COVID-19 and Its Effects on the Driving Style of Spanish Drivers

VÍCTOR CORCOBA[1]**, (Member, IEEE), XABIEL G. PAÑEDA**[1]**, DAVID MELENDI**[1]**,
ROBERTO GARCÍA**[1]**, LAURA POZUECO**[1]**, AND SARA PAIVA**[2]
[1]Department of Computer Science, University of Oviedo, 33003 Oviedo, Spain
[2]Escola Superior de Tecnologia e Gestão, Instituto Politécnico de Viana do Castelo, 4900-347 Viana do Castelo, Portugal

Corresponding author: Víctor Corcoba (corcobavictor@uniovi.es)

ABSTRACT Spain is one of the countries most affected by COVID-19. Until May 5, 2021 there have been 3.54 million people infected and 78,399 deaths according to the Johns Hopkins Institute. This has meant that Spain is one of the countries in the world where the most restrictive measures have been adopted and which have had a strong impact on the economic, social, and mental health of citizens. One of the consequences of this pandemic is a severe increase in the strain on the healthcare system. Many of those infected had to be admitted to hospitals and even to Intensive Care Units (ICU). In this scenario, it is essential to reduce traffic accidents in order to avoid overcrowded hospitals. However, the Spanish General Directorate of Traffic highlights in several traffic reports that despite the decrease in the volume and distance of trips, the number of traffic accidents has not altered significantly and even during some periods has been higher than before the pandemic. The aim of this work is to establish if there has been a change in the driving style of drivers during the pandemic and to identify the group of people adopting a more inefficient and unsafe driving style. To this end, a study was carried out with 30 volunteers and their current driving style was compared with their driving style before the pandemic. The results show that drivers have adopted a more aggressive driving style than before the pandemic, especially women and those who have suffered anxiety due to COVID-19.

INDEX TERMS Driving style, road safety, COVID-19, energy efficiency, driving patterns, traffic accidents.

I. INTRODUCTION

Covid-19 has caused 3.15 million deaths worldwide according to the Johns Hopkins Institute [1]. The pandemic has had a strong impact on both the economy and the unemployment rate [2]. COVID-19 has deteriorated the physical and mental health of society as a whole, regardless of having been infected by the virus or not [3]. Diagnosis and treatment of illnesses have been delayed [4] and mental problems such as anxiety and stress have increased [5]. One of the measures that most countries have adopted to reduce the number of infections is lockdown. This led to a decrease in traffic volume, which at first also meant a reduction in the number of traffic accidents [6]. In Spain, the number of fatalities decreased by 59% from March 15 to June 21, 2020 compared with the previous year. However, in the summer period from June 22 to August 31, the number of fatalities only decreased

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by 4% despite a 9% decrease in the number of trips [7]. Over Easter 2021 the data was even worse and traffic accidents increased by 18.5% compared to 2019 [8]. This could be due to a change in driving style.

Several studies highlight that the average speed has increased due to low traffic density. In [9] the researcher observed a 1% increase in speeding-related collisions in North Carolina. In other regions such as Virginia the increase has been even greater [10]. In this case, between March 13, 2020 and April 30, 2020, traffic accidents due to speeding involved 23% of total collisions, increasing by 18.5% compared with the same period of the previous year. Excessive speed is the origin of a large number of traffic accidents [11]. In [12], the authors compared the driving style of drivers before and during the pandemic. The results show an increase in speeds, speeding rates, frequency of abrupt events, and the use of mobile phones during the pandemic, all of which could worsen road safety. To remedy this, the researchers propose the establishment of new speed limits, the installation

of surveillance cameras and the implementation of awareness campaigns highlighting the dangers of speeding.

According to numerous studies, there is a strong relationship between driving style, fuel consumption and safety [13], [14]. For this reason, both industry and researchers have focused on proposing methods to classify driving style, as well as solutions to improve it. Proposals for categorizing driving style can be grouped into two sets: based on self-reporting or based on driving monitoring.

Among the self-report solutions, the most important are the Driver Behavior Questionnaire (DBQ) [15], Driving Style Questionnaire (DSQ) [16], Driving Behavior Inventory (DBI) [17], and Multidimensional Driving Style inventory (MDSI) [18]. Each of these approaches focuses on different areas of driving safety. For example, DBQ evaluates aberrant driving behavior such as speeding, traffic violations, and driving distractions and is one of the most widely used methods. DSQ investigates drivers' decision-making and risk-taking skills. DBI assesses driving stress and aggressive driving style. MSDI is a tool that attempts to bring together all aspects of driving safety. MSDI defines four different domains (careless and reckless driving style, anxious driving style, angry and hostile driving style, patient and careful driving style), and 44 items. Some of these items were already present in DBQ, DSQ and DBI, and others are new.

Solutions based on vehicle telemetry and driving context use artificial intelligence algorithms to determine driving style. These algorithms are usually based on rules, models or machine learning [14]. For example, in [19] the authors proposed a method based on the transition probability between maneuvers and the random forest algorithm. The researchers observed that transitions relating to five maneuver states (free driving, approaching, near following, constrained left and right lane changes) allow to accurately categorize the driving. The driving context is a relevant factor in the evaluation of driving. The driver does not behave in the same way when traffic is heavy or normal. In [20] the authors presented a system to assess driving style using the smartphone sensors. The proposal detects the type of maneuver the driver is performing, the traffic state and the car's sensitivity to accelerations from the data collected by the smartphone and employing an ensemble learning method. Finally, the maneuver is categorized as dangerous or safe using a rule-based fuzzy inference system. The authors achieved at least 94% accuracy in their driving tests.

The driver's mental state could also be another factor influencing the sustainment or even increase of traffic accidents. Numerous previous studies have associated high levels of stress, anxiety and depression with an increased likelihood of aggressive or risky driving behavior as well as traffic accidents [21]–[23]. The pandemic has globally deteriorated mental health. In [24] researchers found high rates of anxiety symptoms (6.33% to 50.9%), depression (14.6% to 48.3%), psychological distress (34.43% to 38%) reported by the general population during the COVID-19 pandemic in China,

Spain, Italy, Iran, the US, Turkey, Nepal, and Denmark. The main risk factors for suffering these problems were age, gender, presence of chronic diseases, employment situation, and exposure to news about COVID 19. Spain is one of the countries in which the number of infections has been highest and this has also caused an important impact on the psychological health of its citizens. In [25] the authors conducted a study on mental health in Spain analyzing anxiety, depression and life satisfaction. A total of 1,659 people participated in the study. The results showed that many people suffered from anxiety and depression. Women and young people had the highest anxiety scores and the lowest emotional stability. In conclusion, the authors observed an increase in psychological problems. This could imply an increase in alcohol and drug use. In the study carried out by [26], it was found that 25% of those surveyed reported consuming more alcohol and 6% more cannabis during the pandemic. To avoid this, it is important to maintain police controls on the road. In [27] the authors observed the emergence of new drink drivers due to the suspension of static roadside random breath testing.

In conclusion, the number of studies about the effects of the pandemic on driving is very limited. Most of them are focused on analyzing how COVID-19 has affected traffic volume and its implication in the spread of the virus. For example, in [28] the authors conduct a study comparing vehicle use before and during COVID-19 restrictions. The study involved drivers aged 16 to 18 in the state of Alabama (USA). The results showed that the COVID-19 measures reduced both the number of days they drove, and the distance driven. However, the decrease in vehicle use was less among ethnic minorities and older teens in employment. The authors suggest that health professionals should target their messages to these groups in order to make them aware of the importance of changes in travel activities. On the contrary, older drivers appear to be the most likely to minimize travel according to [29]. In addition, they also reduced speeding incidents, drove more slowly, and completed shorter trips.

The aim of this work is to discover whether the driving style has worsened during the pandemic from an ecological and safety point of view. Another goal is to analyze whether the anxiety caused by COVID-19 and gender influences driving. To this end, a smartphone app has been developed in order to evaluate driving style based on a set of indicators that model risky and energy-inefficient driving behaviors. The conclusions of this study are expected to be useful to avoid a worsening of road safety. Reducing the number of road accidents is especially important in this context due to the strain on the healthcare system caused by the pandemic.

The rest of the paper is organized as follows: the proposed methodology and the indicators used to evaluate the driving style are discussed in Section II. Section III describes the experimental setup. Results are presented in Section IV. Discussion of the results is included in Section V. Section VI explains the limitations of the study. Finally, the conclusions of the study are presented in Section VII.

II. METHODOLOGY

A. MATERIALS AND INSTRUMENTS USED

In this paper, a survey and a smartphone are employed in order to analyze the impact of COVID-19 on driving behavior. The survey consists of two parts. In the first part, the objective is to obtain information about the driver (age, gender, and driving experience). The second part is based on the Coronavirus Anxiety Scale (CAS) [30]. The CAS allows to evaluate mental health and identify probable cases of dysfunctional anxiety associated with the COVID-19 crisis. This questionnaire consists of 5 questions and is based on the responses of 775 participants who suffered anxiety due to COVID-19. The CAS is able to distinguish between people with and without dysfunctional anxiety using a cut-off score of 9. If the score obtained is equal to or higher than this value, it means that the subject suffers from dysfunctional anxiety. The survey consists of the following questions:

First part
- Gender
  Type of Answer: Female or Male
- Age
  Type of Answer: Number
- Number of years driving
  Type of Answer: Number

Second part
- How often have you experienced the following states over the last 2 weeks?
  I felt dizzy, lightheaded, or faint, when I read or listened to news about the coronavirus.
  I had trouble falling or staying asleep because I was thinking about the coronavirus.
  I felt paralyzed or frozen when I thought about or was exposed to information about the coronavirus.
  I lost interest in eating when I thought about or was exposed to information about the coronavirus.
  I felt nauseous or had stomach problems when I thought about or was exposed to information about the coronavirus.
  Type of Answer: Likert scale
  0) *Not at all.*
  1) *Rarely, less than a day or two.*
  2) *Several days.*
  3) *More than 7 days.*
  4) *Nearly every day over the last 2 weeks.*

The app was developed in 2019 for a study to evaluate the impact of external factors such as drowsiness or work stress on driving style. It runs on Android smartphones and uses the GPS to obtain the location and vehicle speed. The participant has to run the app before starting to drive. The first time the app is run it asks for permission to obtain the location. The participant has to grant this permission in order to participate in the experiment. Then, the driver has to press the start button. When the device obtains a GPS signal, it notifies the driver with a message and indicates that the trip can be commenced. When the trip is finished the participant has to press the stop button. The app calculates the driving style

indicators that will be described in the next section, sends them to a central server and shows them on the screen. The app is shown in Figure 1.
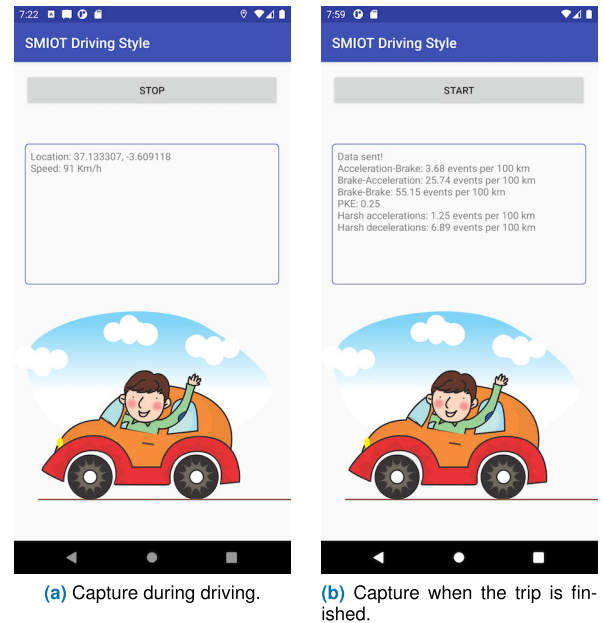

(a) Capture during driving.   (b) Capture when the trip is finished.

FIGURE 1. Smartphone App developed to evaluate driving style.

B. DRIVING STYLE INDICATORS

Driving style has a strong relationship with driving safety and fuel consumption. Aggressive driving behavior is associated with high energy consumption and a higher probability of traffic accidents [31]. The aim of this work is to compare the driving style of drivers before the COVID-19 pandemic and after the lockdown adopted by many countries, including Spain, as a measure to reduce contagion. In addition, the goal is also to assess the degree to which the psychological impact of the COVID-19 disease has affected driving and the influence of gender. Recent studies in Spain show that the pandemic has had a strong impact on mental health, increasing depression and anxiety, especially in the case of women and people suffering from loneliness [32], [33]. In order to assess driving, the following variables and driving patterns related to safe driving and fuel consumption were used. Some of these variables have been proposed by the authors in previous works [34].

1) NUMBER OF SUDDEN ACCELERATIONS PER 100 km

Many researchers find that abrupt events are strongly correlated with driving risks and are critical for driving assessment [35]–[38]. Furthermore, they also have a significant impact on energy efficiency [39]. When the driver presses the accelerator pedal, fuel is burned to generate the required energy. The amount of fuel burned depends, among other parameters, on the intensity of acceleration. Driving based on sudden accelerations and decelerations can cause up to 33% of the fuel to be wasted [40]. In this work, an acceleration

is considered abrupt when it is higher than 2.5 m/s². This threshold is based on [41].

2) NUMBER OF SUDDEN DECELERATIONS PER 100 km
This variable affects both safety and fuel consumption. When the driver uses the brakes, part of the energy generated is wasted in the form of heat. In addition, this action can cause traffic accidents if the driver of the vehicle behind does not have enough time to react. In Spain in 2016 there were more than 24,000 accidents due to rear-end collisions in which the safety distance was not respected [42]. In this work a deceleration is classified as abrupt when it is less than -1.5 m/s² [41].

3) POSITIVE KINETIC ENERGY (PKE)
This variable measures the aggressiveness of driving [43], [44]. Its value depends on the intensity and frequency of the accelerations. If it is high, it means that the driver accelerated sharply and frequently. A high fluctuation in vehicle speed has negative effects on both fuel consumption [45] and driving safety [46]. The drivers of surrounding vehicles have a harder time predicting driver behavior. The PKE was proposed by [47] and it is estimated over a period of time as follows:

$$\text{PKE} = \frac{\sum \left(v_i^2 - v_{i-1}^2 \right)}{d}; \quad v_i > v_{i-1} \tag{1}$$

where v_i and v_{i-1} are respectively the final and the initial speed (in m/s) at each time interval for which v_i - $v_{i-1} > 0$, and d is the total distance traveled (in m).

4) ACCELERATION-BRAKE
It is defined as the number of times per 100 km that the driver accelerates strongly and brakes almost immediately (the time window is two seconds). The acceleration must be higher than 2.5 m/s² [41]. A low value of this variable is correlated to a good ability to anticipate the traffic flow.

5) BRAKE-BRAKE
It is defined as the number of times per 100 km that the driver brakes sharply twice or more in a ten second time window. This pattern is related to an inadequate speed that increases the probability of suffering traffic accidents and high energy consumption [46]. The intensity of deceleration must be equal to or lower than -1.5 m/s². It has been demonstrated in many works that a deceleration value equal to or higher than this threshold significantly increases fuel consumption and emissions [41], [48].

6) BRAKE-ACCELERATION
It is defined as the number of times per 100 km that the driver brakes abruptly (≤ -1.5 m/s²), and then accelerates (≥ 0.8 m/s²) in one of the next two seconds. A low value is associated with the keeping of an adequate safety distance and better use of the energy produced by the engine.

TABLE 1. Driving experience.

Driving experience (years)	Number of drivers	Average Age
1-5	1 man	33.00 ± 0.00
6-10	1 man, 1 woman	27.50 ± 3.53
11-20	11 men, 9 women	34.00 ± 3.27
>20	5 men, 2 women	40.71 ± 1.38

C. STATISTICAL ANALYSIS
A paired Student's t-test was conducted in order to determine if there are significant differences between the driving style before and during the pandemic. This method is used because the sample size allows to consider the normal approximation as good. It is subsequently studied whether the change produced was the same according to gender, using Student's t-test for independent samples on this occasion, since again, given the sufficient sample size, the normality hypothesis was assumed to be valid, applying Welch's correction for different variances. Average values are described as mean ± standard deviation. A significance level of $p < 0.05$ is fixed for all statistical tests. Cohen's effect size was also calculated. Statistical analysis was performed using the R program (R Development Core Team), version 3.6.3.

III. EXPERIMENTAL SETUP
A. PARTICIPANTS
30 drivers (18 men and 12 women) participated in the study. The average age of the participants was 35.1 ± 4.52 years (min: 25, max: 42). Table 1 shows their driving experience, taking into account the number of years driving.

The drivers were recruited voluntarily, and they did not receive any payment or benefit for the tests. The selection criteria were that the subject had not previously suffered any psychological problems. Furthermore, they should be healthy, with no history of heart-related diseases, and have good vision. They were also requested not to consume drugs, alcohol or other beverages, or take medication during the experimental period. Finally, all the volunteers were in employment and all maintained their jobs throughout the period of the study.

B. PROCEDURE
Each participant completed 40 trips. The driving tests were conducted in two different time periods. In the first period (June 2019) the drivers performed 20 driving tests. The second period was during the pandemic in June 2020 and, as in the first period, the participants completed 20 driving tests.

The driving tests are a daily commute to the workplace and the routes are located in Castilla la Mancha (Spain), Madrid (Spain), and Granada (Spain). On all routes, the drivers spent most of the time driving on a highway. The drivers drove without any driving assistance except the use of power steering. Figure 2 captures one of the routes completed by the participants and situated in Granada (Spain).

Before starting to drive in the second period (during the pandemic), the participants completed the survey described

in Section 2. During the driving tests the volunteers were requested to always follow the same route to go from their home to the workplace at the same time of day. In addition, the drivers had to leave their homes early enough to reach their workplace without time pressure.
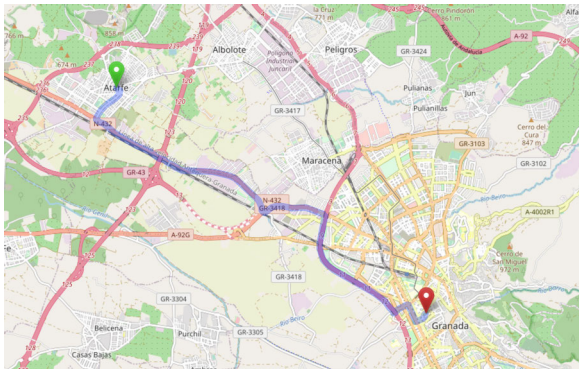

FIGURE 2. Route followed by one of the drivers in the province of Granada (Spain).

IV. RESULTS

A. COMPARISON OF DRIVING STYLE BEFORE AND DURING THE PANDEMIC CONSIDERING ANXIETY

1) DRIVING PATTERNS

Figures 3, 4, and 5 capture the average number of acceleration-brake events, brake-acceleration events, and brake-brake events, respectively. These figures compare the driving patterns before and during the pandemic for drivers with and without anxiety. Table 2 presents the results of Student's t-test for each driving pattern and variable related to driving style.

In the Acceleration-Brake driving pattern, there are no significant differences between driving before and during the pandemic in both groups (drivers with and without anxiety). However, in the Brake-Acceleration driving pattern, this changes. In the group of drivers without anxiety, the number of events of this type per 100 km increased by 6 during the pandemic and Cohen's effect size value (d = 2.48) shows high practical significance. In the case of drivers with anxiety, the increase was 3 times and Cohen's effect size value was 3.15, suggesting high practical significance.

Regarding the Brake-Brake driving pattern, there are no significant differences between the driving samples obtained before and during the pandemic in the group of drivers without anxiety. For drivers with anxiety, the difference is significant but the number of this type of events only increased by 13% during the pandemic and Cohen's effect size value (d = 0.22) suggests low practical significance.

2) POSITIVE KINETIC ENERGY

Figure 6 shows the average positive kinetic energy (PKE) obtained before and during the pandemic, taking into account whether the driver suffered anxiety or not. A high value means that the driver accelerates frequently and intensely, which causes an increase in fuel consumption.
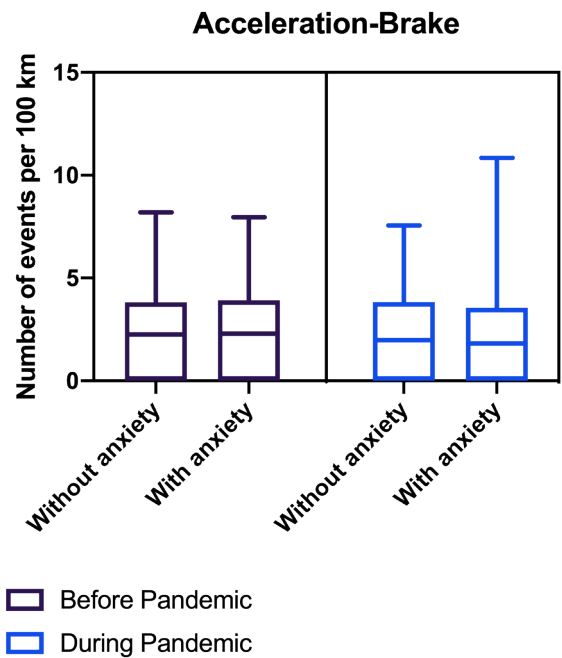

FIGURE 3. Average number of acceleration-brake events per 100 km before and during the pandemic.
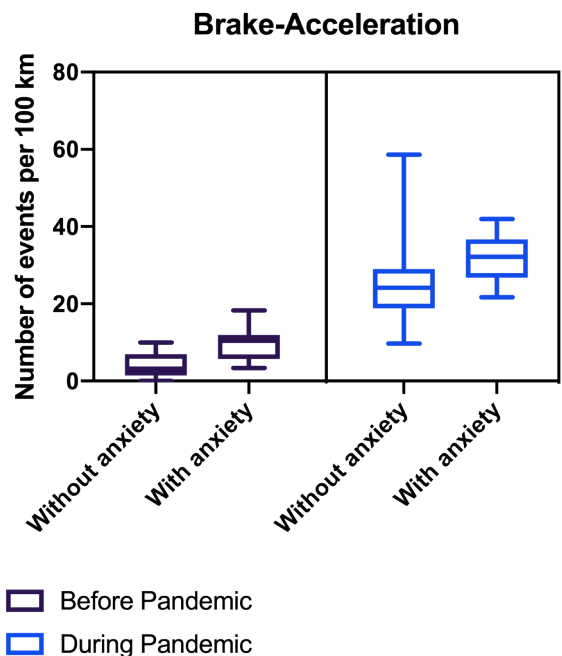

FIGURE 4. Average number of brake-acceleration events per 100 km before and during the pandemic.

In the group of drivers without anxiety, there are significant differences between driving before and during the pandemic. Furthermore, Cohen's effect size value (d = 1.32) suggests high practical significance. The average PKE value increased by 14% during the pandemic. In the case of the group of
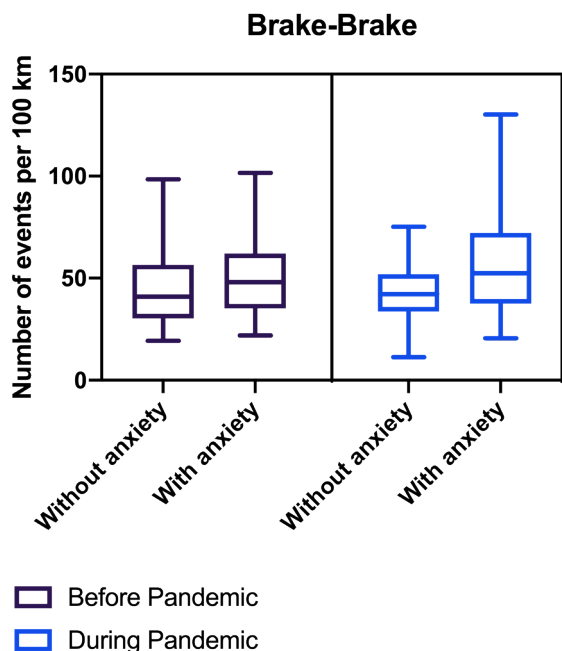
Brake-Brake

FIGURE 5. Average number of brake-brake events per 100 km before and during the pandemic.
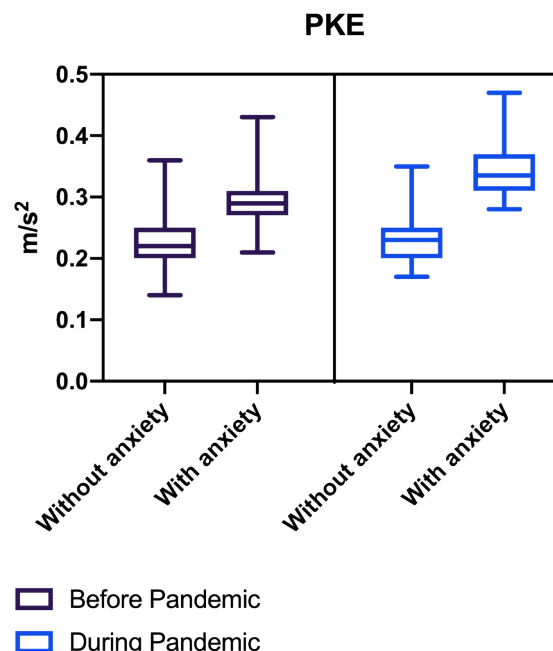
PKE

FIGURE 6. Average Positive Kinetic Energy (PKE) per 100 km before and during the pandemic.

TABLE 2. Result of Student's t-test comparing driving style before and during the pandemic.

Driving pattern	Student's t-test	
Acceleration-Brake	Without anxiety	t(359) = -1.71; p = 0.09
	With anxiety	t(239) = -1.38; p= 0.17
Brake-Acceleration	Without anxiety	t(359) = 47.02; p <0.05*
	With anxiety	t(239) = 48.76; p <0.05*
Brake-Brake	Without anxiety	t(359) = -1.87; p= 0.06
	With anxiety	t(239) = 3.41; p <0.05*
PKE	Without anxiety	t(359) = 25.06; p <0.05*
	With anxiety	t(239) = 30.28; p <0.05*
Sudden Accelerations	Without anxiety	t(359) = 26.45; p <0.05*
	With anxiety	t(239) = 18.76; p <0.05*
Sudden Decelerations	Without anxiety	t(359) = 5.15; p <0.05*
	With anxiety	t(239) = 6.71; p <0.05*

* indicates p-value smaller than 0.05.

drivers with anxiety, there are also significant differences, and the increment is even higher (19%). Cohen's effect size value (d = 1.95) also indicates high practical significance.

3) SUDDEN ACCELERATIONS AND DECELERATIONS
Figures 7 and 8 capture the number of sudden accelerations/decelerations per 100 km obtained by drivers, respectively. Regarding sudden accelerations, there are significant differences between driving before and during the pandemic in the group of drivers without anxiety. The average number of sudden accelerations per 100 km increased by 202% during the pandemic. Moreover, Cohen's effect size value (d = 1.39) indicates high practical significance. The same happens in the group composed by drivers with anxiety. In this case, this type of events increased by 147% during the

pandemic. Cohen's effect size value (d = 1.21) suggests high practical significance.

There are also significant differences regarding sudden decelerations between driving before and during the pandemic in both groups (drivers with and without anxiety), according to the Student's test. In the group of drivers without anxiety, this variable increased by 11% during the pandemic. Cohen's effect size value (d = 0.27) shows low practical significance. For drivers with anxiety, the average number of sudden accelerations per 100 kilometers increased by 19%. Cohen's effect size value (d = 0.43) suggests low-medium practical significance.

B. DIFFERENCES BEFORE-DURING THE PANDEMIC CONSIDERING THE GENDER
1) DRIVERS WITHOUT ANXIETY
Table 3 shows the differences between the values obtained by drivers without anxiety during and before the pandemic for each driving pattern and grouped by gender. This table also presents the results of the Student's t-test for independent samples in order to analyze whether the differences found are significant or not.

It can be observed that in all driving patterns there are significant differences between men and women. On the one hand, the biggest difference is found in the Acceleration-Brake driving pattern. Women increased the number of events of this type during the pandemic by 2.30 on average while men reduced it by 1.17. In this case, Cohen's effect size value (d = 1.44) suggests high practical significance. On the other
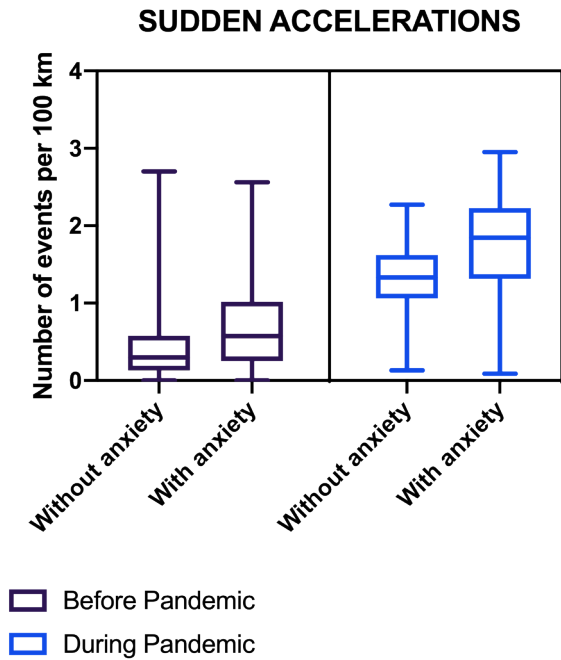
SUDDEN ACCELERATIONS

FIGURE 7. Average number of sudden accelerations before and during the pandemic obtained by drivers with and without anxiety.
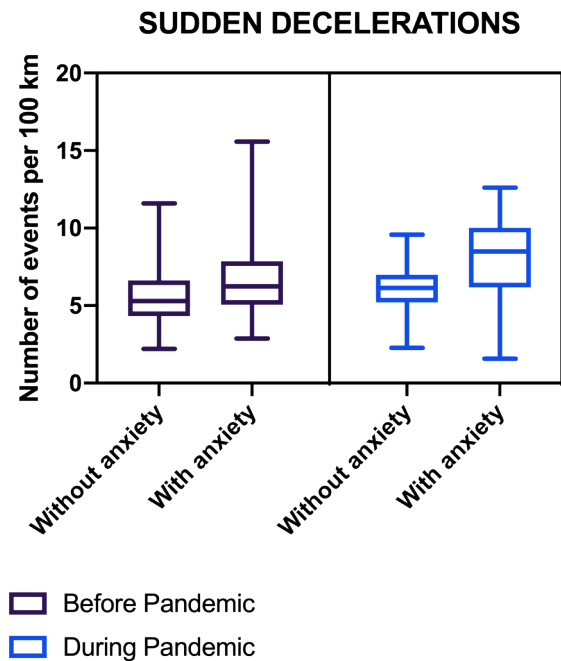
SUDDEN DECELERATIONS

FIGURE 8. Average number of sudden decelerations before and during the pandemic obtained by drivers with and without anxiety.

hand, the smallest difference according to the gender is found in the Brake-Brake driving pattern. Men reduced the number of events of this type during the pandemic compared to their results before the pandemic. However, the standard deviation

TABLE 3. Post/Pre differences according to gender: Drivers without anxiety.

Driving pattern		Result	Student's test
Acceleration-Brake	Women	2.30 ± 2.47	t(358) = 12.226; p <0.05*
	Men	-1.17 ± 2.46	
Brake-Acceleration	Women	23.61 ± 8.14	t(358) = 4.656; p <0.05*
	Men	19.21 ± 7.97	
Brake-Brake	Women	3.43 ± 19.79	t(358) = 3.041; p <0.05*
	Men	-4.30 ± 22.24	
PKE	Women	0.07 ± 0.05	t(358) = 3.488; p <0.05*
	Men	0.06 ± 0.04	
Sudden Accelerations	Women	1.21 ± 0.45	t(358) = 7.306; p <0.05*
	Men	0.77 ± 0.66	
Sudden Decelerations	Women	1.44 ± 2.07	t(358) = 4.413; p <0.05*
	Men	0.30 ± 2.26	

* indicates p-value smaller than 0.05.

TABLE 4. Post/Pre differences according to gender: Drivers with anxiety.

Driving pattern		Result	Student's test
Acceleration-Brake	Women	-0.46 ± 3.13	t(238) = 0.721; p = 0.472
	Men	-0.15 ± 3.69	
Brake-Acceleration	Women	26.64 ± 6.00	t(238) = 10.094; p <0.05*
	Men	18.21 ± 5.90	
Brake-Brake	Women	9.65 ± 31.93	t(238) = 1.351; p = 0.178
	Men	4.18 ± 30.79	
PKE	Women	0.12 ± 0.06	t(238) = 1.388; p = 0.166
	Men	0.11 ± 0.06	
Sudden Accelerations	Women	1.23 ± 0.80	t(238) = 3.488; p <0.05*
	Men	0.85 ± 0.88	
Sudden Decelerations	Women	2.04 ± 2.73	t(238) = 3.650; p <0.05*
	Men	0.63 ± 3.25	

* indicates p-value smaller than 0.05.

is higher than for women. Cohen's effect size value (d = 0.36) suggests low-medium practical significance.

2) DRIVERS WITH ANXIETY

Table 4 shows the differences between the values obtained by drivers with anxiety during and before the pandemic for each driving pattern and grouped by gender. This table also presents the results of the Student's t test for independent samples. There are significant differences between men and women in the Brake-Acceleration driving pattern and in sudden accelerations and decelerations. The most practical significance is the Brake-Acceleration driving pattern where Cohen's effect size value is 1.3. In the other two variables, Cohen's effect size values are very similar, 0.45 for sudden accelerations and 0.47 for sudden decelerations.

V. DISCUSSION OF THE RESULTS

The Acceleration-Brake driving pattern is related to the driver's ability to anticipate traffic. During the pandemic, fewer vehicles on the road should make it easier to predict traffic flow. However, no significant differences were found between the values obtained before the pandemic and during the pandemic. The increase in average speed during the pandemic could be the reason that drivers did not obtain lower values in this pattern. In Spain, speed violations detected using fixed safety cameras increased by 39% during the lockdown period [49].

Regarding the Brake-Acceleration driving pattern, its presence increased during the pandemic both for drivers with anxiety and without anxiety. The observed change in this driving pattern between the data obtained before and during the pandemic was different by gender. Women both with anxiety and without anxiety presented worse values than men. This driving pattern is linked to maintaining the driving safety distance. A high value indicates that the driver does not respect the safety distance and adopts an aggressive driving style in which sudden decelerations proliferate, with the consequent waste of energy. Anger, fear, and anxiety are the most frequent emotional responses to the COVID-19 epidemic [50], [51]. Pandemics have historically increased inequalities and stress in the population and have worsened physical and mental health [52]. Anger is a negative emotion that affects both cognitive and behavioral levels. Drivers who experience this emotion are more likely to speed, reduce the safety distance, accelerate sharply, and infringe traffic rules. Furthermore, they are less aware of road hazards.

The Brake-Brake pattern is associated with driving speed. A high value in this pattern means that the driver is driving at an inappropriate speed, often leading to sudden braking. In this case, uneven behavior is observed. On the one hand, men without anxiety reduced the number of events of this type during the pandemic. This could be because, since fewer vehicles are in circulation, they only have to brake sharply when there is a pedestrian or an obstacle. On the other hand, both women (who are generally more prone to experiment anxiety) and drivers with anxiety (caused by COVID-19) significantly increased the number of these types of events in their driving. The cause could be inattention. According to numerous studies, there is a positive relationship between anxiety, traffic violations, and aggressive driving [18]. People with anxiety may have no intention of violating traffic rules or driving aggressively. However, they do so more frequently due to cognitive overload.

The positive kinetic energy and the numbers of abrupt accelerations and decelerations indicate more aggressive driving behavior during the pandemic in driving with and without anxiety. However, gender also seems to have an effect, and women have a worse driving style than men, especially when they do not suffer from anxiety. In [12] the authors also observed an increase in harsh events (accelerations and decelerations) during the months of March and April 2020 in Greece and the Kingdom of Saudi Arabia (KSA), possibly due to increased speed. These researchers highlight that although these changes in driving behavior have not increased the number of traffic accidents in Greece, they could potentially deteriorate road safety. They also suggest that it is necessary for the authorities to set new speed limits and to conduct media campaigns to raise awareness of the risks of speeding. However, the Spanish Directorate-General for Traffic has observed an increase in road crashes. During the Easter week of 2021, the number of traffic accident fatalities was 18.5% higher than in the Easter week of 2019, and this in spite of the fact that there were perimeter lockdowns and that mobility was reduced by 46% [8].

Analyzing the gender of the drivers and in the case of not having suffered anxiety, we observed that women adopted a significantly more inefficient and unsafe driving style than men. In all driving patterns and variables evaluated, women obtained worse results. In the literature it has been reported that there are significant differences in driving style between men and women [53], [54]. However, in these studies, women tend to adopt a smooth and safe driving style, while men have better perceptual-motor skills [55]. The results we have obtained may be due to the psychological effect caused by the pandemic. With respect to drivers who suffered from anxiety, there are significant differences in only three of the five variables used to assess driving style. This indicates that anxiety is a factor that has a strong impact on driving regardless of the gender and is in line with the conclusions obtained in [56].

VI. CONCLUSION

This paper analyzes whether there has been a change in driving behavior during the pandemic in three regions of Spain. The results show that drivers have adopted a more aggressive and energy inefficient driving style compared to the driving style they had before the pandemic. Among the different driving patterns and variables analyzed, the brake-acceleration driving pattern, positive kinetic energy and the number of sudden accelerations per 100 km stand out as those with the greatest differences. The brake-acceleration driving pattern models a context in which the driver does not respect the safety distance. The other two variables are associated with an aggressive driving style. Drivers who suffered from anxiety due to COVID-19 score even worse in these indicators than drivers who did not suffer from anxiety. Gender is another important factor; women had a significantly smoother driving style than men before the pandemic. However, in driving tests conducted during the pandemic, the indicators show a more aggressive driving style than men. Several studies on the effects of the pandemic on mental health show that gender is a variable that increases the likelihood of distress.

COVID-19 has caused an abrupt change in almost everyone's lives and has increased intra- and interpersonal conflicts. As a result, people tend to focus on themselves and are intransigent towards others. In the face of similar future situations, governments should run campaigns to encourage empathy among road users, as well as to show the consequences of transferring tension and stress to driving. The installation of cameras or sensors on roads can help to detect uncivil behavior. However, the population may feel controlled by the government. Instead, it might be more interesting for each vehicle to have a driving assistant that allows the driver to evaluate his or her own behavior. It could also have a positive effect to recognize, disseminate and reward

empathetic actions of drivers in order to promote emotional contagion.

On the one hand, the main strength of this study is that it was conducted in a real driving environment and integrated into the daily routine of the participants. The use of driving simulators can produce distorted results. Many people feel that the driving environment is safe and drive more aggressively than they would in reality. In addition, some drivers suffer from motion sickness.

On the other hand, the main limitation of this work is the impossibility of having a control group due to the nature of the event analyzed, as virtually the whole population has been affected. Therefore, some of the observed differences could be due to factors unrelated to the pandemic, such as the weather or the age difference of the participants (1 year older). However, we have tried to minimize this problem by comparing driving in the same month (June 2019 and June 2020), following the same route and at the same time.

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VÍCTOR CORCOBA (Member, IEEE) received the M.Sc. degree from the University of Granada, Spain, and the Ph.D. degree from the University Carlos III, Madrid, Spain. He is currently an Associate Professor with the Computer Science Department, University of Oviedo, Spain. In the past, he was a Postdoctoral Researcher for telematics engineering at the University Carlos III, Madrid. He is working on wearable devices, stress detection, and intelligent systems for improving driving safety and fuel consumption. He has more than nine years of experience working in research projects related to intelligent transportation systems. He is the author of four books and more than 40 articles on energy efficiency and safety in vehicles.

XABIEL G. PAÑEDA received the Ph.D. degree from the University of Oviedo, in 2004. He is currently an Associate Professor at the University of Oviedo. His main research interests include the Internet of Things and edge-computer architectures. He has been working on these topics and others, such as HCI and learning technologies to design advanced driving assistant systems for the last ten years.

DAVID MELENDI received the Ph.D. degree from the University of Oviedo, with a focus on multimedia systems, human–computer interaction, efficient driving, *ad-hoc* networks, and intelligent transportation systems. He is currently a Computer Science Engineer and an Associate Professor with the University of Oviedo. His current research interests include systems for efficient and safe driving in combustion vehicles, edge-computer architectures, human–computer interaction devices, and advanced driving assistant systems.

LAURA POZUECO received the M.Eng. degree in Oviedo and the Ph.D. degree from Open University, both in higher telecommunications engineering. She is currently an Assistant Professor at the University of Oviedo. She is also a certified expert in several CISCO technologies, including CCNA, securing networks with cisco routers and switches, securing networks with PIX and ASA, and advanced wireless LAN for field engineers. Her current research interests include efficient driving and telecom networks and services.

ROBERTO GARCÍA received the M.Sc. degree in telecommunications from the Polytechnic University of Madrid, Spain, and the Ph.D. degree from the University of Oviedo, Spain. He is currently an Associate Professor of telematics engineering at the University of Oviedo. In the past, he was an Associate Professor for electronic technology at the University of Alcalá, Spain. His current research interests include systems for efficient and safe driving in combustion vehicles, edge-computer architectures, human–computer interaction devices, and advanced driving assistant systems.

SARA PAIVA received the Ph.D. degree from Vigo University, Spain. She is currently an Assistant Professor with the Instituto Politécnico de Viana do Castelo, Portugal. She is also a Postdoctoral Researcher at the SMIOT Research Group, University of Oviedo. She works with applied mobile computing and mobility solutions in smart cities, namely for optimized route recommendation for people with disabilities. She is currently the Vice-Chair of the IEEE Smart Cities Marketing Committee, an editor of 13 books with international publishers, and the author of more than 50 indexed publications.

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