018; Ledesma et al., 2010; Qu et al., 2015; Valero-Mora et al., 2015) and cognitive errors in daily life (Gresham et al., 2021).

In a driving simulation study, Valero-Mora et al., (2015) found that high ARDES scores were associated with poor task performance (e.g., r correlation $= -0.32$ with lateral control). Moreover, ARDES scores were related to performance in a Hazard Prediction test, where participants had to report what happened next in a series of video clips that cut to black just as the hazards started to develop (Castro et al., 2019). Novice drivers that self-reported more attention-related errors were less able to detect the hazards. Studies have also reported a relationship between the ARDES and performance-based attention measures. Gresham et al., (2021) found that higher ARDES scores were related to decreased performance on the Continuous Performance Test. In another study, Montes et al., (2016) reported that higher ARDES scores were associated with poor performance on a visual selective attention task.

Prior studies did not show consistent differences in ARDES scores by socio-demographic variables. No differences were found in terms of sex and educational level in validation studies conducted in Argentina (Ledesma et al., 2010), China (Qu et al., 2015), Spain (Roca et al., 2013) and the UK (Peña-Suárez et al., 2016). Only a USA study (Barragán et al., 2016) found differences by sex and education, with higher scores among women and those with a lower education level. Some studies found a weak and negative relationship with age, but this was not significant when controlled for years of driving experience (Barragán et al., 2016; Montes et al., 2016; Qu et al., 2015; Roca et al., 2013). Further, the relationship with driving experience is not consistent across studies. Ledesma et al., (2010) found no association with driving experience, but other studies show a slight relationship between driving experience and the ARDES after controlling for age (Gresham et al., 2021; Peña-Suárez et al., 2016; Qu et al., 2015). A study in China even found a negative relationship (Qu et al., 2015), while one in the UK found a positive relationship (Peña-Suárez et al., 2016). These differences could be because of cultural factors, but also because of differences in research design (e.g., differences in the composition of the samples).

There is only one prior study that applied the ARDES to a population of motorcyclists, and that study was conducted in Argentina (Nucciarone et al., 2012). This research resorted to an adapted version of the ARDES, preserving several of the original items but also adding new items for motorcyclists. The adapted scale, referred to as ARDES-M (ARDES for motorcyclists), was administered to a sample of 110 motorcyclists. The results showed psychometric properties for ARDES-M that were very similar to those of the original version for car drivers. A one-factor solution emerged from the results of an Exploratory Factor Analysis. ARDES-M showed a good level of internal consistency (Cronbach's alpha $= 0.80$) and a weak correlation with a social desirability measure. It also correlated with the ARCES ($r = 0.40$), and higher scores were observed among those who reported critical safety events and collisions, although the differences were not significant in all cases.

Previous studies that have used the ARDES suggest it measures a personal tendency to commit driving errors, which is explained mainly by a driver's internal factors (personality traits and cognitive functioning). Nonetheless, it is logical to assume that those who engage in distracting activities also commit more driving/riding errors. However, Ledesma et al., (2015), which studied drivers, failed to find this relationship and concluded that the errors measured by ARDES are relatively independent of the degree of involvement in distracting activities, and that the latter are better explained by a driver's internal factors. On the other hand, Nucciarone et al., (2012), which studied motorcyclists, found that ARDES-M correlated moderately (r = 0.40) with rider's engagement in distracting activities. It is possible that distractions have a greater impact on the task of riding a motorcycle than on driving a car. In any case, it seems that further research is necessary on the role distractors play in producing riding errors that, over the long term, can lead to critical safety events.

This study seeks to contribute to the literature on motorcycle rider inattention and distractions. Its first objective was to adapt the original ARDES-M and to provide validity evidence of ARDES-M for the Spanish context. Its **s**econd objective was to analyse the relationship between engagement in distracting activities and self-reported riding errors as measured by ARDES-M. We hypothesize that involvement in distracting activities will be associated with higher riding errors. The third objective was to analyse the associations of errors and distractions while riding with self-reported crashes and near-crashes. It is expected that those who report higher levels of error and engagement in distracting activities will also report higher involvement in road incidents. Lastly, the study explores differences in riding errors and distractions according to sex, age, riding experience, frequency of motorcycle use, and motorcycle engine size.

2. Methods

2.1. Participants

Four hundred and eighteen Spanish motorcyclists participated in the study. The age of the participants ranged from 18 to 81 years (M = 39.45, SD = 13.74); 40.4% were in the 18–29 age group, 21.6% in the 30–44 age group, and 38% were above 44 years of age. Women accounted for 31% of the sample. 2% of participants attained a primary level education, 48% a secondary level education and pre-university studies, and 50% university level studies. Most participants rode motorcycles regularly (43% every day or almost every day; 31% a couple of times a week). In terms of driving experience, 78% had ridden a motorcycle for more than 3 years, 17% between 1 and 3 years, and 5% less than a year. Participant distribution in terms of motorcycle engine size was 50 cc (19%), 51–125 cc (36%), 126–500 cc (21%), and >500 cc (24%).

2.2. Measures

2.2.1. Attention-Related Driving Errors Scale for Motorcyclists (ARDES-M)

ARDES-M is a 22-item self-report measure of individual differences in driving inattention. This scale was originally developed for car drivers and called ARDES (Ledesma et al., 2010); the original ARDES has already been adapted to Spain's language and context (Roca et al., 2013). Later, the scale was adapted for motorcyclists in Argentina (Nucciarone et al., 2012). The scale asks participants to read each item and indicate the frequency with which they experience the situation described using a 5-point scale, ranging from (1) never or almost never to (5) always or almost always. In the original Argentine sample, the ARDES-M measure had a Cronbach's alpha value of 0.80, 95% CI [0.74, 0.85]. It should be noted that although the original ARDES-M is in the same language (Spanish), there are several differences between Argentina and Spain in terms of the vocabulary and expressions used. There are also differences in driving habits and road culture that should be considered when adapting an assessment instrument (ITC, 2017). An expert-appraisal method was used to obtain an appropriate and culturally relevant version of ARDES-M for motorcyclists in Spain (see Appendix A).

2.2.2. Attention Related Cognitive Errors Scale (ARCES)

ARCES is a 12-item scale that assesses everyday cognitive failures that result from attentional lapses (Cheyne et al., 2006). It includes failures associated with inadequate monitoring of highly familiar everyday tasks (example item: "I have absent-mindedly placed things in unintended locations - e.g., putting milk in the pantry or sugar in the fridge -"). ARCES employs a 5-point scale, ranging from (1) never to (5) very often. The total score is obtained by adding all item scores (the higher the score, the higher the level of everyday inattention). For this study, we used the revised version of the ARCES (Carriere et al., 2008). Cronbach's alpha in the current sample was 0.90, 95% CI [0.89, 0.91].

2.2.3. Involvement in Distracting Activities (IDA)

A questionnaire on engagement in distracting activities while driving was administered (Ledesma et al., 2015). The questionnaire covered the following activities: answering phone calls; making phone calls; reading/listening to a message; texting or recording a message; checking the phone for new messages/notifications; checking social media networks on a smartphone; adjusting a motorcycle device or accessory (e.g., a mirror); using GPS / map navigation; and listening to the radio or to music. Participants were asked how often they engaged in these activities over the previous two weeks on a response scale ranging from (1) never or almost never to (5) always or almost always. To simplify the analysis, the item scores were added up into a total score that was labelled Involvement in Distracting Activities (IDA). Cronbach's alpha in the current sample was 0.82, 95% CI [0.79, 0.84].

2.2.4. Socio-demographic variables

A structured questionnaire was developed to obtain socio-demographic data and variables related to motorcycle use, including sex, age, educational attainment, years of riding experience, frequency of motorcycle use, motorcycle engine size, and motor vehicle collisions and near-crashes over the past 12 months.

2.3. Procedure

An on-line questionnaire was administered using the Unipark software (QuestBack, 2019). Participant recruitment was undertaken by the online panel provider Netquest, which meets quality requirements for this service (ISO 26362). After given informed consent, participants completed the battery of questionnaires (ARDES-M, ARCES, IDA and Socio-demographic and driving habits questionnaire). On average, participants took 10.8 min to answer the survey questionnaire (SD = 6.1).

The ARDES-M's internal structure was explored via Exploratory Factor Analysis (EFA) as recommended by Ledesma et al., (2021). EFA was conducted with the FACTOR software (Lorenzo-Seva and Ferrando, 2006). The model was estimated with Unweighted Least Squares (ULS) using the polychoric inter-item correlation matrix as input data. The correlation matrix's factorability was examined as an initial step by inspecting the determinant of the matrix, the Bartlett's statistic, and the Kaiser-Meyer-Olkin (KMO) test. Multiple criteria were used to determine the number of factors, including statistical methods (MAP, Parallel Analysis and Hull's method), visual inspection of the Scree plot, interpretability of the factor/s, and variance accounted for by the factor/s. Factor-loadings above 0.50 were considered acceptable for item-retention. The scale's internal consistency was estimated using the Cronbach's Alpha coefficient. The Spearman's rank correlation coefficient was computed to estimate the strength of the relationship between ARDES-M, IDA and ARCES. The Kruskal-Wallis H test was used to compare ARDES-M scores between those with involvement in traffic

Table 1
ARDES-M (Attention-Related Driving Errors Scale for Motorcyclists) items. Factor analysis and descriptive statistics.

ARDES-M's items	M	SD	Median	Skewness	Kurtosis	Factor-loading	Corrected item-scale correlation
1. Be "on autopilot" and make a dangerous maneuver without realizing it	1.49	0.70	1	1.30	1.02	0.45	0.36
2. Make a maneuver (accelerate, brake, turn…) and surprise myself because it was not what I had really wanted or intended to do	1.44	0.64	1	1.29	0.94	0.62	0.46
3. I unintentionally hit an object or vehicle behind me because I didn't realize it was there	1.32	0.60	1	2.09	5.20	0.64	0.48
4. For a brief instant, I forget where I am riding to	1.67	0.81	1	0.97	0.03	0.57	0.49
5. I head out to a destination and suddenly realize I'm going the wrong way	1.72	0.84	1	0.82	−0.39	0.67	0.55
6. Unintentionally make a wrong turn or head the wrong way down a one-way street	1.48	0.70	1	1.43	1.67	0.62	0.49
7. At a street corner, I fail to notice that a pedestrian is crossing the street	1.61	0.66	2	0.66	−0.38	0.61	0.49
8. When at an intersection, I get distracted and fail to see a vehicle coming the other way	1.51	0.62	1	0.87	0.03	0.77	0.61
9. I realize that I've run a traffic light because I got distracted.	1.49	0.64	1	1.07	0.53	0.68	0.54
10. Suddenly, I realize I'm lost or took the wrong route when riding to a known destination	1.45	0.73	1	1.60	1.88	0.71	0.59
11. Run out of gas on the road	1.15	0.42	1	2.92	8.12	0.53	0.30
12. Another driver honks at me because I've failed to realize that the traffic light has turned green	1.50	0.65	1	1.08	0.44	0.53	0.42
13. I signal a maneuver but unintentionally make another (for example, I turn on the right-turn signal, but turn left instead)	1.29	0.53	1	1.78	2.84	0.66	0.46
14. I fail to notice that the vehicle in front of me has slowed down, and I have to brake abruptly to avoid a crash	1.86	0.79	2	0.69	0.29	0.69	0.59
15. While driving, forget what gear I'm in (second, third, fourth…)	1.79	0.97	1	0.95	−0.20	0.46	0.39
16. When riding to a familiar place, I unintentionally ride past it because I was not paying attention	1.69	0.75	2	0.85	0.10	0.66	0.56
17. Without meaning to, make a maneuver that causes the motorcycle to lose stability	1.42	0.62	1	1.52	2.83	0.74	0.59
18. Because of a distraction, fail to notice a speed bump or a pothole	1.87	0.76	2	0.55	0.02	0.64	0.52
19. When at an intersection, instead of looking in the direction of oncoming traffic, I look in the opposite direction	1.45	0.67	1	1.53	2.53	0.72	0.58
20. When riding somewhere, I take a longer route than necessary	2.02	0.89	2	0.64	−0.09	0.61	0.54
21. Following the traffic in front of me, I unintentionally ride through a traffic light that has just turned red	1.85	0.88	2	0.79	−0.06	0.59	0.51
22. When starting to move forward, forget to lift up the kickstand	1.39	0.70	1	1.92	3.29	0.54	0.40

Note. Extraction method: Unweighted Least Squares (ULS); Type of inter-item correlation matrix: polychoric. Determinant of the matrix = 0.00001; Bartlett's statistic = 4704.7 (df = 231; p < 0.001); Kaiser-Meyer-Olkin (KMO) test = 0.92 (very good); Variance accounted for by the factor: 42%.

Table 2
Response percentages for IDA (Involvement in Distracting Activities) items and correlations with the ARDES-M (Attention-Related Driving Errors Scale for Motorcyclists).
IDA's Items

IDA's items	Never or almost never	Rarely	Sometimes	Often	Always or almost always	M	SD	Correlation with ARDES-M (Spearman's Rho)
1. Use a navigator (GPS, Google Maps) to orient myself while driving	24.4	27.5	30.1	15.1	2.9	2.44	1.10	0.26**
2. Listen to the radio or music on an electronic device	45.7	9.6	15.1	19.4	10.3	2.39	1.47	0.16**
3. Adjust an element of the motorcycle, such as the mirrors or accessories	19.9	38.8	28.2	11.0	2.2	2.37	0.99	0.32**
4. Focus attention on the motorcycle's indicators for a prolonged period of time (for example, the gas or oil gauge)	37.6	42.6	12.9	5.3	1.7	1.91	0.92	0.25**
5. Answer a telephone call while driving	57.9	19.6	12.7	5.3	4.5	1.79	1.13	0.16**
6. Make a telephone call while driving	64.8	17.0	11.2	5.0	1.9	1.62	0.99	0.20**
7. Read or listen to a cellphone message	66.3	20.8	9.1	3.6	0.2	1.51	0.82	0.30**
8. Write a text message or send an audio message on a cellphone	71.3	17.0	7.7	3.8	0.2	1.45	0.81	0.26**
9. Check the telephone to see if there is something new (messages, notifications)	75.6	13.6	7.4	3.1	0.2	1.39	0.77	0.35**
10. Check social media networks	94.7	2.6	1.7	0.7	0.2	1.09	0.43	0.23**

Note. ** $p < 0.01$.

incidents and those without. In this case, effect sizes for non-parametric tests were computed (Lenhard and Lenhard, 2016). The same procedure was used to compare ARDES-M and IDA scores by age, sex, years of motorcycle riding experience, and motorcycle type.

3. Results

3.1. Factor analysis and reliability of the ARDES-M

Evidence of factorability for the polychromic correlation matrix was obtained (matrix determinant = 0.00001; Bartlett's statistic = 4704.70 [df = 231; $p < 0.001$]; and Kaiser-Meyer-Olkin [KMO] test = 0.92). Parallel Analysis, MAP, Hull's test, and Scree-Plot suggested a one-factor

Table 3
Response percentages for ARCES (Attention Related Cognitive Errors Scale) items and correlations with the ARDES-M (Attention-Related Driving Errors Scale for Motorcyclists).

ARCES's items Original Item / *item in Spanish*	Never	Rarely	Sometimes	Often	Very often	M	SD	Correlation with ARDES-M (Spearman's Rho)
1. I have gone into a room to get something, got distracted, and wondered what I went there for/ *Entrar a una habitación para buscar algo, distraerme y salir* sin *lo que fui a buscar*	12.0	31.1	38.3	17.2	1.4	2.65	0.94	0.52**
2. I have to go back to check whether I have done something or not (e.g., turning out lights, locking doors) / *Tener que volver para comprobar si he hecho algo o no (por ejemplo, apagar las luces o cerrar las puertas)*	12.9	30.6	40.7	12.4	3.3	2.63	0.97	0.38**
3. When reading I find that I have read several paragraphs without being able to recall what I read / *Estar leyendo y darme cuenta de que he leído varios párrafos* sin *poder recordar lo que he leído*	17.9	27.5	34.9	17.0	2.6	2.59	1.04	0.43**
4. I go into a room to do one thing (e.g., brush my teeth) and end up doing something else (e.g., brush my hair) / *Entrar a una habitación a hacer una cosa y terminar haciendo otra diferente (por ejemplo, ir al baño a buscar algo y terminar lavándome las manos)*	19.1	30.6	32.3	17.5	0.5	2.50	1.01	0.46**
5. I have lost track of a conversation because I zoned out when someone else was talking / *Perder la noción de la conversación por desconectar cuando alguien está hablando*	17.5	32.1	36.6	12.7	1.2	2.48	0.96	0.51**
6. I begin one task and get distracted into doing something else / *Estar haciendo una tarea, distraerme y terminar haciendo otra cosa*	17.7	34.0	34.2	12.7	1.4	2.46	0.97	0.51**
7. I make mistakes because I am doing one thing and thinking about another / *Cometer un error por hacer una cosa mientras estoy pensando en otra*	16.3	38.5	38.8	6.0	0.5	2.36	0.84	0.52**
8. I fail to see what I am looking for even though I am looking right at it / *Estar buscando algo y darme cuenta de que lo tenía delante de mis ojos*	17.7	41.9	30.4	9.1	1.0	2.34	0.90	0.46**
9. I have gone to the fridge to get one thing (e.g., milk) and taken something else (e.g., juice) / *Abrir el frigorífico para coger una cosa (por ejemplo, leche) y coger otra (por ejemplo, zumo)*	35.6	33.3	25.8	4.5	0.7	2.01	0.93	0.44**
10. I have absent-mindedly mixed up targets of my action (e.g., pouring or putting something into the wrong container) / *Por estar distraído, puedo cometer pequeños "deslices" en mis acciones (por ejemplo, verter o poner algo en el recipiente equivocado)*	34.0	45.0	19.1	1.7	0.2	1.89	0.78	0.49**
11. I have absent-mindedly misplaced frequently used objects, such as keys, pens, glasses, etc / *Me cuesta encontrar objetos de uso diario como llaves, bolígrafos, gafas, etc.*	44.0	32.8	16.5	5.0	1.7	1.88	0.97	0.39**
12. I have absent-mindedly placed things in unintended locations (e.g., putting milk in the pantry or sugar in the fridge) / *Por estar distraído, poner cosas en lugares equivocados (por ejemplo, poner la leche en el mueble de la cocina o el azúcar en el frigorífico)*	44.3	33.3	16.5	5.7	0.2	1.84	0.91	0.47**

Note. $^{**}p < 0.01$.

solution. All 22 items had factor-loadings over 0.40 (range: 0.45 to 0.77, see Table 1) on this single factor, which accounted for 42% of the total variance. The internal consistency of ARDES-M scores was high, Cronbach's alpha: 0.89, 95% CI [0.87, 0.90]. Item-test correlations were greater than 0.40 in 86% of the items, ranging from 0.30 to 0.61.

3.2. Relationships between ARDES-M, IDA and ARCES measures

Table 2 shows the response percentages for the various distracting activities that were evaluated, as well as the means and correlation of each item with the ARDES-M. The activities are ordered by mean such that the most frequent appear at the top of the table: use of navigators or maps; listening to the radio or to music; and adjusting an element of the motorcycle, such as a mirror. The various forms of cellphone use were relatively minor, with "Answer a telephone call while driving" being the most widely reported, and "Check social media networks" the least.

For all distracting activities, weak to moderate correlations were observed with the ARDES-M (from 0.16 to 0.35). The highest correlation

Table 4
ARDES-M (Attention-Related Driving Errors Scale for Motorcyclists) scores for different types of traffic events.

		N	Mean	SD	Average range	Kruskal-Wallis H test	Effect size
Type of event							
Crash with another vehicle in motion	*Yes*	28	37.43	8.31	256.41	4.533*	0.18
	No	390	34.23	8.79	206.13		
Crash with a fixed object or a stopped vehicle	*Yes*	20	39.40	8.48	281.78	7.531**	0.25
	No	398	34.20	8.74	205.87		
Lose control of the motorcycle	*Yes*	90	37.02	9.38	246.09	10.538***	0.30
	No	328	33.74	8.50	199.46		
Sudden maneuver	*Yes*	220	36.78	9.44	241.08	31.798***	0.56
	No	198	31.86	7.20	174.41		
Consequence of event							
Material damages	*Yes*	73	37.03	9.35	244.21	7.314*	0.24
	No	345	33.90	8.58	202.16		
Human injury	*Yes*	20	40.65	10.08	286.48	8.542**	0.27
	No	398	34.14	8.62	205.63		
No damages (near-crashes)	*Yes*	142	37.40	9.92	247.10	20.861***	0.44
	No	276	32.93	7.74	190.16		

Note. $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

Table 5
IDA (Involvement in Distracting Activities) scores and self-reported traffic collisions.

		N	Mean	SD	Average range	Kruskal-Wallis H test	Effect size
Type of event							
Crash with another vehicle in motion	*Yes*	28	19.21	7.71	221.07	0.276*	0.08
	No	390	17.87	5.90	208.67		
Crash with a fixed object or a stopped vehicle	*Yes*	20	17.80	4.86	220.00	0.159*	0.09
	No	398	17.96	6.04	208.97		
Lose control of the motorcycle	*Yes*	90	18.59	6.08	222.93	1.422*	0.06
	No	328	17.78	6.02	205.82		
Sudden maneuver	*Yes*	220	18.93	6.36	229.90	13.300***	0.34
	No	198	16.88	5.47	186.83		
Consequence of event							
Material damages	*Yes*	73	17.96	5.74	212.09	0.041*	0.09
	No	345	17.96	6.11	208.95		
Human injury	*Yes*	20	19.25	6.85	229.55	0.581*	0.06
	No	398	17.89	5.99	208.49		
No damages (near-crashes)	*Yes*	142	19.36	6.62	236.29	10.612**	0.30
	No	276	17.24	5.59	195.72		

*$p > 0.05$; **$p < 0.01$; ***$p < 0.001$.

Table 6
Comparisons of ARDES-M (Attention-Related Driving Errors Scale for Motorcyclists) and IDA (Involvement in Distracting Activities) scores by socio-demographic, motorcyclist and vehicular variables.

Variable	N	Mean		SD		Average range		Kruskal-Wallis H test		Effect size	
		ARDES-M	IDA	ARDES-M	IDA	ARDES-M	IDA	ARDES-M	IDA	ARDES-M	IDA
Age											
18–29	169	36.10	19.92	9.02	6.51	234.05	251.22	14.49***	39.41***	0.35	0.63
30–44	90	34.76	18.06	9.74	6.51	209.73	204.91				
45 or more	159	32.52	15.81	7.56	4.30	183.27	167.76				
Sex[a]											
Female	129	34.25	17.43	8.41	5.88	209.40	197.03	0.05*	1.71*	0.09	0.08
Male	287	34.54	18.15	8.96	6.09	206.49	213.66				
Years of riding experience											
Less than 3 years	93	37.67	19.41	9.78	6.86	252.06	238.18	14.87***	6.77**	0.37	0.23
More than 3 years	325	33.53	17.54	8.27	5.73	197.32	201.29				
Frequency of motorcycle use											
Every or nearly every day	180	34.26	18.01	8.58	6.34	207.47	208.03	3.32*	3.07*	0.11	0.10
Once or twice a week	131	35.27	18.53	8.72	6.01	223.75	222.90				
Once or twice a month/year	107	33.77	17.16	9.22	5.51	195.47	195.57				
Motorcycle engine size											
50 cc	79	35.76	18.22	10.12	6.80	220.93	210.23	4.24*	4.45*	0.04	0.06
51–125 cc	149	34.50	18.24	7.87	5.76	215.12	218.82				
126–500 cc	90	34.51	17.08	9.35	5.58	208.62	191.21				
501–900 cc	74	33.81	18.68	8.51	6.60	201.08	220.12				
901 cc or more	26	31.77	16.54	8.08	4.79	169.58	186.94				

Note. *$p > 0.05$; **$p < 0.01$; ***$p < 0.001$.
[a] Two riders did not answer this question.

was observed with "Check the telephone to see if there is something new". The ARDES-M also had a moderate correlation with the IDA total score, $rho = 0.37$ ($p < 0.001$), indicating that the greater the involvement in distracting activities, the greater the frequency of attention-related errors.

All the items of the ARCES showed a moderate to positive relationship with the ARDES-M (see Table 3), ranging from 0.38 to 0.52. The correlation between the ARDES-M and the total ARCES score was strong and positive, $rho = 0.67$ ($p < 0.001$).

3.3. ARDES-M, IDA and road safety incidents

Tables 4 and 5 shows the ARDES-M and IDA mean scores by different types of road safety incidents. For the ARDES-M, the Kruskal-Wallis' H test indicated statistically significant differences for all categories of events. Motorcyclists who experienced road traffic incidents reported more attention-related errors than those without prior accidents or quasi-accidents. The greatest effect sizes were observed for sudden manoeuvres, crashes without damages (near-crashes), loss of control over the motorcycle, and crashes with human injuries, listed here in descending order. Given that some ARDES-M items are similar in content to those of some of the compared events (e.g., item 3 *"I unintentionally hit an object or vehicle behind me because I didn't realize it was there"* and the event *"Crash with a fixed object or stopped vehicle"*), we also ran the same analysis eliminating such items from the total score. Even so, the results were practically identical. On the other hand, statistically significant differences in IDA scores were only found for "sudden manoeuvre" and "near-crashes" (see Table 5). In both cases, the effect sizes were smaller than those observed for the ARDES-M.

3.4. Differences in ARDES-M and IDA scores by socio-demographic variables

Comparisons of ARDES-M and IDA scores by age, sex, years of riding experience, frequency of motorcycle use, and motorcycle engine size are shown in Table 6. Younger motorcyclists and those with fewer years of riding experience reported higher scores in both ARDES-M and IDA. Because age and riding experience are strongly related, we also performed a partial correlation analysis. Age and ARDES were weakly and negatively correlated after partializing out the effect of experience ($r =$

−0.12, $p = 0.019$). Similarly, age and IDA were negatively correlated after partializing out the effect of experience ($r = -0.27$, $p = 0.001$). On the other hand, when we control for age in the relationship between ARDES and years of riding experience, we find a correlation of $r = -0.15$, $p = 0.002$. In the case of the IDA, correlation with the years of riding experience after controlling for age was near zero ($r = 0.01$, $p > 0.05$). For the remaining socio-demographic variables, effect sizes were near zero and no statistically significant differences were found.

4. Discussion

The results of this study add to the body of knowledge about motorcyclist inattention and distractions while also providing evidence of validity for a novel research instrument in this area: the ARDES-M. The first objective was to adapt the original ARDES-M for the Spanish riding context. The expert-appraisal method performed to obtain a culturally adapted version of ARDES-M, along with validity evidence from psychometrics, allowed us to support this study's interpretations of analysis of the relationships between ARDES-M, distractions and self-reported driving incidents. Further research is needed to evaluate whether the ARDES-M's psychometric properties are replicable in other countries and languages. With regard to the reliability of the ARDES-M, we are aware that response biases such as social desirability (af Wahlberg, 2010), are a potential source of measurement error. This issue has not been addressed in this study and should be examined in future studies.

The second objective was to analyse the relationship between riding errors as measured by ARDES-M and engagement in distracting activities. As hypothesized, and in line with the original study (Nucciarone et al., 2012), a positive relationship was found between these two variables. Likewise, the ARDES-M was strongly associated with a general measure of attentional errors (ARCES), a finding that was also reported in various prior studies (e.g., Barragán et al., 2016; Gresham et al., 2021; Qu et al., 2015). The results support the assumption that the errors measured by the ARDES are associated primarily with a general tendency toward inattention in daily life (Ledesma et al., 2015). But in the case of motorcyclists, they also reveal that engagement in distracting activities impact ARDES-M scores. The most widely self-reported distractions were using map navigation, listening to the radio or to music, and adjusting mirrors or other vehicle devices. Riders reported the various forms of cellphone use to a lesser degree. In all cases, every category of distraction was individually associated with a higher level of self-reported errors. This finding suggests that motorcyclists are not fully capable of compensating for the effects of distractions and commit errors at different levels of the riding task.

The third objective was to analyse the associations of errors and distractions while riding with self-reported crashes, near-crashes, and other safety incidents. All of these event categories were linked to ARDES-M scores, with higher scores for those who reported being involved in incidents. A similar analysis was undertaken with the IDA (distracting activities), but in that case, scores were only linked with near-crashes and sudden manoeuvres. These results are in line with previous studies on car drivers (e.g., Qu et al., 2015; Ledesma et al., 2010; Peña-Suárez et al., 2016; Roca et al., 2013), and support the usefulness of the ARDES-M as a domain-specific measure of inattention in the traffic arena. However, it is important to keep in mind that the ARDES as well as other measures of crashes are self-reported. In order to reduce the risk of common method variance, it is important to use other sources of data (such as official records of crashes) in the future. It would also be valuable for future research to analyse the relationship between the ARDES-M and performance on motorcycle riding simulators, as Valero-Mora et al., (2015) did in the case of drivers.

Finally, riding errors and distractions were compared by socio-demographic variables, and differences were found with respect to age and rider experience. In these cases, higher ARDES-M and IDA scores were observed among both young and inexperienced riders. The effect size for age-group comparisons was particularly high in the case of the IDA, with greater engagement in distracting activities in the 18–44 year-old segment compared with those over the age of 45. This finding is in line with previous studies that indicate a greater tendency to engage in distracting activities among the young (Guo et al., 2017; Huisingh et al., 2015; Lansdown, 2012; Widyanti et al., 2020). With respect to the ARDES, as previously mentioned in the introduction, the findings of prior studies on car drivers have not been consistent in terms of the impact of age and experience (Barragán et al., 2016; Qu et al., 2015; Ledesma et al., 2010; Peña-Suárez et al., 2016; Roca et al., 2013). In the case of motorcyclists, this is the first study that analyses these relationships and further research is needed to confirm its findings. For now, our results suggest that errors and engagement in distracting activities tend to decrease with age and experience, indicating that prevention measures should focus mainly on young and novice riders.

4.1. Conclusions

This study enhances the validity of the ARDES-M and offers new evidence supporting its potential use in road safety research. ARDES-M provides researchers with a short and inexpensive instrument to evaluate the propensity for error in motorcyclists, a population for which few research instruments are available. Unlike other instruments, like the MRBQ, the ARDES-M provides a specific measure of inattention, a key road safety risk factor. We believe the ARDES-M can help improve our understanding of inattention while riding, as well as aid in the study of its cognitive and personality correlates. It is important to keep in mind, however, that it is a self-report instrument, and therefore the limitations inherent in such methods are also present in the ARDES-M (e.g., potential response biases).

The ARDES-M could also be useful for road safety practitioners in the evaluation and design of awareness-raising and training actions for motorcyclists. For example, it could be used as an evaluation tool in Insight training (Gregersen, 1996; White et al., 2011), an action that aims to give users a more realistic perception of their own driving/riding abilities and limitations. In these programs, the ARDES-M could serve as a quick self-evaluation tool to make motorcyclists more aware of their attentional errors and the impact these have on safety. In a more general way, the ARDES-M could also be potentially useful in identifying motorcyclists with a higher propensity to commit attention-related errors in order that they may receive and benefit from special interventions. For example, training to improve their level of attention and alertness on the roadway. In any event, it is difficult to establish a priori the scope and impact of these applications. Further research is needed to analyse its usability, benefits and limitations in practical settings. We hope this study encourages researchers and practitioners to conduct validation studies in other cultures and languages, as well as to evaluate the ARDES-M's possible uses in practical settings.

CRediT authorship contribution statement

Ruben D. Ledesma: Data curation, Methodology, Conceptualization, Formal analysis, Writing - original draft, Writing - review & editing. **Jose-Luis Padilla:** Conceptualization, Investigation, Supervision, Writing – review & editing. **Jeremias D. Tosi:** Data curation, Formal analysis, Methodology, Writing - original draft, Writing - review & editing. **Nuria Sánchez:** Investigation, Writing – review & editing. **Candida Castro:** Conceptualization, Funding acquisition, Investigation, Supervision, Writing – review & editing.

Declaration of Competing Interest

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

Table A1
Item wording and summary of the expert ratings on the ARDES-M (Attention-Related Driving Errors Scale -Motorcyclists), Argentine version. Changes in item wording are noted in bold.

Original item wording	Expert rating		Revised item wording	Authors' English translation
ARDES-M Argentine Version	Mean	SD	ARDES-M Spanish Version	
1. Ir en "piloto automático" y hacer una maniobra peligrosa sin darme cuenta de ello	4.67	0.72	Ir en "piloto automático" y hacer una maniobra peligrosa sin darme cuenta de ello	Be "on autopilot" and make a dangerous maneuver without realizing it
2. Hacer cierta maniobra (acelerar, frenar, **doblar**…) y sorprenderme porque no es lo que realmente quería o planeaba hacer	3.87	0.92	Hacer una maniobra (**p.e.,** acelerar, frenar, **girar**…) y sorprenderme porque no es lo que realmente quería o planeaba hacer	Make a maneuver (accelerate, brake, turn…) and surprise myself because it was not what I had really wanted or intended to do
3. No **advertir** que hay un objeto o un vehículo detrás **del mío** y golpearlo sin querer	4.53	0.63	No **darme cuenta de** que hay un objeto o un vehículo detrás **de mi moto** y golpearlo sin querer	I unintentionally hit an object or vehicle behind me because I didn't realize it was there
4. Por un breve instante, olvidar hacia dónde **estoy manejando**	2.60	1.01	Por un breve instante, olvidar hacia dónde **voy conduciendo**	For a brief instant, I forget where I am riding to
5. Salir hacia un destino y, de pronto, darme cuenta que estoy yendo hacia otro lado	4.47	0.62	Salir hacia un destino y, de pronto, darme cuenta **de** que estoy yendo hacia otro lado	I head out to a destination and suddenly realize I'm going the wrong way
6. Sin querer, **doblar** en el lugar equivocado o meterme en **contramano**	3.00	0.92	Sin querer, **girar** en el lugar equivocado o meterme en **dirección contraria**	Unintentionally make a wrong turn or head the wrong way down a one-way street
7. Al llegar a una esquina, no darme cuenta de que un peatón está cruzando la calle	4.80	0.80	Al llegar a una esquina, no darme cuenta de que un peatón está cruzando la calle	At a street corner, I fail to notice that a pedestrian is crossing the street
8. Al llegar a una intersección, por estar **distraído**, no ver otro vehículo que está llegando a la esquina	4.53	0.84	Al llegar a una intersección, por estar **distraído/a,** no ver otro vehículo que está llegando a la esquina	When at an intersection, I get distracted and fail to see a vehicle coming the other way.
9. Por ir **distraído, advertir** que **directamente** no he visto el semáforo	4.20	0.95	Por ir **distraído/a, darme cuenta de** que no he visto el semáforo	I realize that I've run a traffic light because I got distracted.
10. De pronto, notar que he perdido o equivocado **el** camino en un trayecto que conozco	4.00	1.21	De pronto, notar que me he perdido o **me he** equivocado **de** camino en un trayecto que conozco	Suddenly, I realize I'm lost or took the wrong route when riding to a known destination
11. Quedarme a mitad de camino sin **nafta**	1.47	0.93	Quedarme a mitad de camino sin **gasolina**	Run out of gas on the road
12. Otro conductor **me** toca bocina porque me "**tildé**" en el semáforo	1.53	0.84	Otro conductor toca la bocina porque me **quedé absorto/a** en el semáforo	Another driver honks at me because I've failed to realize that the traffic light has turned green
13. **Anunciar** una maniobra y, sin querer, hacer otra (ejemplo, poner el **guiño** para un lado y **doblar** hacia el otro)	2.27	1.01	**Señalizar** una maniobra y, sin querer, hacer otra (p. ej., poner el **intermitente** para un lado y **girar** hacia el otro)	I signal a maneuver but unintentionally make another (for example, I turn on the right-turn signal, but turn left instead)
14. No darme cuenta que el vehículo de **adelante** ha reducido su velocidad y tener que frenar bruscamente para evitar **un choque**	4.47	0.63	No darme cuenta **de** que el vehículo de **delante** ha reducido su velocidad y tener que frenar bruscamente para evitar **chocar**	I fail to notice that the vehicle in front of me has slowed down, and I have to brake abruptly to avoid a crash
15. Ir **manejando** y olvidarme en qué **cambio** voy (segunda, tercera, cuarta…)	2.80	1.03	Ir **conduciendo** y olvidarme **de** en qué **marcha** voy (segunda, tercera, cuarta…)	While driving, forget what gear I'm in (second, third, fourth…)
16. Ir hacia un lugar conocido y, por distracción, pasarme algunas **cuadras**	2.60	1.14	Ir hacia un lugar conocido y, por distracción, pasarme algunas **calles**	When riding to a familiar place, I unintentionally ride past it because I was not paying attention
17. Sin querer, hacer alguna maniobra que me hace perder la estabilidad en la moto	4.87	0.27	Sin querer, hacer alguna maniobra que me hace perder la estabilidad en la moto	Without meaning to, make a maneuver that causes the motorcycle to lose stability
18. Por estar **distraído, no advertir** a tiempo **un lomo de burro o no ver un pozo**	1.67	1.19	Por estar **distraído/a, no ver** a tiempo un **badén o un bache**	Because of a distraction, fail to notice a speed bump or a pothole
19. Al llegar a una intersección, en lugar de mirar hacia dónde viene el **tránsito**, mirar hacia el otro lado	3.27	1.17	Al llegar a una intersección, en lugar de mirar por dónde viene el **tráfico**, mirar hacia el otro lado	When at an intersection, instead of looking in the direction of oncoming traffic, I look in the opposite direction
20. Tener que llegar a un lugar y dar más vueltas de las necesarias	4.93	0.27	Tener que llegar a un lugar y dar más vueltas de las necesarias	When riding somewhere, I take a longer route than necessary
21. Por "seguir el **tránsito**", **cruzar** un semáforo que justo **cambió** a rojo	3.13	0.99	Por "seguir el **tráfico**", **saltarme** un semáforo que justo **acababa de cambiar** a rojo	Following the traffic in front of me, I unintentionally ride through a traffic light that has just turned red
22. Al arrancar olvidarme de subir **el pie** de la moto	4.53	0.63	Al arrancar olvidarme de subir **la patilla** de la moto	When starting to move forward, forget to lift up the kickstand

Data availability

Data will be made available on request.

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Ethics statement

This research received the approval of the Ethics committee 920/CEIH/2019 ("Comité de Ética en Investigación de la Universidad de Granada").

Appendix A. Adaptation of ARDES-M to Spain. Item and scale review

A panel of experts assessed the suitability of the ARDES-M to the language, habits and traffic of Spain. The panel consisted of fifteen researchers from various universities in Spain (7 women and 8 men). They were experts in the fields of experimental and cognitive psychology, road safety and human factors, and psychometrics. On average they had $M = 12.4$ years of research experience, with 10 of the 15 having 10 years of experience or more. They were invited by email to evaluate the original ARDES-M Argentina (in Rioplatense or River Plate Spanish) and to suggest appropriate adaptations to the wording of items, instructions and the response scale. The review sheet was implemented in an online survey platform (QuestBack, 2019). The experts were asked to rate the adequacy of instructions, item response options, and the 22 items of the Argentinian ARDES-M by using a Likert scale from 1 "Not suitable at all" to 5 "Very suitable". In cases where an expert rated an element a 4 or less, she/he was to first identify the inappropriate wording or expression ("Which word/s, expression/s or aspect/s do you consider impair the adequacy?"), and then propose an alternative. Once the appraisal of the experts was collected, it was analyzed both quantitatively and qualitatively, and discussed by the research team to develop the final version. The instructions and the response options were rated as very suitable for the Spanish context. As for the items, a summary of the expert ratings for each item is presented in Table A1, along with the item's original and revised wording. Ten items (45%) received a mean value below 4 and thus required revisions; the adaptation in these cases consisted mainly in replacing expressions or words used in Argentina but not in Spain. The reviewers generally agreed on the identification of these words and also on the proposed alternatives. For example, item 13 included two problematic words: "*giño*" (turn signal) and "*doblar*" (turning), which were changed to "*intermitente*" and "*girar*", which are more suitable to Spanish spoken in Spain. In cases when the alternatives proposed by the experts were vastly different, the adapted wording was discussed intensively by the research team. In order to maintain the highest degree of equivalence with the original version, only the wording that was insufficiently adequate to the Spanish context was changed. The end result was a modified version of the ARDES-M that is more suitable to Spain (see the last column in Table A1).

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