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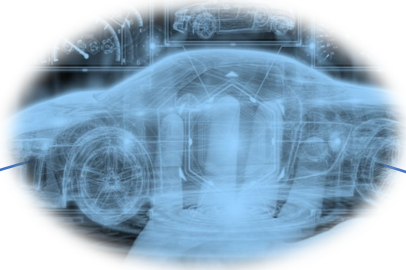

"Conducción, tecnología, intervención y riesgo vial en conductores españoles"

Programa de Doctorado

Investigación en Psicología

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*A mi padre y a mi madre, que me dieron la **vida.***
*A mi hermano y hermana, por el **viaje** de la infancia, adolescencia, juventud y madurez…*
*A mi mujer, por **elegirme**, darme alas y acompañarme **siempre,** y en especial, en los días sin noche.*
*A mis hijas, por darme el privilegio de ser y sentirme **padre** y compartir con ellas.*

*En especial, al **alma de la ciencia** en Seguridad Vial, y Director de esta Tesis, Luis Montoro, juntos casi un cuarto de siglo y "siempre nos quedará Paris…"*
*Con admiración y gratitud a mi codirector, Sergio Useche compañero incansable, positivo y luchador que hace **fácil lo imposible.***
*A mis compañeros y compañeras de trabajo, por la **entrega y apoyo continuo.***

*A todas las personas, que en algún momento formasteis parte importante de mi vida, para **construir** la persona que soy.*

*Gracias y **Carpe-Diem***

Nacho Lijarcio

Índice

1. RESUMEN **7**

2. PRESENTACIÓN **9**

2.1. MARCO DE REFERENCIA 9
2.2. MEDIDAS DE INTERVENCIÓN 13
2.3. TECNOLOGÍA, CONDUCTA HUMANA Y SEGURIDAD VIAL 15
2.3.1. Los sistemas avanzados de asistencia a la conducción. ADAS 16
2.3.2. El vehículo autónomo 21
2.4. SALUD VISUAL, CONDUCCIÓN Y RIESGOS 27
2.5. CONDUCTAS INFRACTORAS REINCIDENTES E INTERVENCIÓN EN POBLACIÓN CONDUCTORA 31

3. OBJETIVOS DEL COMPENDIO DE PUBLICACIONES **35**

4. RESULTADOS DEL COMPENDIO DE PUBLICACIONES **37**

5. PRINCIPALES CONCLUSIONES DEL COMPENDIO DE PUBLICACIONES **39**

6. INVESTIGACIÓN, COMPROMISO Y DIVULGACIÓN **41**

7. ASPECTOS ÉTICOS DE LA INVESTIGACIÓN **43**

8. REFERENCIAS **45**

9. ANEXOS **57**

9.1. ARTÍCULO 1 59
9.2. ARTÍCULO 2 73
9.3. ARTÍCULO 3 85
9.4. ARTÍCULO 4 105

1. Resumen

Lamentablemente, los siniestros de tráfico siguen siendo una de las primeras causas de mortalidad y lesividad en la población española y se han convertido en una pandemia a nivel mundial. La Organización Mundial de la Salud, calcula que alrededor de 1,35 millones de personas siguen muriendo en el mundo anualmente, a causa de los siniestros viales. Actualmente nos encontramos ante un nuevo Decenio de Acción para la Seguridad Vial 21-30, declarado por la Asamblea General de Naciones Unidas, que solicita continuar trabajando para reducir a la mitad la mortalidad y lesividad derivada de estos siniestros. Números estudios siguen afirmando que el factor humano está directamente relacionado con la siniestralidad vial y que, entre el 70% y el 90% de los siniestros, se explican por diversos errores humanos.

Al objeto de reducir la siniestralidad vial y mejorar la movilidad, esta Tesis de Psicología por Compendio de Publicaciones investiga sobre factores emergentes en seguridad vial con efectos determinantes en la población conductora española. Estos factores han sido agrupados en tres ejes temáticos relacionados con la tecnología y la automatización de los vehículos, la salud visual y las conductas infractoras reincidentes, que dieron como resultado cuatro publicaciones científicas. Para el desarrollo de las investigaciones, se elaboraron herramientas específicas de recogida de datos, se realizó investigación documental y de campo, con muestras robustas y representativas a nivel nacional y se analizaron los datos obtenidos en busca de respuestas prácticas a estos factores emergentes. En la parte final de este documento, se encuentran los artículos científicos resultantes y un resumen en castellano de cada uno de ellos.

2. Presentación

2.1. Marco de referencia

Los siniestros de tráfico siguen siendo una de las primeras causas de mortalidad y lesividad a nivel mundial. La Organización Mundial de la Salud (OMS), en su último informe *"Global Status Report on Road Safety 2018"* (WHO, 2018), afirma de manera contundente que las cifras derivadas de los siniestros de tráfico han crecido en todo el mundo, llegando a alcanzar 1,35 millones de personas muertas anualmente y más de 50 millones de personas lesionadas. Estos denominados y mal llamados "accidentes[1]" (que realmente no son accidentales), se han convertido en la primera causa de muerte no natural en personas comprendidas entre los 5 y 29 años.

Según las últimas cifras expuestas en la *"3rd Global Ministerial Conference on Road Safety*" (WHO, 2020), celebrada en la ciudad de Estocolmo en el mes de febrero de 2020, el escenario de la seguridad vial globalmente no ha mejorado mucho, ya que los siniestros de tráfico son la octava causa de mortalidad en todo el mundo y su coste llega a rondar de media el 3% de Productor Interior Bruto (PIB), de los países. En la citada conferencia y en la *Declaración de Estocolmo* (WHO, 2020), nacida de la misma, se instó a realizar un esfuerzo mundial para reducir la siniestralidad vial apoyándose en los *Objetivos de Desarrollo Sostenible 2030* (ODS 2030), llamamiento universal realizado por Naciones Unidas (ONU, 2015), para que los países y sus ciudades emprendan un nuevo camino, para mejorar la vida y las perspectivas de las personas en todo el mundo, poner fin a la pobreza, y proteger el planeta.

1 En el presente documento se utilizará de manera general, la palabra "*siniestros"* (en vez de accidentes). Solamente se utilizará la palabra "accidente" en caso que se sea citada por un autor o aparezca en alguna fuente documental a la que se hace referencia. De esta manera se contribuye a eliminar la conceptualización de "accidental, azaroso, inevitable, etc., que tradicionalmente conlleva la palabra "accidente".

Los ODS 2030, se componen de 17 objetivos mundiales y la seguridad vial se introduce más específicamente en los objetivos 3, 9 y 11, que hacen referencia a: la salud y al bienestar; a la industria, la innovación y a las infraestructuras; y a las ciudades y comunidades sostenibles respectivamente. Concretamente, dentro del objetivo 3, "salud y bienestar", la meta 3.6 insta a reducir a la mitad el número de muertos y lesiones causadas por siniestros de tráfico. La meta 9.1 del objetivo 9, "industria, innovación e infraestructuras", insta a la inversión y el desarrollo de infraestructuras regionales, nacionales y transfronterizas, así como a la investigación y al desarrollo tecnológico, en la meta 9.5. Por último, en el objetivo 11, "ciudades y comunidades sostenibles", se hace un llamamiento en la meta 11.2, para el desarrollo de sistemas de transporte seguros y la mejora de la seguridad vial.

Respaldando los ODS 2030, en agosto de 2020, la Asamblea General de las Naciones Unidas adoptó la resolución A/RES/74/299 (ONU, 2021), donde proclama el segundo *Decenio de Acción para la Seguridad Vial 21-30* (DECENIO 21-30), pues el primero, que abarcó el periodo comprendido entre 2010 y 2020, no consiguió lograr a nivel mundial la mayoría de los objetivos planteados. Este nuevo DECENIO 21-30 se articula en 12 metas mundiales, que los países acogen de manera voluntaria, y que, a nivel general, tratan sobre los principales factores de riesgo, la protección de los vulnerables y los mecanismos de prestación de servicios, políticas, legislaciones y medidas en la esfera de la seguridad vial (WHO, 2021). Es sustancial destacar que, en esta resolución como novedad, se recoge el objetivo de reducir a la mitad los lesionados derivados de los siniestros viales, como también ocurre en el objetivo 3 de los ODS 2030. Tan importante es salvar vidas, como minimizar o evitar el número de lesiones producidas en las víctimas.

Si nos centramos en Europa las cifras son algo más esperanzadoras comparándolas con las cifras mundiales, ya que entre 2010 y 2019 las muertes derivadas de siniestros de tráfico se redujeron un 22%, pero, aun así, en 2019, se produjeron 88.8647 siniestros donde 22.700 personas perdieron sus vidas y 1.153.199 quedaron heridas (EU, 2020). En términos económicos, el coste de los siniestros viales en Europa se estima en unos 280 billones de euros, lo que equivaldría a un 2% del PIB europeo (EU, 2019).

En España, los datos más básicos sobre siniestralidad son sobrecogedores. Entre 1950 y 2020 han muerto 320.527 personas en núcleos urbanos y carreteras (Fesvial, 2021). Durante los últimos cinco años se han producido de media unos 102.000 siniestros de tráfico, causando 1.700 fallecidos y alrededor de unos 8.900 heridos graves (DGT, 2019), y hay que estar atentos a la tendencia del futuro después de un periodo pospandémico, pues es posible que la siniestralidad aumente cuando exista plena movilidad.

Para prevenir y así reducir estas cifras de siniestralidad, mortalidad y lesividad, se debe investigar en seguridad vial para identificar los factores de riesgo emergentes que mayor incidencia tienen en los siniestros. Además, los gobiernos y las administraciones con competencias en esta materia, deben desarrollar políticas, implementar medidas e intervenciones en función del resultado de las investigaciones y el estudio documental.

Según el informe "*Guide for Road Safety Interventions: evidence of what works and what does not work*" (Turner, Job & Mitra, 2021), de la fundación *Global Road Safety Facility from Word Bank*, las mejores intervenciones son aquellas que se basan en el enfoque de "sistema seguro". Este es un enfoque sistémico que asume que el error humano, implicado entre en un 70% y 90% de todos los siniestros viales, se puede producir y pretende anticipar su ocurrencia y reducir sus consecuencias, en caso resultante, a través de la inclusión de factores subyacentes en la gestión de la seguridad vial como: la planificación del territorio, la promoción de transporte multimodal seguro, saludable y sostenible, las infraestructuras y la movilidad seguras, los vehículos seguros, los usuarios seguros y la atención eficaz postsiniestros. Todos estos factores deben trabajar conjuntamente para reducir la mortalidad y la lesividad y en caso que se produzca el siniestro, minimizar sus consecuencias hasta conseguir el ansiado enfoque sueco de *Visión Zero,* donde nadie debe morir o quedar lesionado en un siniestro de tráfico. Pese a ello, es importante destacar que hasta la fecha no todos los gobiernos han asumido este sistema, por lo que existen intervenciones que se han apoyado fundamentalmente en cambios legislativos, supervisión policial, medidas de control de velocidad y consumo de sustancias, así como en mejoras en la vía y en medidas de formación, sensibilización e intervención con conductores, (Staton et al., 2016).

2.2. Medidas de intervención

Al objeto de mejorar la seguridad vial y la movilidad, desde esta Tesis por Compendio de Publicaciones en psicología, se investiga en la población conductora española, de manera innovadora, sobre factores emergentes en la conducción, al objeto de conseguir anticipar y paliar las consecuencias negativas de estos y establecer medidas eficaces dentro del paradigma de "sistema seguro". Concretamente, se investiga sobre los sistemas tecnológicos asociados a la conducción y el vehículo autónomo, la importancia otorgada a la visión como factor de riesgo y la conducta vial infractora reincidente.

Estos temas de estudio han dado como resultado cuatro publicaciones científicas y se han articulado en tres ejes especialmente relevantes en el ámbito de la seguridad vial y la prevención de los siniestros de tráfico, para dar algunas respuestas a los ODS 2030 y a las metas del DECENIO 20-30, y que se detallan a continuación:

1. Tecnología, conducta humana y seguridad vial: trabajando la percepción que tiene la persona que conduce de las tecnologías de los vehículos y los sistemas de ayuda a la conducción, así como la percepción de seguridad y los niveles de confianza y usabilidad de vehículos autónomos, para el desarrollo de intervenciones eficaces que promuevan un uso seguro. El resultado ha sido dos publicaciones en revistas indexadas.
2. Salud visual, conducción y riesgos: poniendo el acento en los problemas de salud visual que puede tener la población conductora y su relación con la siniestralidad vial, para la mejora de los protocolos de exploración visual. El resultado ha sido una publicación en una revista indexada.
3. Conductas infractoras reincidentes e intervención en población conductora: determinando la importancia de las conductas infractoras reincidentes en la seguridad vial, y conociendo la percepción de riesgo que la población conductora tiene sobre los conductores infractores

reincidentes y las posibles aproximaciones de intervención. El resultado ha sido una publicación en una revista indexada.

2.3. Tecnología, conducta humana y seguridad vial

Conducir es un comportamiento humano compuesto de un complejo proceso de toma de decisiones, que requiere que la persona que maneja un vehículo, sea capaz de poner a su disposición recursos atencionales, visuales, motores y cognitivos en el entorno viario que le envuelve (Groeger, 2000; Allahyari, 2008; Strayer, Watson & Drews, 2011; Lee, Lee & Boyle, 2018). Este complejo proceso de toma de decisiones se puede ver afectado por la tecnología ya que, en función de los diferentes componentes tecnológicos, procesos de conducción automatizada y Sistemas Avanzados de Asistencia a la Conducción (ADAS), que lleve incorporado un vehículo, la percepción de seguridad y la asunción del riesgo puede verse alterada por parte de la persona que conduce (Hagl & Kouabenan 2020).

Es importante destacar que cuando en un escenario de conducción los sistemas ADAS entran en funcionamiento y se produce un periodo de maniobrabilidad o de conducción automatizada, el riesgo percibido por parte del conductor tras la detección de un potencial peligro en el tráfico, es una experiencia subjetiva (Elander et al., 1993), muy mediatizada por su estado emocional (Gandrez et al., 2020). Debemos ser conscientes que conducir no es algo funcional, sino que tiene también un valor emocional, de control, de percepción de seguridad, de conocimiento y de privacidad (Hiscock et al., 2002; Hagman, 2003), ya sea en vehículos convencionales o en autónomos (Douma & Palodichuk, 2012; Thomopoulos & Givoni, 2015; Bansal et al., 2016; Hulse et al., 2018).

Esto nos indica que, ante una misma situación vial en la que los sistemas ADAS o la conducción automatizada de un vehículo autónomo entran en funcionamiento, dos personas no percibirán el mismo riesgo y además este estará mediatizado por su estado emocional, su conocimiento, su experiencia, incluso su edad y su género. Esta afirmación se aproxima a la Teoría Homeostática del Riesgo o Teoría de Compensación del Riesgo de Gerald Wilde, (1998). Wilde afirmaba en su teoría que en el complejo proceso de toma de decisiones que es conducir un vehículo, la elección de alternativas de respuesta ante diferentes situaciones viales, viene determinada por la percepción subjetiva del riesgo vial y por el nivel de riesgo que en cada situación está dispuesto a aceptar cada conductor. Posiblemente un vehículo dotado con un importante conjunto de ADAS o con altos niveles de automatización, modificará la percepción subjetiva del riesgo debido a la percepción de seguridad que estos sistemas pueden otorgar (o no) a la conducción, por lo que tendremos que ser conscientes que estos sistemas ADAS, van a ser percibidos de manera subjetiva por parte de cada conductor en función de unas determinadas características.

De la misma manera, un vehículo autónomo o con altos niveles de automatización, tendrá diferentes niveles de percepción de seguridad, diferentes atribuciones sobre su valor para la movilidad y la mejora de la seguridad vial, así como una variabilidad de razones en su intención de uso. En definitiva, un tema de vital importancia en la seguridad vial actual y con una especial proyección en el futuro, debido al avance de las tecnologías.

2.3.1. Los sistemas avanzados de asistencia a la conducción. ADAS

Adentrándonos en la relación entre la conducta humana y la tecnología aplicada a la conducción, es importante comenzar explicando en esta primera investigación del Compendio los sistemas ADAS, para posteriormente desarrollar el concepto de vehículo autónomo. Las siglas en inglés ADAS (Advanced Driver Assistance Systems) significan Sistemas Avanzados de Asistencia a la Conducción, tal como se ha expuesto anteriormente, y hacen referencia a los componentes tecnológicos o sistemas electrónicos incorporados en el vehículo, destinados a optimizar y mejorar la interacción entre la conducta humana y el vehículo mediante diferentes sistemas o mecanismos de asistencia al conductor (ISO, 2013; SAE, 2003).

En la actualidad, existen un número importante de estos sistemas en el mercado y cada uno tiene diferentes objetivos y funciones, aunque todavía no se ha creado una universalización en su nomenclatura, por lo que se puede encontrar con mucha frecuencia, varios nombres para denominar un mismo sistema. Para el desarrollo de esta investigación, se utilizó la categorización y tipología sugerida por la *American Automovil Asociation*, (2019), (AAA, por sus siglas en inglés), con las veintiocho ADAS de mayor comercialización y difusión en el mercado y que se presentan en la Tabla 1.

Tabla 1. Principales ADAS presentes en el mercado según la Asociación Americana del Automóvil

Alertas de colisión / riesgo de colisión	
Alerta de colisión frontal	Detecta, a través del análisis de movimiento del vehículo y del entorno vial próximo, una posible colisión (cercana o inminente), mientras el vehículo está en movimiento y alerta al conductor.
Advertencia de salida de carril	Supervisa la posición del vehículo dentro del carril de conducción y avisa al conductor cuando el vehículo se acerca o cruza los marcadores de carril.
Detección de punto ciego/muerto	Detecta vehículos que circulan en carriles adyacentes cuya visibilidad es limitada, y alerta al conductor sobre su presencia.
Advertencia de colisión (peatones / ciclistas)	Detecta peatones, ciclistas y otros usuarios frente al vehículo, avisando al conductor sobre su presencia para realizar la maniobra de frenado.
Cámara trasera	Detecta los vehículos que se acercan por los lados y la parte trasera del vehículo mientras va en marcha atrás, y alerta al conductor.
Medición de distancia de seguridad	Detecta automáticamente otros vehículos u obstáculos y, en base a una evaluación de campo automática, avisa al conductor para que se mantenga a una distancia mínima de seguridad.
Sistemas de detección de fatiga	Ayuda a prevenir siniestros causados por la fatiga o somnolencia del conductor, al monitorear sus patrones faciales, oculares y/u otros parámetros fisiológicos.
Mitigación de la colisión	
Frenado automático de emergencia (AEB)	Detecta posibles colisiones con el vehículo en marcha, y realiza automáticamente la frenada para evitar o disminuir la gravedad del impacto.
Control antivuelco	Posibilita la estabilidad al vehículo, para reducir el riesgo de vuelco después de un posible choque o pérdida de control en movimiento.
Frenado de emergencia post-colisión	Detiene automáticamente el vehículo inmediatamente después de un choque, con el objetivo de evitar un segundo impacto contra otro vehículo u obstáculo.
Sistema proactivo de protección de ocupantes	Detecta cuando se realiza una maniobra de emergencia y prepara el vehículo y sus sistemas de retención de ocupantes para una posible colisión.
Tareas de conducción automatizadas	
Control de crucero adaptativo	Controla la aceleración y/o el frenado para mantener una distancia adecuada entre el vehículo y aquel que se encuentre enfrente, modulando la velocidad si es necesario.
Asistente de mantenimiento de carril	Controla la dirección para mantener el vehículo dentro del mismo carril de conducción. Puede evitar que el vehículo salga del carril, o bien centrar continuamente el vehículo en este.
Limitador de velocidad	Informa al conductor sobre el límite de velocidad del tramo vial y -según una configuración previa proporcionada por el conductor-, limita automáticamente la velocidad de marcha del vehículo.
Control de descenso en pendientes	Permite un descenso controlado en terrenos inclinados o irregulares sin necesidad de que el conductor opere los frenos, activándolos para desacelerar automáticamente el vehículo.
Iluminación y visibilidad	
Iluminación automática	Aumenta la visibilidad al encender los faros automáticamente cuando se detecta una escasa iluminación en la vía, por debajo de los mínimos óptimos para la conducción segura.
Luces antiniebla dinámicas	Proporcionan una iluminación adicional en las curvas. Cuando el conductor gira el volante o lo indica con el intermitente, la luz antiniebla delantera gira hacia esta dirección.
Control de luz adaptativo	Ayuda a los conductores a ver mejor y más lejos (con mayor profundidad), en la oscuridad. Permite que los faros giren para iluminar mejor la carretera en puntos críticos como curvas o terrenos inclinados.
Sensor de lluvia	Facilita la visión al detectar las gotas de agua en el parabrisas y activar automáticamente los limpiaparabrisas.
Ayudas misceláneas para la conducción	
Navegación GPS	Proporciona indicaciones visuales y auditivas en tiempo real para la elección adecuada de rutas, y proporciona datos útiles sobre el tráfico para optimizar el tiempo y la seguridad del recorrido.
Sistema de estacionamiento automático (manos libres)	Ayuda al conductor a estacionar en paralelo. En sistemas de alta complejidad (mayor automatización), realiza completamente la tarea de estacionamiento del vehículo.
Detección de obstáculos laterales	Alerta al conductor sobre la presencia de posibles obstáculos u otros usuarios viales en el momento de abrir las puertas del vehículo.
E-Call: llamada de emergencia y asistencia localizada	Realiza automáticamente una llamada de emergencia si el vehículo se ve involucrado en un siniestro grave, a la vez que proporciona detalles específicos sobre su ubicación y la gravedad del incidente, para facilitar la ayuda y atención al conductor y/o los ocupantes.
Control de presión de neumáticos	Monitorea la presión de aire dentro de los neumáticos, dando alertas cuando las ruedas revientan o tienen un nivel de presión inadecuado.
Alertas inteligentes para mantenimiento / comprobaciones mecánicas	Informan al conductor sobre posibles fallos o daños en el vehículo que deben revisarse, a través de una alerta basada en el autodiagnóstico.
Apertura automática de puertas (por teléfono inteligente)	Ofrece una opción de entrada al vehículo sin llave y sensores de movimiento para abrir automáticamente cuando el conductor se aproxima a este, a través de una conexión en vivo (normalmente a través del protocolo NFC) con un teléfono inteligente.
Sistemas de detección de señal	También conocido como *Traffic Sign Recognition* (TSR, por sus siglas en inglés). Reconoce las señales de tráfico (p. ej., límites de velocidad o "stops") y muestra al conductor la información reconocida en un panel de visualización.
Control por gestos	Facilita el uso de sistemas integrados a través de comandos basados en la voz y movimiento del conductor, reduciendo la probabilidad de causar un siniestro relacionado con la distracción que implica una manipulación física mientras se conduce.

Fuente: American Automobile Assocation (AAA, 2019), y VIDAS Seguridad Vial y ADAS (FESVIAL 2021)

Los estudios recientes nos indican, dentro de sus limitaciones, los beneficios de estos sistemas para la mejora de la seguridad vial, especialmente en los países industrializados, en los cuales su implementación y uso en la conducción diaria es sustancialmente alta, sobre todo si se ofrecen ya integrados en el momento de la compra del vehículo (Collet & Musicant, 2019). En lo relativo a la siniestralidad, según la literatura científica, estos sistemas podrían ayudar a mitigar o prevenir aproximadamente el 40% de todos los siniestros, el 37% de todas las lesiones tanto de conductores como pasajeros y el 29% de todas las muertes (Benson et al., 2018).

Otro estudio relevante afirma que en Estados Unidos se podrían salvar más de 10.000 vidas al año si algunos sistemas ADAS como el frenado automático de emergencia, la advertencia de cambio de carril y los sistemas de detección de puntos ciegos, estuvieran instalados en todos los vehículos y fueran completamente efectivos en todas las situaciones (Ecola et al., 2018).

Centrándonos en la población conductora y en función de su tipología, estos sistemas estarían encargados fundamentalmente de reducir los riesgos derivados de una baja atención al ecosistema del tráfico, de un déficit en la detección de los riesgos viales o de problemas derivados de la maniobrabilidad, por parte del conductor. Dicho de otra manera, desde el punto de vista "preventivo" y del paradigma del "sistema seguro" estas tecnologías actuarían directamente sobre tres problemas fundamentales de siniestralidad relacionados con el factor humano: las distracciones (o falta de atención), la fatiga y la somnolencia.

Sin embargo, la evidencia reciente ha demostrado que, incluso cuando estas tecnologías están integradas en los vehículos, solo un porcentaje limitado de conductores está debidamente informado sobre el funcionamiento, la utilidad y el potencial real de los ADAS en la seguridad vial (Meiring & Myburgh, 2015; Souders et al., 2018). Diversos estudios indican también que existen importantes barreras latentes entre los conductores para el uso adecuado de los ADAS, así como otros automatismos que pueden estar limitando su potencial funcionalidad. Estas barreras abarcan desde el desinterés, la molestia, la interferencia o el desconocimiento, hasta la posible falta de comprensión de los mismos (Fisher, Pollatsek & Pradhan, 2006; Aksan et al., 2015; Liu et al., 2017;

Kidd et al., 2017; Hannah et al., 2018; Weiss et al., 2018), incluso la dificultad que algunos usuarios tienen en la comprensión de los manuales explicativos que vienen en los vehículos (Oviedo-Trespalacios, Tichon & Briant, 2021).

Para eliminar estas barreras, será de gran utilidad identificar las variables y motivaciones personales y los "grupos clave" de conductores españoles, a los cuales deba dirigirse una mayor atención y recursos para que utilicen los sistemas de asistencia a la conducción, ya que puede ser beneficioso para mejorar su "calidad de vida" en general, y para su seguridad vial, en particular. Concretamente, podría ser el caso de las personas más mayores (Dotzauer et al., 2015; Collet & Musicant, 2019; Wali et al., 2019), o los conductores jóvenes, que, en términos de cantidad y alcance, constituyen uno de los grupos con mayores probabilidades de beneficiarse de las ventajas que ofrecen estos sistemas tecnológicos (Hannan et al., 2018).

Resulta llamativo destacar, según las evidencias, que la "aceptación" de los sistemas avanzados de ayuda a la conducción tiende a ser mucho menor entre los conductores de edades tempranas en comparación con conductores de edades medias y/o adultos mayores, en otras palabras: los conductores jóvenes estarían dispuestos a gastar menos dinero que los más mayores por la equipación de ADAS en sus vehículos (Souders, Best & Charness, 2017). Esto parece ser debido a que los conductores jóvenes (en comparación con los mayores), tienden a confiar más en sus propias capacidades para conducir que en los sistemas automatizados de ayuda a la conducción (Mynttinen et al., 2009; Lijarcio et al., 2019), y también piensan que en los sistemas ADAS pueden aparecer fallos funcionales y de estabilidad que les pongan en riesgo (Hannan et al., 2018; Weiss et al., 2018; Montoro et al., 2019). En definitiva, los jóvenes confían más en sus propias capacidades como conductores que en las tecnologías de asistencia a la conducción.

En los últimos años, los sistemas ADAS también se han incluido dentro de la Tecnología Inteligente de Vehículos (IVT's, por sus siglas en inglés), desarrollada para llegar a la conducción automatizada de alto nivel, gestionada principalmente por una inteligencia artificial instalada en un vehículo autónomo. El objetivo de las IVT´s es mejorar y automatizar la actividad de conducción y proteger a los usuarios de vehículos motorizados de riesgos y siniestros potencialmente evitables en la carretera (Souders, Best & Charness, 2017). Del mismo modo, la automatización de la conducción en situaciones peligrosas, a través de vehículos autónomos, es una oportunidad para la mejora progresiva de la seguridad vial, a través de la reducción de la influencia de las causas atribuibles a los factores humanos en los siniestros viales (Davidse, 2006; Spicer et al., 2018).

2.3.2. El vehículo autónomo

Existen diferentes conceptualizaciones y definiciones sobre el vehículo autónomo y de la misma manera que ocurre con los sistemas ADAS, aparece cierta incoherencia en la terminología empleada por la industria y la ciencia, utilizando palabras como vehículo autónomo[2], vehículo automatizado o robótico, conducción autónoma o automatizada o conducción sin conductor, entre otras, para referirse a la misma idea o concepto.

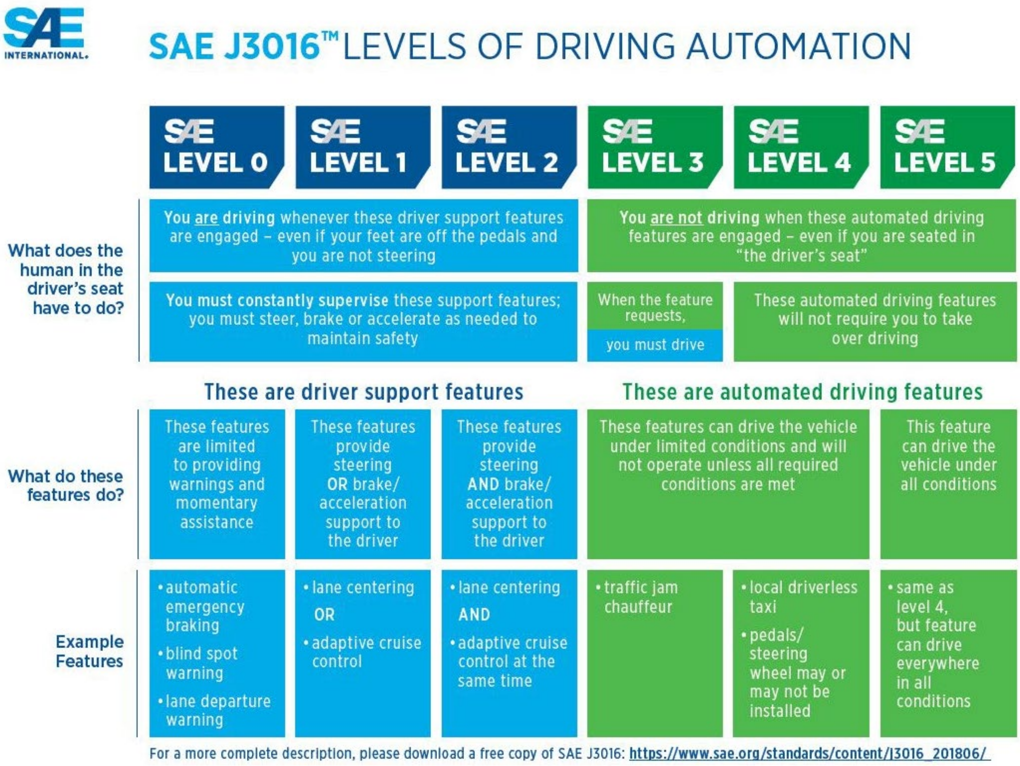
Remontándonos en la historia, una de las primeras definiciones aparece en el documento An Active Senso Controller for the ALVINN (Autonomous Land Vehicle in a Neural Network, Autonomus Driving System, de Sukthankar, Pomerleau & Thorpe (1992), realizado para el Instituto de Robótica de la Universidad de Mellon. En este caso los autores afirmaban que un vehículo autónomo, es aquel capaz de emular las capacidades humanas de manejo y conducción. Percibirá el entorno y tomará decisiones en función de aquellas señales que advierta y considere de relevancia para la consecución de los objetivos para los que el vehículo haya sido programado. Definiciones más recientes como la del Department of Transportation's National Highway Traffic Safety Administration (NHTSA, 2013), comienzan a eliminar la intervención de la conducta humana afirmando, que un vehículo autónomo es aquel que su funcionamiento ocurre sin la intervención directa del conductor para controlar la dirección, la aceleración y el frenado y está diseñado para

[2] En el desarrollo de esta investigación se utilizó el termino de vehículo autónomo (autonomous vehicles AV´s).

que no se espere que el conductor controle constantemente la circulación por la carretera mientras opera en modo de conducción autónoma.

En la actualidad la conceptualización y definición más aceptada, tanto por la industria como por la ciencia, sobre vehículos autónomos y niveles de automatización es la propuesta por la Society of Automotive Engineers de Estados Unidos (SAE, por sus siglas en inglés), y en ella también se "elimina" la conducta humana, incluso la presencia de un ser humano. Esta organización, enfocada al desarrollo de los estándares tecnológicos para todo tipo de vehículos, define el vehículo autónomo como aquel que es capaz de detectar su entorno y operar sin participación humana. No requiere que el humano tome el control del vehículo en ningún momento y tampoco se requiere que esté presente en el mismo. Un vehículo autónomo puede ir a cualquier lugar al que vaya un automóvil tradicional y hacer todo lo que hace un conductor humano experimentado (SAE, 2018). También distingue, como se observa en la tabla 2 una serie de niveles que permiten cuantificar el progreso en la automatización de los vehículos, proponiendo una escala que mide su autonomía en seis niveles que van desde cero (automatización inexistente con necesidad de presencia humana en todo momento) hasta un nivel cinco (vehículo totalmente autónomo sin necesidad de presencia humana, como conductor), (SAE, 2021).

Tabla 2. Clasificación de los niveles de conducción automatizada



Fuente: SAE 2021

Según algunas estimaciones, para el año 2030 se espera que los vehículos con un nivel de automatización cuatro y cinco (total automatización), circulen mayoritariamente por áreas urbanas (TechPats, 2018), y además representen un 30% del parque automovilístico (McKinsey & Co, 2016; Deloitte, 2018), una previsión, que no parece vaya a cumplirse. Diferentes estudios están de acuerdo en afirmar, que los vehículos autónomos serán una revolución en el concepto de transporte y conectividad y ofrecerán grandes beneficios en la gestión de la movilidad, la economía y la seguridad vial, reduciendo los siniestros, las lesiones y los muertos causados por el factor humano, tanto de conductores como ciclistas, automovilistas y peatones (NHTSA, 2013; Schoettle & Sivak, 2014; Fagnant & Kockelman, 2015; Pettigrew, Talati & Norman, 2018). También hay evidencias sobre el impulso existente hacia una movilidad limpia y de bajas emisiones que proporcionarán estos vehículos (Givoni & Banister, 2013). Supuestamente con este tipo de vehículos se contribuirá a cumplir los ODS 2030, se eliminará el error humano y el enfoque de *Vision Zero* será una realidad, aunque frente a este planteamiento también existen investigaciones que califican de excesivo "optimismo tecnológico" este enfoque.

Pero, a pesar de todos los beneficios descritos anteriormente y algunos otros, los siniestros e incidentes ocurridos con este tipo de vehículos, las consecuencias derivadas de los mismos y los fracasos, por parte de las marcas, en el alcance de alguno de sus objetivos tecnológicos publicados en medios de comunicación, están limitando la intención de uso en la población de este tipo de vehículos (Haboucha, Ishaq & Shiftan, 2017), convirtiéndolos en un dilema social, involucrando a las diferentes partes interesadas, como diseñadores, fabricantes, clientes potenciales, gobiernos y legisladores (Bonnefon, Shariff & Rahwan, 2016; Dixit, Chand & Nair, 2016).

De la misma manera que ocurría con los sistemas ADAS, las evidencias científicas indican también que existe una falta de aceptación de los vehículos autónomos debido, en gran medida, al desconocimiento que la población tiene sobre los mismos y sobre las ventajas que para la seguridad vial pueden tener frente a los vehículos convencionales (Bansal & Kockelman, 2017).

Esta falta de aceptación se apoya principalmente en ideas que hacen referencia a la dependencia tecnología y la pérdida de autonomía y control por parte del operador humano. Además, algunos grupos poblacionales asocian la dependencia tecnológica con situaciones peligrosas que pueden comprometer el bienestar de las personas (Kluge, Kowalewski & Ziefle, 2015; Brell, Philipsen & Ziefle, 2018), otros con la pérdida total del control (Howard & Dai, 2014), debido a problemas como caída del sistema, fallos informáticos o ataques de "hackers" informáticos (Douma & Palodichuk, 2012; Howard & Dai, 2014; Fraedrich & Lenz, 2014; Viereckl et al., 2015; Bansal, Kockelman & Singh, 2016; Garfinkel, 2017; Nunes, Reimer & Coughlin, 2018; Hulse, Xie & Galea, 2018).

Otras de las limitaciones secundarias para la adquisición de estos vehículos son aquellas que van relacionadas con los costes, pues se tiene una creencia que tanto el mantenimiento, los componentes de hardware y software y las tarifas de uso de las carreteras serán muy elevados (Casley, Quartulli & Jardim, 2013; Friedrich & Lenz, 2014; Howard & Dai, 2014; Varghese &

Boone, 2015; Fishman & Davies, 2016). Algunos autores también afirman que existen preocupaciones en la población conductora a la hora de circular sobre todo en situaciones de tráfico mixto, donde convivan diferentes vehículos con diferentes niveles de automatización (Thomopoulos & Givoni, 2015), incluso por parte de los peatones, como usuarios vulnerables, existe incertidumbre a la hora de cruzar delante de un vehículo autónomo (Kaye et al., 2022).

La edad, también parece tener un papel decisor ya que, a mayor edad y a mayor distancia de las generaciones más tecnológicas, existe una menor aceptación de la conducción automatizada, debido a la poca experiencia, conocimiento y confianza en la tecnología, (Abraham et al., 2016; Lee et al., 2017). Otros investigadores también ponen de manifiesto, que el género impacta considerablemente en la percepción y aceptación del riesgo en el uso de tecnologías relacionadas con la movilidad (Ziefle et al, 2014; Hohenberger, Spörrle & Welpe, 2016).

Queda evidenciado que la aceptación de la conducción autónoma por parte del usuario, es fundamental para que esta se convierta en una parte realista del transporte futuro (Panagiotopoulos & Dimitrakopoulos, 2018; Xu et al., 2018), y que la mayor barrera para la aceptación generalizada de la conducción autónoma no es de naturaleza técnica sino más bien psicológica (Shariff et al., 2017; Xu et al., 2018), y además variables como la edad y el género van a ser determinantes en la percepción de seguridad, los valores atribuidos y la intención de uso de esta tecnología.

En definitiva, comprender las intenciones y actitudes del individuo hacia la conducción autónoma, es crucial para obtener un conocimiento más profundo de los factores de aceptación relacionados (Buckley, Kaye & Pradhan, 2018; Merfeld, Wilhelms & Henkel, 2019; Nordhoff et al., 2019), y para el éxito de esta innovación (Choi & Ji, 2015; Nordhoff et al., 2016; Xu et al., 2018).

Por todo lo expuesto anteriormente, este estudio pretende conocer y determinar en los conductores españoles, teniendo en cuenta el género y la edad, cómo los sistemas ADAS pueden mejorar la conducción a través de su conocimiento, aceptación, confianza y usabilidad y cuál es la percepción de seguridad, valores asociados e intención de uso de los vehículos autónomos.

2.4. Salud visual, conducción y riesgos

De la misma manera que el conocimiento y percepción de la tecnología tienen un gran efecto en los niveles de seguridad de un conductor, existen variables de salud como la visión, que deben ser estudiadas en mayor profundidad para conocer sus repercusiones en la seguridad vial. Una buena visión permite a los conductores realizar con precisión las tareas relacionadas con la conducción y tomar decisiones seguras a manos de un vehículo. Sin embargo, y según el informe World Report on Vision de la Organización Mundial de la Salud (WHO, 2019), al menos 2,20 millones de personas en todo el mundo tienen problemas de visión importantes y estos pueden repercutir en la conducción. Además, las enfermedades visuales afectan a la calidad de vida de las personas y a la realización de diferentes actividades cotidianas, como el uso de maquinaria o la conducción de vehículos a motor (Bron et al. 2010; Kedar, Ghate & Corbett, 2011).

Recientemente, la United Nations Road Safety Trust Fund (UNECE), puso en valor la importancia del cuidado de la visión para una buena conducción dentro de sus objetivos para mejorar la siniestralidad vial. En su declaración, este organismo instó a los gobiernos y a la comunidad científica a potenciar la investigación y el cuidado de la salud visual y a difundir su relación con la seguridad vial, promoviendo la concienciación, la innovación, el acceso a las revisiones visuales y a la vigilancia de la visión a nivel mundial. Además, en la 82nd Annual Session of the Inland Transport Committee (ITC, por sus siglas en ingles), la plataforma reguladora para el transporte por carretera de las Naciones Unidas, impulsó estas recomendaciones haciendo una especial mención a los profesionales de la conducción (UNECE, 2019). En la misma línea, otros organismos mundiales como la Fédération International de l'Automobile (FIA, por sus siglas en francés), ha desarrollado medidas preventivas específicas para paliar el desconocimiento entre la salud visual y la seguridad vial, al mismo nivel que lo realiza con otros factores de riesgo como el uso del cinturón o el respeto a los límites de velocidad. Concretamente, junto a ESSILOR (líder mundial en oftalmología y el desarrollo de lentes), la FIA ha realizado una campaña internacional sobre la importancia de la salud visual y la revisión de la visión para la prevención de los siniestros en carretera (FIA, 2017).

Como se ha comentado anteriormente, conducir es una tarea compleja y la visión tiene un papel fundamental, ya que es la fuente de información más importante para la toma de decisiones del conductor (Owsley & McGwin, 2010). Según numerosos estudios, entre el 80% y 90% de la información necesaria para conducir con un nivel adecuado de seguridad, se recoge a través de nuestros ojos (Hyerle, 2000). De hecho, existen evidencias que nos indican que los conductores que tienen problemas visuales sufren siniestros viales más graves (TRB, 2004; Erdogan, et al. 2011). Pero pese a estos datos, la población tiene percepciones y creencias erróneas sobre la salud visual, asumiendo que existe problemas "leves o comunes" que afectan a la mayoría de personas como, por ejemplo, la miopía, la hipermetropía y el astigmatismo, por lo que no representan un riesgo importante para la seguridad vial, cuando la evidencia científica nos indica todo lo contrario (Wood et al., 2012; Schallhorn et al.,2010).

Los estudios experimentales han demostrado que los conductores con una agudeza visual[3] inferior a 0,7, tienen una tasa de siniestros un 15% mayor en comparación con los conductores cuya agudeza visual, es igual o mayor que 0,7 (Elvik & Vaa, 2004). Los mismos estudios también indican que en los conductores que sufren mayor sensibilidad al deslumbramiento o tienen problemas de visión nocturna, su tasa de siniestros puede aumentar hasta un 60%, en situaciones con poca iluminación o conducción nocturna (Elvik & Vaa, 2004).

En este contexto es necesario destacar, que el envejecimiento de la población también es determinante para padecer mayores problemas visuales que pueden comprometer la seguridad vial

[3]La agudeza visual según el Reglamento General de Conductores vigente en este momento afirma que; *se debe poseer, si es preciso con lentes correctoras, una agudeza visual binocular de, al menos, 0,5.* (Reglamento General de Conductores Orden PRE/2356/2010, de 3 de septiembre, por la que se modifica el Anexo IV del Reglamento General de Conductores, aprobado por el Real Decreto 818/2009, de 8 de mayo).

(Kaleem et al.,2012; Gruber, Mosimann & Nef, 2013). De hecho, las personas mayores tienen, entre otros problemas, tasas significativamente más bajas de atención visual, un procesamiento más lento de la información y una menor agudeza visual (Brinig et al., 2007).

Con todo lo expuesto anteriormente y según las evidencias científicas se podría afirmar que los problemas relacionados con la visión están presentes, directa o indirectamente, entre el 5% y el 20% de todos los siniestros viales. Además, y aunque existe un alto consenso sobre el hecho de que la visión constituye un factor clave en este campo, como se ha justificado, desde las administraciones y entidades competentes esta no se evalúa de manera adecuada y tampoco se desarrollan medidas preventivas para que los usuarios sean conscientes de este problema. En la mayoría de los casos, las intervenciones se reducen a una mínima exploración visual para la obtención o renovación del permiso de conducir, en un centro de reconocimiento de conductores. Existe una laxitud en los protocolos y los test aplicados en estas intervenciones, no por la falta de rigurosidad de los mismos, sino más bien por la evaluación, ya que normalmente la exploración, se acaba ciñendo simplemente a la agudeza visual, capacidad necesaria pero no suficiente, como se ha justificado, pues existen otros componentes en la visión que también juegan un papel crucial en la conducción segura de vehículos (Salvia, et al., 2016).

En muchos países del entorno europeo, es obligatoria una revisión psicofísica para la obtención o renovación del permiso, donde la exploración visual se establece como un requisito (Grobbel et al., 2016). Sin embargo, aunque existe un marco legislativo, no demasiado clarificante, como se muestra a continuación, esta exploración tiene diferentes protocolos en cada país, no existiendo una estandarización de la misma y con evaluaciones muy básicas que dejan fuera, como se comentaba, algunos parámetros visuales muy importantes para la conducción, (Owsley & McGwin, 2010; Montoro et al., 2020),

En primer lugar, la legislación internacional que hace referencia a la visión, es la Directiva Europea sobre el Permiso de Conducción (EU, 2006), la cual indica que los candidatos a un permiso de conducir deben someterse a las exploraciones apropiadas, entre ellas la visión, y si se sospecha que no se posee una capacidad visual adecuada, el sujeto deberá ser examinado por una autoridad competente, en la que se deberá prestar atención a la agudeza visual, al campo visual, a la visión nocturna y a las enfermedades oculares progresivas. También refleja cuáles son las limitaciones específicas para la agudeza visual, el campo visual y algunas enfermedades, pero la Directiva no contiene mayores indicaciones sobre qué más se debe explorar, cómo debe hacerse y cómo se ha de intervenir.

En segundo lugar, en la legislación española, concretamente el Reglamento General de Conductores (BOE 2010a), recoge las indicaciones de la Directiva y refiere tanto las áreas de exploración visual como los criterios de aptitud, las posibles adaptaciones, restricciones y otras limitaciones derivadas de problemas visuales, pero no hace mención sobre materia preventiva ni discrimina por grupos de edad. También, el Reglamento de Centros de Reconocimiento (BOE 2010b), recoge los elementos y aparataje necesarios para la realización de una exploración visual sin hacer mención a los problemas de salud visual, su cuidado o prevención.

Por lo tanto, para determinar la importación de la salud visual en la población conductora, en esta investigación se explora la percepción que tienen los conductores españoles sobre la importancia de la salud visual y se evalúan tres elementos clave de la visión para la conducción de vehículos, siendo estos: la agudeza visual, que nos indica la calidad visual del usuario, tanto con luz diurna como con poca luz; el campo visual, que nos indica los objetos que podemos ver en la visión lateral (periférica), mientras enfocamos a un punto central; y la recuperación tras un deslumbramiento, que constituye un mecanismo que puede dificultar la detección de otros usuarios o elementos importantes del entorno prolongando de manera peligrosa la latencia de los tiempos de reacción

2.5. Conductas infractoras reincidentes e intervención en población conductora

Como último objetivo de este compendio, se investiga sobre los conductores infractores reincidentes pues son un factor emergente y recurrente en la seguridad vial. Es importante destacar que la comisión de faltas, infracciones o delitos de manera reiterativa por una persona, es un problema de difícil solución pues indica que la amonestación, falta o castigo aplicado no es eficaz para reconducir la conducta. La persona muestra una resistencia al cambio volviendo a incumplir, a veces, en varias ocasiones la norma establecida.

Los estudios clásicos de psicología del aprendizaje, a mediados del siglo XX ya manifestaban que la aplicación de un castigo proporcionado, cuando se incumple una norma, disminuye la probabilidad de que la conducta se repita (Skinner, 1950), pero no existen garantías de que esta conducta no vuelva a ocurrir en otro espacio o tiempo determinado. Concretamente en el caso de las normas de tráfico, según un estudio del Instituto Crimina, más que la magnitud del castigo, lo que parece influir en el comportamiento de muchos infractores reincidentes, es la certeza de que van a ser castigados y la probabilidad de que incumpliendo pueden sufrir un siniestro. Esta influencia puede encontrarse mediatizada, entre otras cosas, por el comportamiento que tiene el grupo cercano y la percepción individual de si es justo o no su incumplimiento y la magnitud del castigo asociado (Ortuño & Llinares, 2015).

Antes de avanzar más, es importante definir el concepto de reincidencia. Estudiando la literatura científica, aparecen múltiples autores y aproximaciones que lo desarrollan, tanto desde el punto de vista de la legislación como desde la intervención. Según Maltz (1984), la reincidencia en el contexto legal de criminología puede definirse como: "la reversión del comportamiento delictivo de un individuo después de haber sido condenado por un delito anterior, sentenciado y (presuntamente) corregido", aunque según especifica el propio Maltz, esta definición puede no cumplirse en algunos casos si el sistema judicial no dispone de todos los datos sobre el penado. Estudios posteriores indican que la reincidencia debe entenderse como el retorno de un penado a un proceso de custodia (SCRGS 2006), o también consiste en volver a realizar un comportamiento delictivo después de recibir una sanción o intervención por el mismo o cumplir un programa (Elderbroon & King, 2014; Hunt & Dumville, 2016). Es evidente que en la conceptualización de la reincidencia debe haber una reiteración de una acción o conducta, pero no se han encontrado criterios homogéneos sobre la tipología de la conducta reincidente (la conducta debe ser la misma u otra diferente), o sobre la frecuencia de realización (cuántas veces ha de realizarse una conducta para entenderse como reincidente) y en qué espacio temporal (cuánto tiempo ha de transcurrir entre una conducta y otra para considerarse una conducta reincidente).

En nuestro país, la reincidencia tiene su origen en el derecho penal como agravación de la responsabilidad criminal. Según la Ley Orgánica 10/1995, de 23 de noviembre, del Código Penal, en el artículo 22. 8ª (BOE, 1995), se indica que: "hay reincidencia cuando al delinquir, el culpable haya sido condenado ejecutoriamente por un delito comprendido en el mismo título de este Código, siempre que sea de la misma naturaleza" es decir, debe existir una condena firme dictada anteriormente a la fecha de la comisión del segundo delito y que ambos estén comprendidos en el mismo título del Código Penal.

También aparece el concepto de reincidencia como ampliación de la pena a cumplir por el condenado en el punto 5 del artículo 66 del Código Penal que afirma que: "cuando concurra la circunstancia agravante de reincidencia con la cualificación de que el culpable al delinquir hubiera sido condenado ejecutoriamente, al menos, por tres delitos comprendidos en el mismo título de este Código, siempre que sean de la misma naturaleza, podrán aplicar la pena superior en grado a la prevista por la ley para el delito de que se trate, teniendo en cuenta las condenas precedentes, así como la gravedad del nuevo delito cometido" (BOE, 1995).

En este caso, la ley penal española hace referencia a reincidencia como la reiteración de una conducta, incluso concretiza la tipología y frecuencia de ocurrencia (tres delitos de la misma naturaleza), como agravante de una pena, pero realmente no precisa de manera específica, el espacio temporal en que debe transcurrir.

La condición de reincidente también aparece en la administración, concretamente en la Ley 40/2015, de 1 de octubre, de Régimen Jurídico del Sector Público (BOE, 2015b), donde en el artículo 29 sobre el principio de proporcionalidad, se indica en el apartado 3d: "la reincidencia, por comisión en el término de un año de más de una infracción de la misma naturaleza cuando así haya sido declarado por resolución firme en vía administrativa". En este caso, la legislación sí que determina la frecuencia de ocurrencia, la tipología y el espacio temporal: más de una infracción de la misma naturaleza en un año.

En el contexto de seguridad vial, según el Real Decreto Legislativo 6/2015, de 30 de octubre, por el que se aprueba el texto refundido de la Ley sobre Tráfico, Circulación de Vehículos a Motor y Seguridad Vial (BOE, 2015a), solo menciona al reincidente en el artículo 81, afirmando que: "la cuantía de las multas establecidas en el artículo 80.1 y en el anexo IV podrá incrementarse en un treinta por ciento, en atención a la gravedad y trascendencia del hecho, los antecedentes del infractor y a su condición de reincidente, el peligro potencial creado para él mismo y para los demás usuarios de la vía y al criterio de proporcionalidad". En este caso el legislador no "clarifica" la condición de reincidente.

Para finalizar, en la Ley 17/2005, de 19 de julio, por la que se regula el permiso y la licencia de conducción por puntos y se modifica el texto articulado de la ley sobre tráfico, circulación de vehículos a motor y seguridad vial (BOE, 2005), en la exposición de motivos el legislador hace referencia a conductores multireincidentes y comportamientos reincidentes, sin que se clarifique estos conceptos, por lo que las leyes en materia de tráfico y seguridad vial, contemplan la reincidencia pero no clarifican cuales son las condiciones que se deben cumplir para ser un reincidente. Cabe destacar que, es la primera vez que se utiliza en la legislación en materia de tráfico y la seguridad, el concepto de "multireincidente", aunque como indica Payne (2007), en la literatura no existen diferencias específicas sobre el concepto de reincidencia y la multireincidencia, aunque independiente del contenido de su definición, no debemos olvidar que a pesar de sus dis/continuidades, la reincidencia y, en particular, la multirreincidencia será, si no lo es ya, uno de los principales indicadores del nivel de eficacia de las estrategias y políticas en movilidad y seguridad vial (Lijarcio et al., 2015).

Una vez contextualizado la reincidencia en el marco legal es importante determinar cuáles podrían ser las variables involucradas en la población conductora y cuál es la percepción del riesgo que se tiene sobre estas conductas y estos conductores. Existen estudios que ya indican que la población delincuente común, comete más conductas infractoras y delictivas de tráfico (Ross, 1992; Junger, Terlouw &Van de Heijden, 1995; Broughton 2007), incluso con una frecuencia de tres o cuatro veces superior a la de la población general (Middendorff, 1981), y además con resultado de lesiones graves o fatales (Brace et al., 2009). Broughton (2007), en su estudio además identificó que los conductores varones (hombres) con delitos clásicos, eran más propensos que los no delincuentes a la comisión de delitos de alcoholemia. De la misma manera, Ortuno y LLinares (2014), en su estudio sobre conductas criminales comunes y delincuencia vial en la provincia de Alicante, detectaron que el perfil del delincuente vial era de: hombres, con una edad alrededor de los 30 años.

Esto nos indica que variables como el género masculino, la edad y el haber cometido otras conductas delictivas relacionadas o no con la seguridad vial, pueden ser determinantes de la reincidencia y de la percepción que el resto de conductores puede tener sobre el conductor reincidente, pero se debe averiguar si existe alguna evidencia más. Po ello, el estudio de este último eje del compendio de publicaciones, pretende determinar qué tipo de variables podrían ser predictores de la percepción del riesgo de los conductores reincidentes, centrándose en el género como factor clave diferenciador, para en un futuro poder desarrollar intervenciones más eficaces en el ámbito de las conductas infractoras viales.

3. Objetivos del Compendio de Publicaciones

El objetivo general de esta Tesis por Compendio de Publicaciones, es el estudio de factores emergentes en la conducción de vehículos en la población conductora española, concretamente en los siguientes temas: la tecnología asociada a la conducción y el vehículo autónomo; la importancia de la salud visual como factor de riesgo; y la percepción de riesgo de la conducta vial infractora reincidente.

A su vez, los objetivos específicos de esta Tesis, se encuentran relacionados con cada una de las cuatro publicaciones científicas que la conforman y son los que se detallan a continuación:

1) Examinar la disponibilidad y demanda de los sistemas tecnológicos ADAS en conductores españoles y explorar las limitaciones percibidas y las razones para evitar el uso. https://doi.org/10.1109/ACCESS.2019.2939302

2) Conocer la percepción de seguridad, los valores asociados y la intención de uso de los vehículos autónomos en la población conductora española y determinar si existen diferencias significativas por grupos de edad, por género o por lugar de residencia. https://doi.org/10.1016/j.dib.2019.104662

3) Conocer la percepción que tienen los conductores españoles sobre la importancia de la salud visual en la conducción, y evaluar tres elementos clave de la visión para la conducción: la agudeza visual, la campimetría y recuperación de la visión tras el deslumbramiento. https://doi.org/10.3390/ijerph17093195

4) Conceptualizar la reincidencia vial y determinar la percepción de riesgo que sobre los infractores reincidentes tienen los conductores españoles, en base al rol predictivo de las características sociodemográficas, psicosociales y de conducción, analizando el género como factor diferenciador clave. https://doi.org/10.5093/ejpalc2022a4

4. Resultados del Compendio de Publicaciones

De acuerdo con el artículo 8 del Reglamento sobre Depósito, Evaluación y Defensa de la Tesis Doctoral, el resultado de este Compendio de Publicaciones es la publicación de cuatro artículos científicos originales, firmados por el doctorando, todos ellos desarrollados en el marco del programa de investigación en psicología y centrados en conocer los efectos de la conducción de vehículos y su relación con tecnología y los vehículos autónomos, la salud visual y las conductas reincidentes, en la población conductora española.

Los cuatro artículos están firmados por el doctorando como primer autor y han sido previamente; 1) desarrollados, analizados, escritos y enviados a revistas especializadas sobre la materia de investigación; 2) evaluados por pares; 3) aceptados por los revisores y la revista para su publicación; 4) publicados en lengua inglesa, exclusivamente en revistas especializadas de alto impacto, debidamente indexadas en los cuartiles según los índices JCR (Journal Citation Reports), y SJR (Scientific Journal Rankings) del último año.

Para que se pueda conocer el resultado especifico de cada una de las publicaciones, se anexan un resumen y los textos completos en la sección Anexos.

5. Principales conclusiones del Compendio de Publicaciones

Después del trabajo de investigación realizado incluido en las cuatro publicaciones científicas originales y dando respuesta al objetivo general y a los objetivos específicos, se podrían sintetizar las siguientes conclusiones:

1) La oferta de sistemas ADAS va a ir en aumento en el mercado de vehículos durante los próximos años, existiendo barreras en la población española que limitan su uso y aceptación. Para eliminarlas y aumentar su conocimiento, usabilidad y beneficios se debe fortalecer su aceptación e inclusión en los grupos clave a través de intervenciones y programas de formación específicos sobre la seguridad y los beneficios relacionados con el uso de las tecnologías ADAS, en la conducción.

2) El vehículo autónomo en algún momento será una realidad en el territorio nacional, por lo que es determinante conocer las creencias y valores de los potenciales usuarios de estos vehículos para el desarrollo de intervenciones eficaces, tiendo en cuenta el grupo de edad y la generación a la que pertenecen, el género y el lugar de residencia, ya que los datos indican que son variables determinantes para la aceptación, intención de compra y uso de los mismos.

3) Existe una relación directa entre la salud visual y la siniestralidad vial, pero la población conductora española no es muy consciente de la importancia de tener una buena visión para el manejo de un vehículo. Existen grupos demográficos de mayor riesgo ya que presentan varias deficiencias de salud visual, que deben ser atendidas. Para paliar estos problemas, se deben realizar acciones preventivas y mejorar los protocolos actuales de revisión visual, tanto para la obtención como para la renovación del permiso de conducción.

4) Las conductas infractoras reincidentes son un problema para la seguridad vial y un riesgo inminente para el resto de conductores. El riesgo percibido sobre los infractores reincidentes por parte de la población conductora, viene determinado por el género y se puede predecir a

través de variables psicosociales y variables relacionadas con la conducción. Esta información ayudará al diseño de intervenciones educativas y reeducativas mucho más individualizadas para prevenir la reincidencia en el campo del tráfico y de la seguridad vial.

6. Investigación, compromiso y divulgación

Como resultado del trabajo desarrollado para conformar esta Tesis Doctoral por Compendio de Publicaciones, es importante destacar que los estudios realizados, son pioneros en población conductora española y que abren nuevas líneas de investigación en el ámbito de la psicología, la seguridad vial y la movilidad.

Además, las investigaciones, se encuentran totalmente alineadas con los objetivos 3, 9 y 11 de los ODS 2030 y con las metas del DECENIO 21-30, con la pretensión de que la producción científica contribuya a mejorar la siniestralidad, la mortalidad y la lesividad en el próximo decenio y ayude a instaurar la Vision Zero.

De la misma manera, los objetivos planteados en cada una de las publicaciones científicas, han intentado tener un carácter totalmente práctico y de servicio público, para que las entidades, administraciones o gobiernos que tengan competencias en esta materia, encuentren respuestas y soluciones de fácil aplicación.

Es importante destacar, que algunos de los resultados obtenidos en las cuatro investigaciones que conforman este compendio, han sido presentados en diferentes congresos científicos internacionales como: el Congreso Internacional de Psicología Jurídica y Forense, el Congreso Nacional de Psicología, el Congreso Colombiano del Colegio Oficial de Psicología y la Jornada Internacional de Tecnología y Seguridad Vial (TECVIAL).

También se han presentado a organismos nacionales como: la Dirección General de Tráfico (DGT), el Ministerio de Justicia (Fiscalía del Estado de Seguridad Vial), el Congreso de los Diputados (Comparecencias en la Comisión de Seguridad Vial y Movilidad Sostenible), e internacionales de alto nivel como; la International Commission for Driver Testing (CIECA), el Observatorio Iberoamericano de Seguridad Vial (OISEVI), y la United Nations Road Safety Fund (UNECE). Es posible que en breve espacio de tiempo se puedan ver algunas aplicaciones derivadas de estos resultados.

7. Aspectos éticos de la investigación

Para el desarrollo de este compendio de publicaciones, se han tenido en cuenta las consideraciones éticas, así como los principios de transparencia, voluntariedad y confidencialidad de la información facilitada por las personas participantes en cada uno de los estudios, todo ello plasmado en un formato de consentimiento informado en concordancia con lo establecido por la Declaración de Helsinki para este tipo de investigaciones con seres humanos.

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9. Anexos

Artículos incluidos en el compendio de publicaciones

9.1. Artículo 1

Lijarcio, I., Useche, S.A., Llamazares, J., & Montoro, L. (2019). Availability, Demand, Perceived Constraints and Disuse of ADAS Technologies in Spain: Findings from a National Study. *IEEE Access 7*: 129862-129873. https://doi.org/10.1109/ACCESS.2019.2939302

[Disponibilidad, demanda, limitaciones percibidas y usabilidad de las tecnologías ADAS en España: resultados de un estudio nacional]

Resumen

Introducción: Los Sistemas Avanzados de Asistencia al Conductor (ADAS), creados para mejorar la experiencia de conducción y prevenir activamente los siniestros de tráfico, se han incorporado progresivamente en la fabricación de vehículos, especialmente durante la última década. Sin embargo, la literatura reciente ha demostrado que existe un determinado grupo de conductores que, aunque disponen y conocen estos sistemas, en muchas ocasiones, no hacen uso de ellos eliminando los efectos positivos que tienen para la conducción y la seguridad vial.

Objetivos: Este estudio tuvo dos objetivos esenciales: en primer lugar, examinar la disponibilidad y demanda de los sistemas tecnológicos ADAS entre los conductores españoles y, en segundo lugar, explorar las limitaciones percibidas y las razones para evitar su uso con el fin de poder implementar futuras medidas de acción.

Métodos: Para el desarrollo de este estudio se creó y aplicó un cuestionario estructurado con dos secciones. La primera de ellas, recogía los datos sociodemográficos de la muestra (edad, sexo, nivel educativo, frecuencia de conducción, etc.). La segunda, recogía una clasificación y explicación de los veintiocho ADAS más comunes presentes en el mercado y se preguntaba sobre su conocimiento, su disponibilidad, la utilidad percibida para la seguridad vial, el uso de estos sistemas y razones para su no uso. El cuestionario fue contestado por 1.207 conductores españoles de las 17 comunidades autónomas y sus datos fueron analizados estadísticamente.

Resultados: Los resultados muestran que, por un lado, los sistemas de navegación GPS, los sensores de lluvia y la iluminación automática son los sistemas ADAS más utilizadas en España, y por otro, que el control gestual, el E-call y la frenada de emergencia post-colisión, son los menos usados y demandados. En líneas generales estos sistemas son valorados positivamente por la población conductora, pero, existen diferencias basadas en la edad y el género, ya que concretamente las mujeres y las personas más mayores, los valoran mejor a nivel general que los jóvenes que, aunque también realizan valoraciones positivas, los perciben como menos útiles y necesarios. Además, el bajo valor percibido, la falta de confianza y la posible distracción constituyen las principales limitaciones que perciben los conductores para utilizar activamente estas tecnologías de asistencia mientras conducen.

Conclusiones: La oferta de sistemas ADAS va a ir en aumento en el mercado de vehículos. En este sentido, para aumentar su conocimiento y usabilidad, así como para eliminar las barreras que limitan su uso, mejorar su aceptación e inclusión en grupos clave y su progresiva utilización en la conducción diaria, es importante realizar intervenciones y programas de formación específicos sobre la eficacia, la seguridad y los beneficios para la conducción relacionados con el uso de las tecnologías ADAS.

Palabras clave: ADAS (Sistemas Avanzados de Asistencia a la Conducción), conductores, demanda, fiabilidad, no uso.

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Availability, Demand, Perceived Constraints and Disuse of ADAS Technologies in Spain: Findings From a National Study

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ABSTRACT Advanced Driver Assistance Systems (ADAS), created for enhancing the driving experience and actively preventing road crashes, have been progressively incorporated in vehicle designing essentially during the last decade. However, the literature has shown how some of these assisting technologies are not used by drivers in tandem with their potential. The aims of this study were, first, to examine the availability and demand of ADAS technologies among Spanish drivers and, secondly, to explore the perceived constraints and discouraging reasons for avoiding the use of ADAS available in their vehicles. For this national cross-sectional study, data from 1,207 Spanish drivers were analyzed. The results of this study show that, on one hand, GPS navigation, rain sensors and automatic lighting are the most frequently used ADAS features in Spain and, on the other, that gestural control, E-call and post-collision emergency braking are the less demanded. Also, there are age and gender-based differences in the valuation of certain ADAS features. Further, low perceived value, lack of confidence and potential distractibility constitute the main constraints perceived by drivers to actively use these assisting technologies while driving. In this regard, and jointly with a progressive vehicle automatization, a deeper emphasis on driver training, safety and efficiency-related benefits of ADAS technologies may strengthen its acceptance and progressive inclusion in everyday driving.

INDEX TERMS Advanced driver assistance systems (ADAS), drivers, demand, reliability, disuse.

I. INTRODUCTION

Advanced Driver Assistance Systems (ADAS) can be understood as electronic systems intended to enhance human-machine interaction and increase both vehicle and overall road safety, by means of aiding people while driving. Also, ADAS have been included within the several improvements of the Intelligent Vehicle Technology (IVT), that aim to improve driving experience and protect motor vehicle users from potentially preventable risks and crashes on the road [1]. Different benefits from ADAS, such as timely warnings and autonomously intervening in hazardous situations, undoubtedly constitute an opportunity for the progressive improvement of road safety through the reduction of causalities attributable to human factors [2], [3].

ADAS technologies may even contribute to strengthen road safety numbers of some specific population groups reporting considerably greater rates of traffic crashes, such as young and elderly drivers, since assisting features are designed to help drivers reacting properly to key critical events and difficult driving maneuvers [4], [5]. In other words, safety of drivers using ADAS are expected to be increased over time, to the extent that this population gives more frequent and better use to them [6]. Nevertheless, the recent evidence has demonstrated that, even when these features may be already integrated to their vehicles, only a limited percentage of drivers might be properly informed about the functioning, usefulness and actual potential of ADAS for road safety [7], [8]. In this regard, some studies [9]–[14] have identified several latent barriers for ADAS and other automated features, that may be limiting their potentiality and functionality among drivers [15], including: a relative disinterest from drivers for ADAS intervention during risky driving [9], the interference of ADAS in the skill development of novice drivers [9]–[11], the often low driver' trust on assisting features [12], [13] and the potential lack of proper understanding and using of ADAS in particular age-based groups, such as elderly drivers [7], [14]. Another evident

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barrier for the interaction between users and technical-commercial information on ADAS is the (sometimes inconsistent) nomination of these technologies between sources, that may explain potential confusions among customers at the moment of interacting with potentially useful information in this regard; as an example, the Automatic Emergency Braking (AEB) may be frequently presented using terms such as ''active braking'', ''front automatic braking'', ''pre-collision assist'', etc., making difficult its identification through a single nominal standard [16], [17].

Despite the above-mentioned barriers and limitations perceived by their potential users, the positive impact of ADAS in road safety issues has been previously documented in different recent studies. As a summary, developments such as forward collision warning systems have been demonstrated to shorten response times in high-risk (younger and older) groups of drivers [7], [18]. Visual-based sensors (e.g., eye trackers and face monitoring systems) have similarly been characterized as useful resources to prevent both distracted and drowsy driving, decreasing the number of crashes derived from fatigue, sleepiness and task repetitiousness, commonly prevalent in long-haul driving [19], [20]. Also, Lahausse *et al.* [21] found that automatic crash notification systems (ACNs) significantly improve the rapid attention in traffic crash cases, contributing to the decreasing of road fatalities. Other relevant ADAS technologies such as Adaptive Cruise Control (ACC-ISA) have been considered as a critical component for driving automation and crash prevention during the last years [22], [23]. Finally, further positive aspects of ADAS features for driving are worth to be mentioned. First, many efforts from manufacturers and designers have facilitated that, nowadays, on-board assisting features are more affordable and accessible for drivers and their benefits more evident, especially when social acceptance promotes its employment [24]. In this sense, the using of some of them have been normalized along the last decade, allowing vehicle manufacturers and policymakers to enhance the systematic inclusion of ADAS in everyday transport means [13], [25]. Both in the United States and the European Union, it is projected that by the year 2022 all new vehicles will be overall assisted by various ADAS, such as Autonomous Emergency Braking (AEB) and speed limiters [26], [27]. Moreover, by 2030, full-automated vehicles, that include several assisting features, are expected to be commonly commercialized, representing at least 30% of the automotive fleet [28]. Nevertheless, recent studies [29], [30] have found several human-based constraints, such as lack of information and confidence among drivers, fact that may limit their use assisting features during driving. Thus, the core motivation of this study was to describe the state-of-affairs, the availability, use, concerns and perceptions regarding ADAS features among Spanish drivers, as a manner of identifying points to address for strengthening its adoption among users and inclusion into transportation dynamics.

A. STUDY OBJECTIVES AND HYPOTHESES

The first objective of this study was to examine the availability and demand of ADAS (Advanced Driver Assistance Systems) technological features among Spanish drivers. The second aim was to identify the perceived constraints and discouraging reasons for avoiding the use of assisting tools available in their vehicles. Regarding the hypotheses of the study, formulated in accordance to each research aim, it was expected to find that: 1) the availability of more conventional ADAS features is currently high, but some of them - essentially related to higher SAE automatization levels- are still scarce, and 2) lack of confidence and distractibility may constitute the two main perceived constraints for using these features, even when available on-board.

II. METHODS

A. SAMPLE

The data was collected along the second half of year 2018 from a full sample of 1,207 Spanish drivers from all the 17 autonomous communities of Spain. In order to keep its proportionality to the driving population in the country, the sample was stratified using quotas, according to sex, age and regions of residence, through the use of quotas for the sampling procedure. An initial calculation of a sample size representative of the Spanish driving population was 665 individuals (assuming a confidence level of 99% and a maximum margin of error of 5%). However, the relatively high response rate allowed us to collect more than 1,200 respondents for the final sample.

From these 1,207 participants, 551 (45.7%) of them were females, and 656 (54.3%) males, aged between 18 and 65, with a mean value of $M = 40.5$ ($SD = 11.05$) years. All of them were frequent and licensed drivers, being the last in accordance with the current licensing regulations of the European Union for maneuvering motor vehicles. Regarding their tenure as drivers, 17% of participants had between 0 and 5 years, 31.1% between 5 and 15 years, and 51.9% has more than 15 years of (licensed) driving experience.

B. QUESTIONNAIRE AND PROCEDURE

For gathering the data, we used a structured live-survey, always applied and assisted by a member of the research staff, fact that, in addition, allows researchers to solve potential doubts from participants during the data collection, thus minimizing data biasing derived from the misunderstanding of questions or statements. Respondents were informed on the purposes of the study, its scientific value and relevant ethical aspects explained in the next section. Once they agreed to participate, it was applied the survey, that was structured in two sections (also fully available in the Appendix):

In the first section, demographic data on the participants (age, sex, education, driving tenure, frequency and intensity) was collected.

In the second section, and with the aim of: *a*) ensuring that participants had a proper understanding of ADAS, and

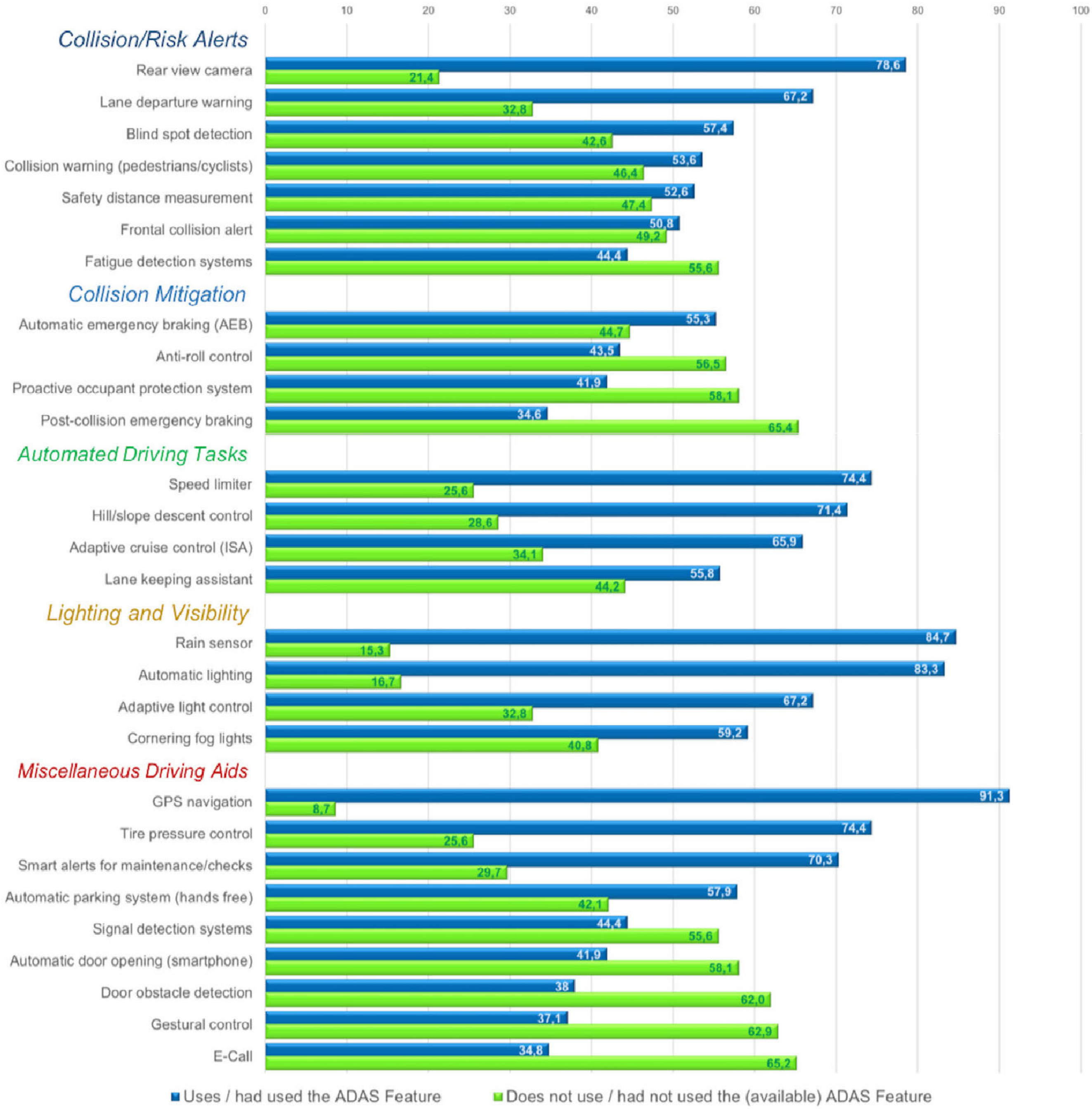

FIGURE 1. Demand of available assisting features of ADAS among Spanish drivers (percentages).

b) avoiding potential confusions regarding the naming and function of each one of the 28 ADAS included in this study, participants were provided with a summary stating its name (standard) and basic features, as shown in the Appendix of this paper. Once read this material, the survey included a series of questions on the availability (yes/no) and use (yes/no) of 28 ADAS presented by the interviewer. Also, participants were asked on how useful do they perceive these ADAS are, using a numeric scale (ranging between 1 = Not useful at all, and 10 = Very useful) to obtain their appraisal on the utility of each ADAS feature. Finally, participants were asked on why they do not use some ADAS that they stated not using despite having them available, with five potential response options, posteriorly identified through categorical analysis of the retrieved responses: *a) I don't need it/find it useless. b) I don't know how it works. c) I don't trust this feature; d) It distracts me; e) I find it annoying/uncomfortable.*

TABLE 1. Descriptive results of the study: Availability, usage, demand and valuation of ADAS technologies among Spanish drivers.

Class[a]	ADAS Technology	On-board Availability[1]		Overall Usage[2]		Demand[3]	User Valuation[4]	
		Percent	n	Percent	n	Percent	Mean	SD
MA	GPS navigation	40.0%	483	36.5%	441	91.3%	8.61	1.59
LV	Automatic lighting	39.2%	473	32.6%	394	83.3%	8.54	1.74
LV	Speed limiter	38.5%	465	28.7%	346	74.4%	8.37	1.79
LV	Rain sensor	34.7%	419	29.4%	355	84.7%	8.15	1.95
MA	Tire pressure control	32.4%	391	24.1%	291	74.4%	8.44	1.77
AT	Adaptive cruise control (ISA)	25.5%	308	16.8%	203	65.9%	8.48	1.79
AT	Cornering fog lights	24.2%	292	14.3%	173	59.2%	8.10	2.12
CR	Adaptive light control	20.0%	241	13.4%	162	67.2%	8.31	1.75
MA	Rear view camera	19.0%	229	14.9%	180	78.6%	8.72	1.65
AT	Smart alerts for maintenance/checks	18.4%	222	12.9%	156	70.3%	8.30	1.90
CR	Hill/slope descent control	17.4%	210	12.4%	150	71.4%	8.51	1.60
CM	Safety distance measurement	16.2%	196	8.5%	103	52.6%	8.12	2.19
CR	Blind spot detection	14.6%	176	8.4%	101	57.4%	8.42	1.95
AT	Automatic emergency braking	12.4%	150	6.9%	83	55.3%	8.58	1.71
CR	Anti-roll control	11.4%	138	5.0%	60	43.5%	8.48	1.58
CR	Signal detection systems	11.2%	135	5.0%	60	44.4%	8.28	1.85
CR	Post-collision emergency braking	11.0%	133	3.8%	46	34.6%	8.41	1.63
CR	Lane departure warning	10.9%	131	7.3%	88	67.2%	8.51	1.60
MA	Fatigue detection systems	10.4%	126	4.6%	56	44.4%	7.57	2.14
MA	Frontal collision alert	9.9%	120	5.1%	61	50.8%	8.49	1.88
CM	Automatic parking system (hands free)	9.4%	114	5.5%	66	57.9%	7.98	2.18
MA	E-Call: emergency call and localized assistance	9.3%	112	3.2%	39	34.8%	8.59	1.55
LV	Door obstacle detection	8.9%	108	3.4%	41	38.0%	8.24	1.87
CM	Gesture control	8.7%	105	3.2%	39	37.1%	7.85	1.63
MA	Lane keeping assistant	7.1%	86	4.0%	48	55.8%	8.48	1.57
CM	Proactive occupant protection system	7.1%	86	3.0%	36	41.9%	8.53	1.56
MA	Collision warning (pedestrians/cyclists)	5.7%	69	3.1%	37	53.6%	8.89	1.31
MA	Automatic door opening (smartphone)	5.1%	62	2.2%	26	41.9%	8.23	1.77

Notes: [a]Classification of ADAS: CR=Collision/Risk Alerts; CM=Collision Mitigation; AT=Automatic Driving Tasks; LV=Lighting and Visibility; MA=Miscellaneous Driving Aids. [1]Drivers whose vehicles include the ADAS feature. [2]Absolute percentage of drivers using the ADAS feature (considering the full sample). [3]Relative percentage of drivers using the ADAS feature (among those having it in their vehicles). [4]Valuation based in a 1 to 10 scale.

Following the typologies and basic definitions suggested by the American Automobile Association (AAA) [31], the ADAS included in this study were classified in five different groups, according to its function and main features: Collision/Risk Alerts (CR); Collision Mitigation (CM); Automatic Driving Tasks (AT); Lighting and Visibility (LV); and Miscellaneous Driving Aids (MA). For further information, please see Figure 1 and the glossary of Appendix.

C. ETHICAL CONSIDERATIONS

To carry out this multidisciplinary study, the Social Science in Health Research Ethics Committee of the University of Valencia was consulted, certifying that our research responded to the general ethical principles, and certifying its accordance with the Declaration of Helsinki, and that funding issues do not interfere with the quality and transparency of the results (IRB approval number H15355481258595). Furthermore, an Informed Consent Statement containing ethical principles and data treatment details was used, explaining the objective of the study, the mean duration of the survey, the treatment of the personal data and the voluntary participation, always provided to the participants before surveying. Personal and/or confidential data were not used, and the partaking was anonymous, implying no potential risks for the integrity of our participants. Respondents did not receive any payment or economical reward for their participation in the study.

TABLE 2. Significant differences in the valuation of available ADAS by sex and age group of drivers.

Gender-based significant differences								
Class[a]	ADAS feature	Female drivers		Male drivers		Mean comparison test		
		Mean	SD	Mean	SD	df	F	p-value[1]
CM	Automatic emergency braking (AEB)	9.08	1.49	8.12	1.77	1, 81	19.047	0.010
CM	Post-collision emergency braking	9.11	1.24	7.93	1.70	1, 44	15.051	0.014
MA	Smart alerts for maintenance/checks	8.63	2.12	8.02	1.65	1, 154	14.012	0.049
MA	Door obstacle detection	8.89	1.18	7.68	2.12	1, 58	14.997	0.036

Age group-based significant differences									
Class[a]	ADAS feature	Mean/Age Group					Mean comparison test		
		<25	25-34	35-44	45-54	>54	df	F	p-value[1]
CR	Rear view camera	9.00	8.08	8.92	8.86	9.31	4, 175	2.793	0.028
CM	Automatic emergency braking (AEB)	8.82	8.87	7.71	9.07	9.25	4, 78	2.642	0.047
AT	Hill/slope descent control	8.17	8.76	8.00	8.90	9.18	4, 145	2.944	0.022
AT	Adaptive cruise control (ISA)	9.29	8.30	8.28	8.67	8.77	4, 57	3.197	0.020
LV	Rain sensor	8.12	8.00	7.95	8.24	9.07	4, 261	2.854	0.024
MA	Automatic parking system (hands free)	8.00	8.25	7.35	8.13	9.67	4, 55	3.813	0.019

Notes: [a] Classification of ADAS: CR=Collision/Risk Alerts; CM=Collision Mitigation; AT=Automatic Driving Tasks; LV=Lighting and Visibility; MA=Miscellaneous Driving Aids. [1] Significant at the level 95% of confidence when p<0.05.

D. STATISTICAL ANALYSIS (DATA PROCESSING)

Prior to the data analysis, data curation was carried out, checking and categorizing the responses provided by the participants of the study. Frequency analyses were performed in order to obtain percentages of on-board availability and usage of the 28 stated ADAS features. Overall usage rate was estimated through the absolute frequency of drivers using each ADAS technology. The values on ADAS demand were calculated using relative percentages, i.e., number of drivers using it over number of vehicles having the feature. User valuation (perceived usefulness) was estimated through basic descriptive analyses (means and standard deviations). Also, comparisons on the valuation of available ADAS according to the gender and age group of drivers were carried out through ANOVA-based robust tests with a level of significance of $p<0.05$. Finally, discouraging reasons for available ADAS technologies were calculated through a categorical (nominal) analysis, considering only the available and non-used features of each participant. All statistical analyses were performed using ©IBM SPSS (Statistical Package for Social Sciences), version 24.0.

III. RESULTS

Descriptive results of the study are summarized in Table 1. Overall, the most frequently available assisting features were GPS navigation (40%), automatic lighting (39.2%), speed limiter (38.5%), rain sensors (34.7%) and tire pressure control (32.4%). On the other hand, the less available ADAS features in the vehicles used by Spanish drivers were: automatic door opening-via smartphone (5.1%), collision warning for pedestrians and cyclists (5.7%), proactive occupant protection systems and lane keep assistant (both available only in 7.1% of vehicles), and gesture control (8.7%).

Moreover, and considering the fact that the sole availability of ADAS does not necessarily imply their acceptance and use among drivers, a demand analysis was carried out. Therefore, it was calculated the percentage of Spanish drivers using (and not using) the whole list of 28 ADAS features presented in the survey, based in the relative percentage of participants whose vehicles include each one of the assisting systems. Figure 1 shows, hierarchically, the most and the least demanded features. Individual frequency-based analyses shown that the most commonly used (available) systems or features were GPS navigation (91.3% of drivers have used it), rain sensors (84.7%), automatic lighting systems (83.3%), rear view camera (78.6%) and tire pressure control (74.4%).

On the other hand, the least used ones, even when available in vehicles, were post-collision emergency braking (65.4% of drivers had never used it), E-Call (65.2%) (these two subjected to the fact of having suffered a traffic crash), gestural control (62.9%), door obstacle detection (62%) and proactive occupant protection systems (58.1%). Further, other emerging ADAS such as fatigue detection systems, safety distance measurement and frontal collision alerts

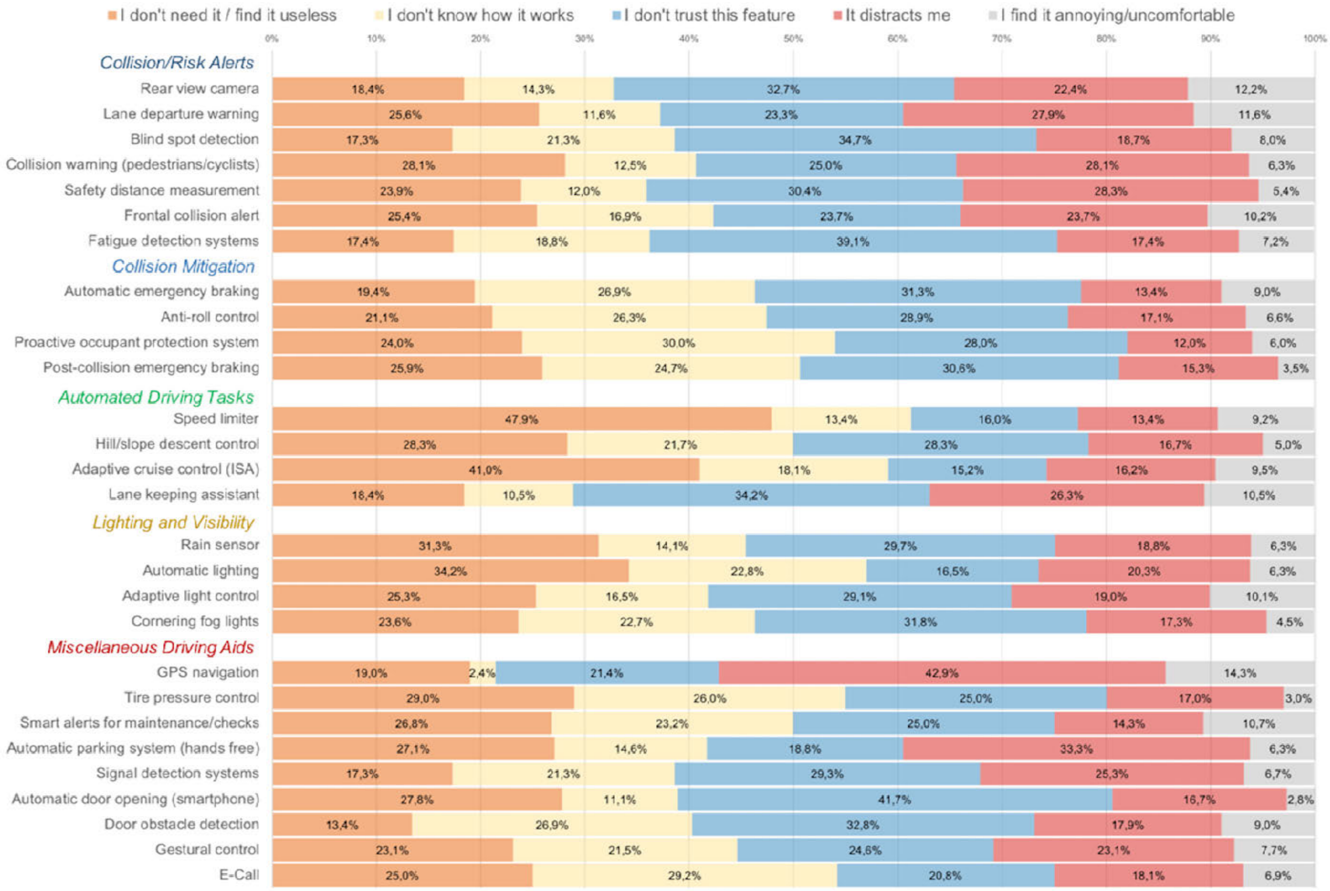

FIGURE 2. **Reasons for avoiding the use of available ADAS technologies (percentages).**

present a fairly balanced demand trend, with around half of drivers using it when available in their vehicles (see also Table 1).

A. AGE AND GENDER-BASED DIFFERENCES IN USEFULNESS-VALUATION OF ADAS

Since demographic variables or features of drivers may explain differences in their valuation of ADAS features, comparative analyses were performed using two categorical variables for contrasting the mean valuation (how useful do they perceive each feature) provided on the ADAS already available in the vehicles of participants: gender (female vs. male drivers) and age group, by splitting the sample in five intervals: *1)* drivers younger than 25; *2)* drivers between 25-34; *3)* drivers between 35-44; *4)* drivers between 45-54; and *5)* drivers older than 54 years (55 or more). The results show that: a) there are differences in the valuation of four ADAS features between genders, and b) significant differences by age group are present in the case of six ADAS. In the first case (gender), it was found that female drivers have a significantly greater valuation of Automatic emergency braking, Post-collision emergency braking (collision mitigation ADAS), Smart alerts for maintenance/checks and Door obstacle detection (miscellaneous driving aids). As for the second set of comparisons (based in age groups), it was found that age-based differences exist for the case of Rear view camera, Automatic emergency braking, Hill/slope descent control, Rain sensor and Automatic parking system (all higher for drivers >54), as shown in Table 2, where specific means anre found for other ADAS features.

B. REASONS FOR NOT USING ADAS TECHNOLOGIES

As it was pointed before, drivers do not only perceive benefits, but some key constraints and risks related to the use of ADAS. Although some of the ADAS features included in this study reported a high demand (e.g., the case of GPS navigation, rear view cameras and smart alerts), participants also alleged critical reasons for avoiding its employment. Particularly, categorical analyses on the provided responses allowed to establish five dismiss criteria: finding the specific feature useless or unnecessary; not knowing how to use it; not trusting the feature; considering that it distracts them; and finding it uncomfortable. Figure 2 presents the percentage of responses provided for the case in which they decided not using each one of the ADAS they have available in their vehicles.

In brief, categorical analyses shown that, depending on the perceived constraint, the disuse trend may vary according to each individual assisting feature. Firstly, most of drivers stated not using the following ADAS since they perceive them as useless or unnecessary: speed limiters (47.9%), adaptive cruise control (41%), automatic lighting (34.2%), rain sensors (31.3%), tire pressure control (29%), slope descent control (28.4%), collision warnings (28.2%), smart alerts (26.8%), and frontal collision alert (25.4%). The second category was related to driver do not properly knowing how specific assisting technologies work. Two ADAS were majorly characterized under this typology: proactive occupant protection systems (30% of drivers) and E-Call (29.2%). Thirdly, the disuse of some ADAS was related to the lack of confidence of users: automatic door opening (41.7%), fatigue detection systems (39.1%), blind spot detection (34.7%), lane keeping assistants (34.2%), door obstacle detection (32.8%), rear view cameras (32.7%), cornering fog lights (31.8%), automatic emergency braking systems (31.3%), post-collision emergency braking (30.6%), safety distance measurement systems (30.4%), signal detection systems (29.3%), adaptive light control (29.1%), anti-roll control (28.9%), and gestural control (24.6%). As for the fourth category, three assisting features were not used by drivers, since they considered them as distracting sources, as main disusing reason: GPS navigation (42.9%), automatic parking systems (33.3%), lane departure warnings (27.9%). Finally, for the case of the lack of comfortability as a perceived constraint, it was found that, although in none of the cases it constitutes a core reason for dismissing them, GPS navigation (14.3%), rear view cameras (12.2%) and lane departure warnings (11.6%) were the assisting features in which that perception was prevalent (see Figure 2).

IV. DISCUSSION AND CONCLUSION

Based on the information provided by 1,027 Spanish drivers taking part in this research, and bearing in mind the aims of the study, this paper examined, first, the availability and demand of ADAS' assisting features among Spanish drivers and, secondly, the perceived constraints and discouraging reasons for avoiding the use of available assisting tools in their vehicles.

As for the first objective, we found how, in accordance to the global trends observed along the last decade in most of European countries, some ADAS present a high availability, supported on the fact that -due to its proven utility and adaptation to transport dynamics- nowadays are easily involved in vehicle design trends (even in low ranges of vehicles), enhancing their demand by different groups of drivers but, at the same time, opening the discussion on potential implications for the road safety of vulnerable ones [1], [4], such as younger and older drivers [3], [5], [32]. Overall, the most commonly available ADAS features were GPS navigation (40% of on-board availability and 91.3% of demand among drivers), followed by other common technologies such as automatic lighting (39% of availability and 83% of demand) and speed limiters (38.5% and 74%, respectively). It is worth mentioning that, regardless of demand, all ADAS presented in this study had a considerably high valuation among users, with means oscillating between 7.5 (fatigue detection systems) and 8.9 (collision warnings) over 10, suggesting that, even when eventually disused -or misused-, ADAS features are noticeably positively valued among drivers.

Although an overall *positive* valuation does not directly imply potential users' demand, it reflects, in accordance to other studies such as the performed by Eby *et al.* [33], a certain level of awareness of drivers in different population segments on the ADAS' benefits and their protective value for the strengthening of road safety. Thus, it raises a further question that should be subsequently investigated: why, and despite the relatively positive assessment they give, some drivers decide not to use certain ADAS they have available in their cars? Based on the data provided by this study and other previous researches in the field of vehicle automation [13], [15], [30], confidence and knowledge may play a crucial role on: *a*) increasing the demand of ADAS features that are already available to drivers, and *b*) raising more interest in acquiring other ADAS that may improve, even more, their driving safety and comfort.

A. WHY COULD BE DRIVERS DISUSING SOME ADAS TECHNOLOGIES?

As for the second aim (i.e., to identify the constraints perceived by drivers in ADAS, that may explain their disuse), the core analysis was based in five main categories, using the responses provided by the participants of the study. In short, previous researches on the field have highlighted different constraints perceived by users on aspects such as the utility, usage directions and potential implications of on-board systems related to vehicle automation, being interesting to find how these studies have discussed the role of driving-assistance tools as a *double-edge sword* [6], [9], [10], [15]. Even though some assisting devices/systems only entail a passive use from drivers, other features need some level of direct intervention of users to intend the expected result, creating secondary tasks that may interfere with driving performance throughout small inattention lapses and distractions, or well requiring a continuous manual handling from users [34], [35]. This is the case of, for instance, GPS navigation systems; even when new alternative functions such as voice control, spatial learning and usual trip recognizance were applied along the last years to most existing interfaces [36], some disparities on the ratio between available functions vs. user's awareness on it have been recently identified [32], [37].

Particularly on the disuse reasons of ADAS reported by Spanish drivers, 9 out of the 28 studied ADAS (32.2%) were mainly perceived as useless or unnecessary by them (see Figure 2). Further, a relevant proportion of drivers stated not knowing how to properly handle ADAS features as main reason for not using them, even though they were already available in their vehicles. Specifically, both proactive occupant protection systems (a collision mitigation feature that may protect drivers and passengers during a traffic crash) and E-Call (1 out of each 3 of drivers affirm not knowing how it works, that makes sense when considering that its use may highly depend on the fact of having suffered an accident) are perceived as assisting features difficult to be operated,

Root Questionnaire [Researcher Form]

Study on Advanced Driving Assistance Systems (ADAS). FESVIAL – Samsung, 2018

[Basic instructions for respondents]

Thanks for your participation. Next, we will ask you a series of questions about **Advanced Driving Assistance Systems (ADAS)**: we would like to know your opinion and personal appraisal on this topic.

Prior to start responding, please refer to the sheet you received. There, you will find a detailed explanation on each one of the ADAS we are inquiring about; please use it anytime during responding to this survey.

There are no good or bad answers, so you can answer with full sincerity. As previously explained in the Informed Consent form, your answers will remain anonymous and will be treated confidentially.

Questions for participants:

[Please fill answers into the response sheet by using the assigned codes]

1. **Age** [*Quotas*]: _______
2. **Sex** [*Quotas*]: Male___ Female___
3. **Autonomous Community (Region)** [*Quotas*]: __________________
4. **Educational level:**
   No studies ____; Primary studies ____; Secondary-mid-high school ____; Technical/meduim studies ____; University studies ____
5. **Job Situation / Occupation:**
   Working ____; Retired ____: Unemployed ____; Student ____; Other (specify): ______________
6. **Driving experience (licensed):**
   Less than 5 years ____; Between 5-15 years _____; More than 15 years ____
7. **Driving frequency:**
   Once a week or less ____; Between 2-5 days a week ____; More than 5 days a week ____
8. **Which of these ADAS do u have already available in the vehicle you regularly drive?**

   [Check the indicated (**available ADAS**) ones for proceeding with the next question]

9. **From these ADAS that are available in your vehicle, which of them do you have used at least once?**

   [Check the indicated (**ADAS used**) ones for proceeding with the next question]

10. **What is the level of UTILITY you assign to these ADAS features that you use?**
    Please rate from 1 to 10 the ADAS you use, based on this scale:

    1=Not useful at all - 10=Very useful

    [Please ensure the participant understands the degree scale before checking]

11. **Now, let's talk about the ADAS that, despite being available in your vehicle, you decided not to use. We are interested in knowing why you don't use them*.**

    [Please refer to the ADAS available in the question 8, but not checked in the question 9]

    ***The following categories were found once performed the categorical analysis of the data provided by participants:**

a) *I don't need it / find it useless.*
b) *I don't know how it works.*
c) *I don't trust this feature.*
d) *It distracts me.*
e) *I find it annoying/uncomfortable.*

Glossary: Detail on ADAS features – Names and definitions

[Please provide it to participants and ensure they read it before starting to respond the questionnaire section on ADAS]

Advanced Driver Assistance Systems (ADAS) can be defined as electronic systems intended to enhance human-machine interaction and increase both vehicle and overall road safety, by means of aiding you while driving. Below, you will find a summary of the ones included in this study:

Collision/Risk Alerts	
Frontal Collision Alert	Also known as Forward Collision Warning. Detects impending collision while traveling forward and alerts driver.
Lane Departure Warning	Monitors vehicle's position within driving lane and alerts driver as the vehicle approaches or crosses lane markers.
Blind Spot Detection	Detects vehicles to rear in adjacent lanes while driving and alerts driver to their presence.
Collision Warning (pedestrians/cyclists)	Detects pedestrians, cyclists and other users in front of vehicle and alerts driver to their presence.
Rear View Camera	Detects vehicles approaching from side and rear of vehicles while traveling in reverse and alerts driver.
Safety Distance Measurement	Automatically detects other vehicles or obstacles and, based in a field appraisal, alerts drivers to keep a minimum safety distance from them.
Fatigue Detection Systems	Help preventing accidents caused by the driver getting drowsy by monitoring facial-eye patterns of drivers and/or other physiological parameters.
Collision Mitigation	
Automatic Emergency Braking (AEB)	Detects potential collisions while traveling and automatically applies brakes to avoid or lessen the severity of impact.
Anti-Roll Control	Gives stability to the vehicle, in order to reduce risk of rollover after a crash or loss of control.
Post-Collision Emergency Braking	Automatically stops a car after a crash, to avoid a more than possible second impact against another obstacle or vehicle.
Proactive Occupant Protection System	Detects when an emergency maneuver is being made and prepares the vehicle and its occupant restraint systems in advance of a possible collision.
Automated Driving Tasks	
Adaptive Cruise Control	Controls acceleration and/or braking to maintain a prescribed distance between it and a vehicle in front. May be able to come to a stop and continue.
Lane Keeping Assistant	Controls steering to maintain vehicle within driving lane. May prevent vehicle from departing lane or continually center vehicle.
Speed Limiter	Advise drivers of the current speed limit and, based on a previous configuration provided by the driver, automatically limit the speed of the vehicle as needed.
Hill/Slope Descent Control	Allows a controlled hill descent in rough terrain without any brake input from the driver, activating the brakes to automatically slow the vehicle
Lighting And Visibility	
Automatic Lighting	Increases visibility by lighting the headlight automatically when the surrounding illuminance is detected and found to be a minimum value or less.
Cornering Fog Lights	Provide an additional illumination when cornering. When the driver turns the steering wheel or indicate, the front fog light turns towards this direction.
Adaptive Light Control	Help drivers see better and further in the darkness. Allows the headlights to swivel and rotates to better illuminate the roadway through corners and in other circumstances.
Rain Sensor	Protect the interior of an automobile from rain and support the automatic mode of windscreen wipers.
Miscellaneous Driving Aids	
GPS Navigation	Provide visual and vocal live directions for route-choosing and traffic data useful for optimizing trips.
Automatic Parking System (hands free)	Help drivers to parallel park; in high-complexity systems, perform the full parking task.
Door Obstacle Detection	Alerts the driver on the presence of potential obstacles at the moment of opening the doors of the vehicle.
E-Call: Emergency Call and Localized Assistance	Automatically makes a free emergency call if the vehicle is involved in a serious road crash, providing specific details on its location and severity of the incident.
Tire Pressure Control	Monitor the air pressure inside the pneumatic tires, showing alerts when tires blow-out or have an inadequate pressure level.
Smart Alerts for Maintenance/Checks	Notify the driver on potential failures or damages in the vehicle that need to be revised, through a self-diagnose-based alert.
Automatic Door Opening (Smartphone)	Offers a keyless entry option and motion sensors to automatically open when the driver approaches, through a live connection with the smartphone.
Signal Detection Systems	Also known as Traffic Sign Recognition (TSR). Recognizes traffic signs (e.g., speed limits) and displays the recognized information on a display panel.
Gesture Control	Makes easier to use built-in systems through voice and motion-based commands, reducing the probability of causing a distraction-related crash.

implying the need of putting more efforts on informing and training drivers for its proper use.

Other studies such as the performed by Souders *et al.* [1] and Eby *et al.* [33], have shown the significant differences that exist in the valuation of some assisting features between age-based groups, suggesting that the willingness to acquire, adopt and use ADAS should be highly influenced by driver's demographic factors, as suggested in this study when finding that: *a*) female drivers and tend to value more positively collision mitigation and miscellaneous ADAS, such as automatic and post-collision emergency braking (CM), and smart alerts - obstacle detection systems MAs) than males, and *b*) drivers aged over 55 years tend to perceive more usefulness in some ADAS features of all types (see Table 2). In brief, various ADAS technologies directly aimed at improving in-trip safety, such as lane departure warning systems still present a considerably high disuse among drivers: the *disused when available* percentage reaches 22% in Braitman *et al.* [38], in a study performed with North American drivers, and 32.8% for the specific case of Spanish users.

Further, the basic question on in what extent attitudes and acceptance influence the use of ADAS is still pending to be responded; while the numbers demonstrate that some of them have been systematically naturalized in everyday driving, as previously seen in the results of this study, some others remain highly disused as a consequence of the lack of awareness, negative appraisals and different concerns on their reliability, stability and usefulness. In this sense, automotive designers may find useful putting these key aspects on the social discussion on automation technologies applied to the field of transportation, showing potential users how these developments may strengthen their safety and welfare.

Finally, it is worth stating some potential practical implications of this study. First of all, this research offers useful information about the state-of-affairs on the current availability, demand and concerns about different ADAS features among drivers, allowing other researchers to have a preliminary diagnosis on the matter. Secondly, and since this study was carried out on the basis of the interest of corporative and market stakeholders, the information can be used for strengthening the promotion of non-frequently used ADAS, that also may play a relevant role in the improvement of driving safety and comfort. Finally, gender and age-based differences on valuation of ADAS identified in this study may help to address population segments on which more work and information is needed to increase the knowledge, value and use of assisting driving features.

V. LIMITATIONS OF THE STUDY

Research on transportation and technology issues may be biased by different factors. Although our sample size was considerably large and nationally representative, basic parameters and data curation were accurately and satisfactorily tested, some specific issues should be listed as potential sources of bias. First, this study is based on a self-report method, implying the risk of presenting common method biases, frequently observed in cross-sectional designs for research [39]. These sources of bias may range from social desirability to lack of sincerity and acquiescence bias, and may still affect participants even though they were informed on the non-existence of wrong answers [40]. Also, if we consider that the survey addressed a topic encompassed in the current social discussion, it may emerge concerns expressed by many sectors of society about whether vehicle automatization may imply potential risks for drivers and other road users [41], [42]. This is a common problem in transportation research when based on self-reports, since some research topics, such as vehicle automatization, may be socially stigmatized and therefore tend to be biased, and may affect driver's perceptions on the usefulness and reliability of assisting features.

Moreover, and as for further studies on the area, it is worth suggesting, firstly, a deeper assessment on encouraging reasons, trustiness and perceived safety of ADAS features by means of supplementary measures; secondly, the complementary collection of qualitative data that would allow researchers to obtain more insights in this regard; thirdly, it is worth suggesting to study this matter in population aged over 65 years, considering their relevant role on road safety issues; and finally, we would like to suggest the crossing of data on ADAS with other interesting indicators, such as the individual accident history and driving patterns, that might increase the knowledge on the relationship between technological advances in traffic and road safety issues.

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APPENDIX

Root Questionnaire [Researcher Form] is shown at the top of the page 8 and Glossary: Detail on ADAS features - Names and definitions is shown at the top of the previous page.

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9.2. Artículo 2

Lijarcio, I., Useche, S. A., Llamazares, J., & Montoro, L. (2019). Perceived benefits and constraints in vehicle automation: Data to assess the relationship between driver's features and their attitudes towards autonomous vehicles. *Data in brief*, *vol 27*, 104662. https://doi.org/10.1016/j.dib.2019.104662

[Percepción de beneficios y limitaciones en la automatización de vehículos: datos para evaluar la relación entre las características del conductor y sus actitudes hacia los vehículos autónomos]

Resumen

Introducción: Diferentes estudios coinciden en afirmar que los vehículos autónomos, serán una revolución en el concepto de transporte y conectividad, ofrecerán grandes beneficios en la gestión de la movilidad, la economía y la seguridad vial, reduciendo los siniestros, las lesiones y los muertos causados por el factor humano. A pesar de estas evidencias, existe una falta de aceptación de los vehículos autónomos debido al desconocimiento que la población tiene sobre los mismos y sobre las ventajas, que para la seguridad vial pueden ofrecer, frente a los vehículos convencionales.

Objetivos: Los objetivos de este estudio se centran en conocer la percepción de seguridad, los valores asociados a los vehículos autónomos y la intención de uso en población conductora española y determinar si existen diferencias significativas por grupos de edad, por género o por el tamaño de población de residencia.

Métodos: Para realizar este estudio se creó y aplicó un cuestionario estructurado en tres secciones. La primera de ellas, recogía los datos sociodemográficos de la muestra (edad, sexo, nivel educativo, lugar de residencia y situación laboral). La segunda, recogía cuestiones relacionadas con conductas y hábitos de conducción (antigüedad del permiso, tipo de vehículo, número de días de conducción, kilómetros recorridos diariamente y siniestros sufridos). La tercera, hacía referencia a características y percepciones asociadas a vehículos autónomos (percepción de seguridad, valores asociados e intención de uso). El cuestionario fue contestado por 1.205 conductores españoles pertenecientes a las 17 comunidades autónomas y los datos resultantes fueron consolidados y analizados estadísticamente.

Resultados: Los resultados indican que tanto la variable edad, como el género, y el tamaño del municipio donde reside el encuestado, son determinantes en la percepción de seguridad, los valores atribuidos y en la intención de uso de vehículos autónomos. Las mujeres puntúan mucho menos en estas tres variables que los hombres. Los conductores más jóvenes, sobre todo los menores de 25 años, son los que también puntúan más bajo en estas variables y, por el contrario, los mayores de 55 años, son los que mayor puntúan en intención de uso y valores atribuidos, siendo el grupo de edad de 46 a 55 los que mayor percepción de seguridad atribuyen a los vehículos autónomos. De la misma manera, los conductores que viven en municipios menores a 5.000 habitantes, son los que puntúan más bajo en las tres variables.

Conclusiones: El vehículo autónomo, posiblemente sea una realidad en un periodo de tiempo no muy lejano, por lo que es determinante conocer y entender los pensamientos y las creencias que la población puede tener sobre los niveles de seguridad, la importancia y beneficios que a nivel individual y para la seguridad vial ofrecen estos vehículos, la intención de compra y uso de vehículos autónomos frente a vehículos convencionales. Además, atendiendo a la diversidad, es importante conocer qué piensan los diferentes destinatarios en función del género, la edad y el lugar de residencia, para establecer medidas que faciliten un uso seguro.

Palabras clave: conductores españoles, vehículos autónomos, actitudes, percepción, intención de uso, seguridad vial.

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Data Article

Perceived benefits and constraints in vehicle automation: Data to assess the relationship between driver's features and their attitudes towards autonomous vehicles

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ABSTRACT

This data article examines the association driver's features, perceptions and attitudes towards autonomous vehicles (AVs). The data was collected using a structured self-administrable and online-based questionnaire, applied to a full sample of 1205 Spanish drivers. The data contains 4 parts: the full set of bivariate correlations between study variables; descriptive statistics and graphical trends for each main study variable according to gender, age group and city/town size; and, finally, the dataset for further explorations in this regard. For more information, it is convenient to read the full article entitled "*Perceived safety and attributed value as predictors of the intention to use autonomous vehicles: A national study with Spanish drivers*" [1].

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Specifications Table

Subject area	*Psychology*
More specific subject area	*Autonomous Vehicles; Spanish Drivers; Demographics; Acceptance; Attitudes; Road Safety.*
Type of data	*Tables, graphs, database*
How data was acquired	*Original data was collected through a national web-based survey. The questionnaire is available as supplementary material of this data article. The data was consolidated and analyzed through the statistical software package IBM SPSS (version 24.0) for descriptive procedures and IBM SPSS AMOS (version 24.0) for structural/inferential ones*
Data format	*Raw, filtered and analyzed*
Experimental factors	*Population consisted of a sample of Spanish drivers, about which their perceptions and valuations on the autonomous vehicles (AVs) were analyzed*
Experimental features	*Study of user profile-based differences on the acceptance and attitudes towards AVs through comparative and graphical analyses*
Data source location	*Europe*
Data accessibility	*Data is with this article*
Related research article	*Montoro L, Useche S, Alonso F, Lijarcio J, Bosó-Seguí P., Martí-Belda A. Perceived safety and attributed value as predictors of the intention to use autonomous vehicles: A national study with Spanish drivers. Saf Sci. 120C (2019).* https://doi.org/10.1016/j.ssci.2019.07.*041*

Value of the Data

- This data can be useful since it provides information on how Spanish drivers perceive the safety and value of the autonomous vehicles (AVs), and their intention to use them.
- This data can be used by other researchers, road safety practitioners and market stakeholders to identify demographic-based patterns and profiles of potential users of AVs, according to the trends and differences identified in this study.
- The perceived safety and value attributed to autonomous vehicles can be analyzed according to different user-related features, such as their age, gender, educational level, city/town size and occupation, variables also contained in the annex dataset.
- Additionally, the data contained in this article can be compared with other samples/studies, in order to examine means, associations and trends on perceptions and attitudes towards the autonomous vehicles (AVs) among drivers.

1. Data

The dataset of this article provides information on a set of demographics, perceptions on autonomous vehicles and crash-related factors of the sample, fully composed of licensed Spanish drivers. Table 1 presents the descriptive information on the items contained in the questionnaire. Fig. 1 presents graphically the full set of bivariate correlations among the three main study factors and individual features of drivers.

Table 2 shows the descriptive statistics obtained for the three attitudinal AV-related variables included in this data article (i.e., perceived safety, value attributed and intention to use), both for the full sample and split by gender, and Fig. 2 specifically shows trends on acceptance of autonomous vehicles according to the gender of drivers. Table 3 allows to identify the specific differences between drivers by age through a One-way ANOVA (Analysis of Variance), summarizing the statistical differences among different age groups for these variables, and Fig. 3 graphically shows the mean score reported by each age group.

Finally, Table 4 presents the mean scores reported on perceived safety, value attributed and intention to use autonomous vehicles (AVs) according to the size of the town/city of residence of participants. In addition, this article includes, as supplementary materials: the questionnaire (form) used for performing the study, and the dataset (SPSS -.sav), that will allow researchers to perform additional tests and comparisons using the entire set of measured variables. It is important to remark that no inferences, interpretations or conclusions on the data are presented in this paper, but are available in the complementary article [1].

Table 1
Descriptive statistics of AV-related study variables (factors) contained in the data set and gender-based differences.

Items in the questionnaire	N[1]	Min[2]	Max[3]	Mean[4]	SD[5]
Factor 1: Perceived Safety (5 items; $\alpha = 0.735$)					
1. Overall. AVs would help make my journeys safer than they are when I use conventional cars	1205	1	5	3.29	1.00
2. AVs would act better than myself in a complicated traffic situation	1205	1	5	2.95	.99
3. A driverless/automated vehicle may be not "smart" enough for guaranteeing my safety during the journey (−)	1205	1	5	3.79	1.00
4. AV-related systems could easily break down, or be hacked, thus compromising my safety (−)	1205	1	5	3.81	1.03
5. AVs would respond adequately to unexpected situations that commonly require rapid responses from drivers	1205	1	5	2.62	1.20
Factor 2: Value Attributed (5 items; $\alpha = 0.739$)					
1. They would help improve the traffic flow, making journeys more agile and efficient	1205	1	5	3.22	1.05
2. They would reduce fuel use and improve the environment	1205	1	5	3.46	.99
3. They might contribute to reduce crashes and injuries caused by traffic accidents	1205	1	5	3.22	1.04
4. I believe the cost-benefit relation of AVs would not be balanced, and costs might overcome the benefits (−)	1205	1	5	3.88	1.00
5. They would contribute to reducing the misbehaviors of drivers, and to strengthening respect and co-existence on the road	1205	1	5	4.22	.95
Factor 3: Intention to Use (5 items; $\alpha = 0.929$)					
1. I would prefer using an AV more than a conventional car when driving on urban/city roads	1205	1	5	2.63	1.33
2. If during the next years I will have enough budget, I plan to buy an AV	1205	1	5	2.41	1.27
3. I would prefer using an AV than a conventional car if I were tired	1205	1	5	3.72	1.31
4. I am totally against the option of buying an autonomous car (−)	1205	1	5	2.61	1.36
5. Considering the need of adapting to transport dynamics, planning to buy an AVs at some point in the next years sounds adequate	1205	1	5	2.77	.98

Notes: Negative (-) items have been recoded for factor scoring.; [1]n= sample size; [2]Min= lower value; [3]Max= higher value; [4]Mean= Arithmetic mean (*average*); [5]SD= Standard Deviation.

2. Experimental design, materials, and methods

2.1. Participants

For this cross-sectional research, it was collected and analyzed the data of a nationally representative sample of $n = 1025$ drivers from the 17 autonomous communities of Spain.

In accordance with the pursued analyses and some previous research experiences dealing with different gender and age-based groups of population [2,3], the data was analyzed considering both the full sample and specific sub-groups built up bearing in mind these individual features, already supported by literature as potential key factors on decision-making in urban mobility-settings [4–6]. Thus, for making comparisons in the study variables, the full sample was divided: *a*) by gender (538 females, and 667 males); and *b*) in five intervals, composed as follows: <25 years ($n = 113$, composing 9.4% of the sample); 25–35 years ($n = 271$, composing 22.4% of the sample); 36–45 years ($n = 359$, composing 29.8% of the sample); 46–55 years ($n = 326$, composing 27.1% of the sample); and >55 years ($n = 136$, composing 11.3% of the sample). Additionally, it was taken into account the size of the town/city of residence of the driver, as recent evidences suggest that attitudes towards autonomous vehicles may differ according to the place of residence [6] and other settings related to driving habits and lifestyle [3,4].

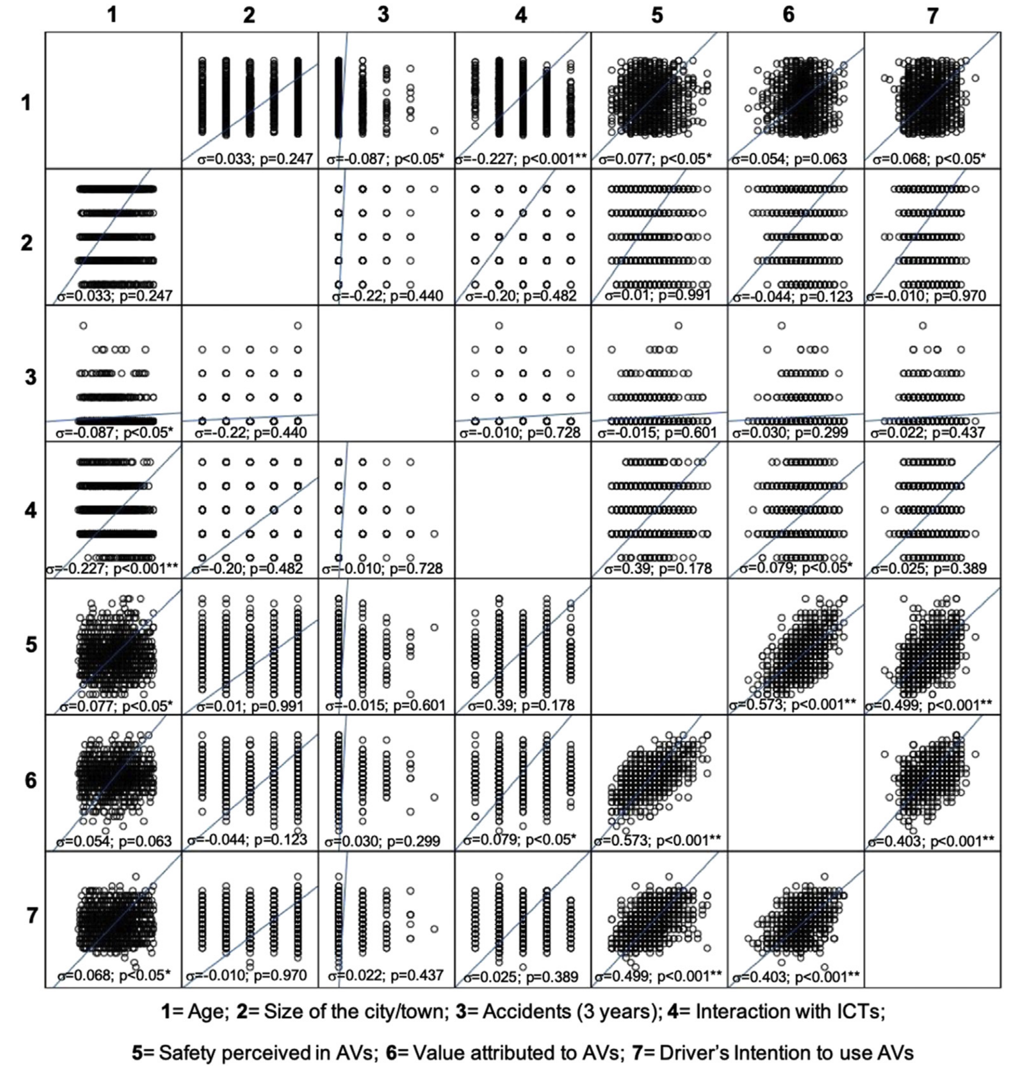

Fig. 1. Bivariate correlations between study variables (demographics, driving issues and AV-related perceptions) among Spanish drivers.

2.2. Questionnaire

For the original research [1], the questionnaire was administrated exclusively in Spanish (professionally translated for publication) and consisted of three main sections. The first part asked about individual and demographic variables, such as age, gender, city/town of provenance (and its size) and main current occupation.

In the second part, participants were asked about their level of interaction with Information and Communication Technologies (ICTs) in a scale between 1 (less interaction) and 5 (more interaction). It also contained a short form about driving-related issues such as: crashes suffered while driving conventional cars (along the last 3 years), driving tenure (years licensed) and driving patterns, including

Table 2
Descriptive statistics of AV-related study variables (factors) contained in the data set and gender-based differences.

Variable	Gender	N	Mean	SD[1]	SE[2]	95% CI[3]		ANOVA		
						Lower	Upper	F	p	Sig.
Perceived Safety	Female	538	12.62	3.20	.14	12.35	12.89	32.665	<.001	**
	Male	667	13.75	3.59	.14	13.48	14.03			
	Total	1205	13.25	3.47	.10	13.05	13.44			
Value Attributed to Autonomous Vehicles	Female	538	15.81	2.62	.11	15.59	16.03	21.685	<.001	**
	Male	667	16.58	3.00	.12	16.35	16.80			
	Total	1205	16.24	2.86	.08	16.07	16.40			
Intention to Use an Autonomous Car	Female	538	13.82	2.97	.13	13.56	14.07	11.194	.001	*
	Male	667	14.39	2.95	.11	14.17	14.61			
	Total	1205	14.13	2.97	.09	13.97	14.30			

Notes: [1]*SD* = Standard Deviation; [2]*SE* = Standard Error; [3]*95% CI* = Confidence Interval at the level 95%; *Significant at the level 0.05; **Significant at the level 0.01.

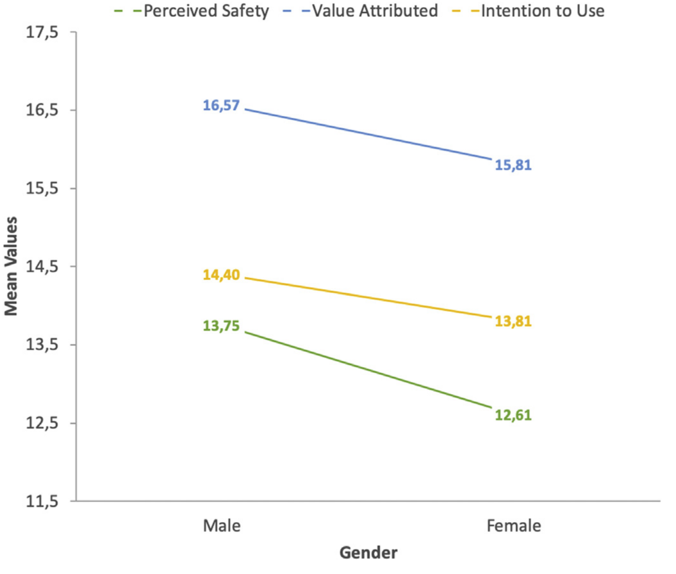

Fig. 2. Gender-based trends in the autonomous vehicle' appraisal of Spanish drivers.

the type of vehicle most frequently driven, number of kilometers (Km) a day, and their average frequency (times a week), in order to estimate the driving intensity.

As for the third part of the research questionnaire, a 5-item scale ($\alpha = 0.735$) was used for measuring the perceived safety of autonomous vehicles among drivers. It asked the level of agreement of drivers with statements related to the safety features of AVs through a Likert scale between 1 = total disagreement to 5 = total agreement. In order to assess the value attributed to the AV for traffic sustainability and road safety, it was applied a 5-item scale ($\alpha = 0.739$), aimed at obtaining the appraisal of participants on topics related to the impact of AVs on better and safer transport dynamics, using a Likert form ranging from 1 to 5. Finally, and in order to measure the intention of using autonomous vehicles, a 12-item ($\alpha = 0.929$) Likert scale (1 = total disagreement to 5 = total agreement), designed under the guidelines suggested by Van Der Laan et al. [7] was applied. It asked participants about different situations in which they would decide (or not) to use an autonomous vehicle, considering the potential benefits seen on it by them. The full set of items included in the questionnaire and their descriptive statistics are shown in Table 1.

Table 3
Age-based differences in perceptions on the autonomous vehicle among Spanish drivers.

Variable	Gender	N	Mean	SD[1]	SE[2]	95% CI[3]		ANOVA		
						Lower	Upper	F	*p*	Sig.
Perceived Safety	<25	113	12.70	3.15	0.30	12.11	13.29	2.49	.050	*
	25–35	271	13.12	3.53	0.21	12.70	13.54			
	36–45	359	13.07	3.35	0.18	12.72	13.41			
	46–55	326	13.64	3.69	0.20	13.24	14.04			
	>55	136	13.49	3.30	0.28	12.93	14.04			
	Total	1205	13.25	3.47	0.10	13.05	13.44			
Value Attributed to AVs	<25	113	15.90	2.91	0.27	15.36	16.45	1.47	.210	N/S
	25–35	271	16.32	2.93	0.18	15.97	16.67			
	36–45	359	16.03	2.91	0.15	15.72	16.33			
	46–55	326	16.42	2.73	0.15	16.12	16.72			
	>55	136	16.46	2.83	0.24	15.98	16.94			
	Total	1205	16.24	2.86	0.08	16.07	16.40			
Intention to Use AVs	<25	113	13.77	2.73	0.26	13.26	14.28	2.68	.031	*
	25–35	271	14.19	2.98	0.18	13.84	14.55			
	36–45	359	13.84	2.91	0.15	13.54	14.14			
	46–55	326	14.33	3.01	0.17	14.00	14.66			
	>55	136	14.63	3.14	0.27	14.10	15.16			
	Total	1205	14.13	2.97	0.09	13.97	14.30			

Notes: [1]*SD* = Standard Deviation; [2]*SE* = Standard Error; [3]*95% CI* = Confidence Interval at the level 95%; *Significant at the level 0.05.

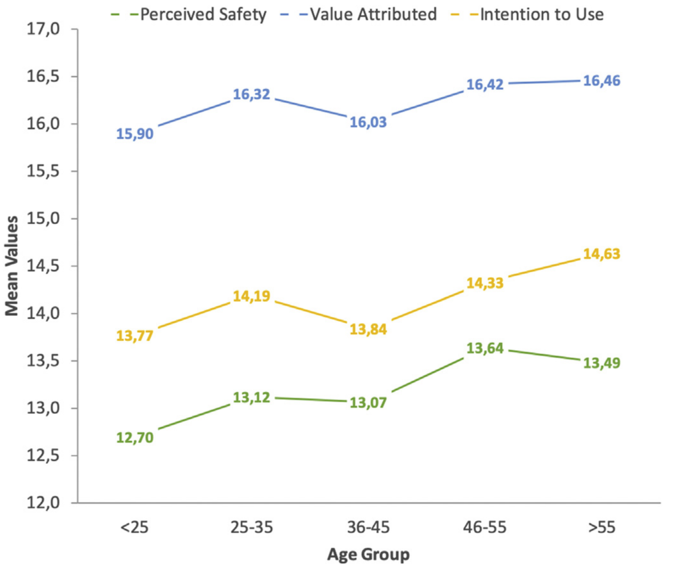

Fig. 3. Gender-based trends on the autonomous vehicle' appraisal (safety, value and intention).

2.3. Statistical analysis

First of all, basic descriptive analyses (i.e. means and standard deviations of the study variables) were obtained, and bivariate correlation analyses were carried out, in order to establish measures of association between pairs of these factors. Further, and with the aim of comparing the scores obtained on attitudes towards autonomous vehicles, One-way ANOVA (Analysis of Variance) was performed for the categorical factors: 1) gender; 2) age group - using five intervals, as described in the sample section;

Table 4
Town-size-based differences for main study variables.

Variable	Gender	N	Mean	SD[1]	SE[2]	95% CI[3]		ANOVA		
						Lower	Upper	F	*p*	Sig.
Perceived Safety	<5000	96	13.69	3.71	0.38	12.94	14.44	0.798	.525	N/S
	5000–0.2 M	208	12.97	3.57	0.25	12.48	13.46			
	0.2 M–0.5 M	172	13.31	3.34	0.25	12.81	13.81			
	0.5 M–1 M	145	13.12	3.85	0.32	12.49	13.75			
	>1 M	584	13.29	3.33	0.14	13.02	13.56			
	Total	1205	13.25	3.47	0.10	13.05	13.44			
Value Attributed to AVs	<5000	96	17.23	2.67	0.27	16.69	17.77	3.307	.010	*
	5000–0.2 M	208	16.03	2.79	0.19	15.65	16.41			
	0.2 M–0.5 M	172	16.13	2.72	0.21	15.72	16.54			
	0.5 M–1 M	145	16.22	3.34	0.28	15.67	16.77			
	>1 M	584	16.18	2.80	0.12	15.95	16.41			
	Total	1205	16.24	2.86	0.08	16.07	16.40			
Intention to Use AVs	<5000	96	14.94	2.87	0.29	14.36	15.52	3.205	.013	*
	5000–0.2 M	208	13.66	3.02	0.21	13.25	14.08			
	0.2 M–0.5 M	172	14.05	2.96	0.23	13.60	14.49			
	0.5 M–1 M	145	14.27	3.01	0.25	13.78	14.76			
	>1 M	584	14.16	2.95	0.12	13.92	14.40			
	Total	1205	14.13	2.97	0.09	13.97	14.30			

Notes: [1]SD = Standard Deviation; [2]SE = Standard Error; [3]95% CI = Confidence Interval at the level 95%; *Significant at the level 0.05.

and 3) width of the city of provenance. The full set of variables and cases composing the study is available in the annex dataset.

Acknowledgments

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Conflict of 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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.dib.2019.104662.

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Supplementary material

Questionnaire contents (root - researcher form)

Questionnaire code: _________

Section I.

Please answer the following questions. Remember that <u>*in no case*</u> *we will ask for your name, or for any personal data that could identify you.*

Age: _____

Gender: _________

City or town of residence: ___________________________________

Size (population) of your city/town of residence:

- o <5,000 inhabitants
- o Between 5,000-20,000 inhabitants
- o Between 20,000-50,000 inhabitants
- o Between 50,000-100,000 inhabitants
- o >100,000 inhabitants

Highest academic level (completed):

- o None (no studies)
- o Primary studies
- o Secondary studies / high school
- o Technical studies
- o University studies

Current occupation: ____

Section II.

In this section, we will ask some questions about your driving habits and other related variables. Please tell us:

For how long (years) have you had your driver license?: __________ years.
Note: if you do not own a driver license, please finish the survey here.

What type of vehicle do you drive the most, meaning routinely?:

- o Private car
- o Motorcycle/moped/two-wheeled
- o Van
- o Heavy vehicle (truck, bus, freight)
- o Other: _________________.

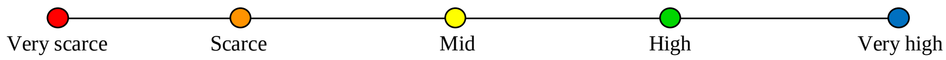
Approximately, how many days per week do you drive? (0-7): __________.
Note: if you drive less than once per month, please finish the survey here.

How many kilometers do you drive daily, considering the sum of all your usual journeys?:

- o <10 Km/day
- o Between 10-30 Km/day
- o Between 31-70 Km/day
- o >70 Km/day

Regardless of their severity, how many traffic accidents have you suffered during the past three (3) years?: _______

Interaction with ICTs – Please tell us your degree of usual interaction with this type of technology (cellphones, computers and/or smart devices which are normally connected to the Internet). Below the question you will find some criteria that will help you answer.



Very scarce: No use of these devices, except in some specific cases in which it is absolutely necessary.
Scarce: My interaction with this type of devices could be considered low. I use them only when necessary.
Mid: I sometimes interact with this type of devices, but not with a regular frequency.
High: I use them very frequently, but not necessarily every day nor for most of my activities.
Very high: I interact with technological devices on a daily basis, and I use them for almost all of my activities.

Section III.

Perceived safety - *In this section, we will mention some issues related to how safe Autonomous Vehicles (AVs) are, according to your perception. Please, state to what extent you agree with the following statements:*

Totally disagree – Disagree – Neutral – Agree – Totally agree

1. Overall, AVs would help make my journeys safer than they are when I use conventional cars
2. AVs would act better than myself in a complicated traffic situation
3. A driverless/automated vehicle may be not “smart” enough for guaranteeing my safety during the journey (-)
4. AV-related systems could easily break down, or be hacked, thus compromising my safety (-)
5. AVs would respond adequately to unexpected situations that commonly require rapid responses from drivers

Value - *Below, we will address some potential improvements in different spheres that AVs may (or not) imply. Please, state to what extent you agree with the following statements:*

Totally disagree – Disagree – Neutral – Agree – Totally agree

1. They would help improve the traffic flow, making journeys more agile and efficient
2. They would reduce fuel use and improve the environment
3. They might contribute to reduce crashes and injuries caused by traffic accidents
4. I believe the cost-benefit relation of AVs would not be balanced, and costs might overcome the benefits (-)
5. They would contribute to reducing the misbehaviors of drivers, and to strengthening respect and co-existence on the road

Intention – *Finally, we would like to present some brief statements about your intention of using AVs instead conventional vehicles:*

Totally disagree – Disagree – Neutral – Agree – Totally agree

1. I would prefer using an AV more than a conventional car when driving on urban/city roads
2. If during the next years I will have enough budget, I plan to buy an AV
3. I would prefer using an AV than a conventional car if I were tired
4. I am totally against the option of buying an autonomous car (-)
5. Considering the need of adapting to transport dynamics, planning to buy an AVs at some point in the next years sounds adequate

9.3. Artículo 3

Lijarcio, I., Useche, S. A., Llamazares, J., & Montoro, L. (2020). Are your eyes "on the road"? Findings from the 2019 National Study on Vision and Driving Safety in Spain. *International Journal of Environmental Research and Public Health, 17* (9), 3195. https://doi.org/10.3390/ijerph17093195

[¿Están tus ojos "en la carretera"? Hallazgos del Estudio Nacional de 2019 sobre la visión y la seguridad en la conducción en España]

Resumen

Introducción: Los problemas de visión son un factor de riesgo indiscutible para la explicación de muchos siniestros viales relacionados con el factor humano. Entre el 80% y el 90% de la información necesaria para conducir, se recoge a través de nuestros ojos, pero debido a la gran prevalencia de problemas visuales en la población, especialmente en población mayor, estos no se relacionan con riesgos para la seguridad vial. Además, existen evidencias sobre la laxitud que se tiene en la exploración visual a la hora de obtener un permiso o la renovación del mismo.

Objetivos: El objetivo de este estudio fue conocer la percepción que tienen los conductores españoles sobre la importancia de la salud visual en la conducción y evaluar tres elementos clave de la visión para la conducción: la agudeza visual, la campimetría y recuperación de la visión tras el deslumbramiento, con el fin de formular pautas para mejorar la conducción.

Métodos: Para averiguar la percepción sobre la salud visual se construyó un cuestionario online compuesto de dos secciones. La primera de ellas, recogía variables sociodemográficas y relacionadas con la conducción de vehículos y la segunda, recogía información sobre hábitos y actitudes relacionadas con la visión y la conducción de vehículos. Para evaluar los componentes de la visión se utilizó una herramienta de cribado y evaluación de la visión (Visiosmart), desarrollada por Essilor. La muestra estaba formada por 3.249 conductores españoles pertenecientes a las 17 comunidades autónomas. Los datos resultantes fueron analizados estadísticamente.

Resultados: De manera general los conductores consideran que conducir con problemas de visión es un riesgo para la seguridad vial, pero son las mujeres y los conductores de mayor edad los que atribuyen mayor importancia a las condiciones visuales para una buena conducción. En materia de autopercepción sobre la salud visual, solo el 18.3% de la muestra afirma que su visión es pobre o muy pobre. Las pruebas realizadas con el Visiosmart permitieron determinar que el 15% de los conductores españoles tienen problemas de agudeza visual, concretamente una mala visión fotópica y el 38% de ellos presenta una inadecuada visión mesópica. Además, el 23% de los conductores tienen deficiencias en la campimetría del campo visual periférico, y el tiempo promedio para la recuperación de la visión completa después de un deslumbramiento de 10 segundos fue de 27 segundos. Además, se encontraron diferencias significativas en las variables de género, edad y tipo de conductor (profesional versus no profesional).

Conclusiones: Los hallazgos de este estudio apoyan la idea de que ciertos grupos demográficos de la población de conductores presentan varias deficiencias en la salud visual. En general, se estima que el 29,5% de los conductores españoles presentan problemas visuales, que deben ser atendidos para mejorar la prevención de siniestros de tráfico y la seguridad de todos los usuarios de la vía. Estos datos nos indican la necesidad de realizar diferentes acciones, tanto a nivel legislativo y sensibilizador como de mejora en los protocolos de exploración visual en la población conductora española, para la mejora de la seguridad vial.

Palabras clave: visión, conducción, salud visual, conductores españoles, seguridad vial.

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Article

Are Your Eyes "on the Road"? Findings from the 2019 National Study on Vision and Driving Safety in Spain

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Abstract: *Background*: Vision is an undisputable contributor to the explanation of many human-factor related traffic crashes happening every day. The Inland Transport Committee (ITC), the United Nations regulatory platform, included on 1st April 2020 special action on the vision of road users inside the ITC Recommendations for Enhancing Road Safety Systems. The results of this wide-scale study on drivers' vision health conducted in Spain perfectly illustrates the need of global action and its potential impact on the public health figures and the burden of potentially preventable traffic causalities. *Objective*: The aim of this study was to assess three key visual health issues (i.e., visual acuity, visual field campimetry and glare recovery) among Spanish drivers, in order to formulate implications and possible guidelines to enhance road safety. *Methods:* This cross-sectional study examined the visual health of a representative sample of 3249 drivers (70% females and 30% males) with a mean age of 41 (*SD* = 13) years, gathered from all the 17 autonomous communities of Spain. *Results*: The tests performed allowed to determine that 15% of Spanish drivers have a poor photopic vision, while 38% of them present an inadequate mesopic vision. Further, 23% of drivers have deficiencies in peripheric visual field campimetry, and the average time for full-vision recovery after a 10-s glare was 27 s. Sex, age and driver type (professional vs. non-professional) differences were found for the study variables. *Conclusions*: The findings of this study support the idea that certain demographic-based population groups of drivers present several unaddressed deficiencies and impairments in visual health. Overall an estimated 29.5% of Spanish drivers present visual issues, that need to be attended in order to enhance the prevention of driving crashes and the road safety of all road users.

Keywords: vision; driving; visual health; Spanish drivers; road safety

1. Introduction

During the last ten years, the prevalence of visual impairments has systematically been growing in Spain [1,2]. This concerning trend has begun to represent a major concern for public health among public administrations, healthcare providers, researchers and health prevention and promotion practitioners, since visual health maintains a close relationship with population safety and welfare at all ages [3,4].

Visual defects and illnesses adversely impact the psychosocial and economic spheres of people's life, but also the performance of different everyday activities, including operating machinery and motor vehicles [5,6]. Driving constitutes a considerably complex task, in which vision inarguably has a role [7], since it represents the most important information source on the road. Furthermore, numerous driving related injuries are associated with visual problems [8] and visually impaired drivers have more severe traffic crashes than healthy drivers [9]. In other words, an impaired vision can represent a major contributor in the likelihood of suffering a driving crash, as a consequence of not adequately receiving the needed incoming environmental information (*inputs*) that needs to be processed and responded to in a considerably short reaction time range, with potentially severe consequences in case of failure, as also emphasized at the *ITC Recommendations for Enhancing Road Safety Systems*, published by the United Nations Organization [10–13]. Further, applied studies have shown how drivers with certain eye conditions tend to decrease their exposure to the road and limit their driving to the safest times [14] as a manner of decreasing the risk of getting involved in a crash.

Also, recent social research outcomes point the fact that macro-social phenomena such as an aging population, that explains the increasing representation of elderly people into the driver's census, may imply different new challenges for road safety practitioners, if factors such as the loss of visual acuity and other psychomotor impairments related to aging (inside and outside the visual sphere) are considered [10,15]. In the case of Spain, the aging of driving population has been catalogued as a latent threat to traffic safety. As a relevant figure, the official statistics reveal that for the year 2018, about 19% of the drivers were adults older than 65 but, at the same time, 27% of the deceased as a consequence of traffic crashes belonged to this age group. This fact, apart from illustrating the overrepresentation of older adults in traffic victim figures, raises different questions on how elderly drivers should be trained, assessed and monitored to strengthen their road safety [16].

In driving vision factors are more than merely age-related issues. Visual health has several other features, implications and risk groups than those directly explainable through age comparisons. In brief, visual impairments negatively affect the autonomy and functionality of subjects, being also related to poorer mental health, higher cognitive deterioration and greater probabilities of suffering accidental injuries [1,4].

1.1. Importance of Vision Testing for Driving Licensure

In addition to knowledge tests on road rules, visual acuity testing is the most common functional method for determining a driver's eligibility for licensure processes [12,17]. Indeed, most of the countries in which the psychophysical examination of drivers is mandatory have already included vision assessment as a necessary requirement for the qualification for a driver's license (or for its renewal) [18]. However, these assessment processes only take into account certain basic visual parameters, and several other facets of visual function and processing, that are also involved in driving performance, are omitted in driver recognition exams [7]. For instance, and although visual acuity is crucial for safe driving (e.g., the reconnaissance of road patterns, traffic signals and other users' behaviors), other relevant matters related to the driving task, such as campimetry and glare recovery, remain unstudied in driving recognition tests in many countries, although not in Spain. Accordingly, the use of visual acuity as a single criterion for assessing visual standards for driving has been widely criticized in the scientific literature [18]. Also, recent studies have related eye movements with attentional issues and fatigue, factors that may also explain a substantial part of the human-factor related traffic causalities occurring every day [19–22].

Worldwide, driver's assessment is the only standardized process allowing the identification of "problematic" cases whose characteristics can put the road safety of all road users at risk, in order to take the required actions (e.g., specialized diagnosis, treatment, imposing driving restrictions) needed to reduce human factor-related jeopardies potentially deriving in economic losses, injuries and deaths on the road [23,24]. Driver assessment procedures are usually multidimensional, not being reduced to visual issues and the usually also address (although briefly) several issues related to the psychophysical health of subjects through the use of specialized tests, measures and protocols [25]. Nevertheless, some studies have criticized the laxity of some of the tests usually applied in these processes, including those employed for vision assessment, not strictly as a matter of rigor, as the examination is frequently reduced to visual acuity—necessary, but not sufficient—while other aspects may also play a crucial role in the accurate task of driving a motor vehicle [10].

Among several items and parameters that could be used for assessing visual health in driving, there are four issues that acquire special relevance for the accurate performance of this task and, according to the International Commission for Driver Testing (CIECA) [26], should be considered in driver recognizance and licensure processes:

First of all, visual acuity measures, both photopic and mesopic, have been frequently stated as relevant factors to consider for driver' examination [27]. The photopic—high contrast visual acuity indicates the user's visual quality in daylight conditions, and the mesopic visual acuity indicates the vision quality in low light conditions, such as at dusk or when there is fog or rain [28], providing additional insights in regard to functional vision loss processes that may constitute a risk under difficult driving conditions [29]. Secondly, driver's visual field, measurable through pupil campimetry in response to perimetric stimuli [30], contributes to determine whether the subject has visual field defects in an efficient manner (through a quick machine-based screen testing), but needs to be contrasted with other indicators and at different angles (e.g., 45°, 60°, 80° and 90°) in response to the relative stability of the measures [31]. Thirdly, glare recovery constitutes another relevant factor to assess, given that, (especially during night driving) subjects need to face different light sources of high intensity or brightness [32], that may make difficult to detect road signs, patterns and other road users (such as the case of crossing pedestrians), prolonging the latency of reaction times [33].

Besides, much has been written in the literature in regard to the incidence of ametropia, which testing aims to determine the existence of refractive defects related to myopia and hypermetropia (or *hyperopia*), that may enhance the occurrence of driving errors (undeliberate risky road behaviors). Specifically, the prevalence of both myopia and hypermetropia has been determined as considerably high (but highly variant) in many populations, remarking the relevance of ethnic differences in this regard: myopia and hyperopia have an approximated prevalence to, respectively, 25% and 34% in South American countries [34]. In some Asian countries, approximately one out each four people suffer myopia (26.8%) and one out of six subjects (15.8%) presents hypermetropia [8]. Among Europeans, the prevalence of myopia reaches 30.6% (approximately one out of each three subjects), and hyperopia 25% (one out of each four subjects) of the population [35].

1.2. Vision and Driving Safety: Key Evidences and Gaps

As aforementioned, in the practical field visual health plays a crucial role for road safety. Several studies have systematically demonstrated how drivers with better visual parameters tend to perform less risky driving behaviors and to provoke less traffic crashes [9,11], contributing to improve one of the many facets of public health, taking into account that every year 1.3 million people die (and many others are injured) due to "accidents" that can be prevented through timely diagnoses and interventions [36].

However, and although several evidences remark the need of strengthening visual health as a way to face the threat of driving crashes, the panorama becomes certainly challenging when visual health statistics are faced. For instance, 65% of people who are visually impaired are aged 50 and older [37], bearing in mind that visual function, optical quality and intraocular scatter tend to change with age, creating optical deficits that need to be compensated in later stages of life [38,39].

Also, applied studies previously conducted in Spain have pointed out the existence of several gaps and inequalities in terms of visual health, between rural and urban regions, enhanced by factors such as access to information, eye care services and health promotion strategies (whose coverage can be substantially limited to urban areas) and, of course, as a result of economic issues [1]. These figures raise key questions in this regard, such as "to what extent are the driving population "healthy" in visual settings?", and "may the eye care habits of drivers be strengthened via a higher healthcare coverage and further preventive strategies performed by institutional stakeholders?".

1.3. Objectives of the Study

The purpose of this study was to assess three key visual health issues (i.e., visual acuity, visual field campimetry and glare recovery) among Spanish drivers, in order to determine their implications and formulate possible guidelines to enhance road safety.

2. Materials and Methods

2.1. Sample

The data used for this study was collected from a full sample of 3249 Spanish drivers (30% females and 70% males) aged between 16 and 90, with a mean age of $M = 41.05$ ($SD = 12.98$) years. The data was retrieved along the year 2019 across all the 17 regions (autonomous communities) of the Spanish territory. Nearly half (42.6%) of the drivers (39.5% of males and 49.4% of females) who participated in the study used some visual correction system. Within this group, 84.1% use glasses, 7.4% contact lenses and 8.5% both systems (glasses and contact lenses). Additional descriptive data of the sample are described in detail in Table 1.

Table 1. Characteristics of the sample used in the study.

Feature	Category	Frequency	Percentage
Sex	Male	2284	70.3%
	Female	965	29.7%
Age interval	≤25 years	409	12.6%
	26–35 years	775	23.9%
	36–45 years	902	27.8%
	46–55 years	717	22.1%
	56–65 years	310	9.5%
	>65 years	136	4.2%
Type of driver	Non-professional	2491	76.7%
	Professional	758	23.3%
Driving frequency	Once a week or less	70	2.2%
	2–3 days a week	251	7.8%
	4–6 days a week	807	24.9%
	7 days a week	2121	65.3%
Type of vehicle	Private car	2680	82.5%
	Motorcycle/moped/two-wheeled	171	5.3%
	Van/ Light Freight (>3.5 Tons)	200	6.2%
	Heavy Freight (<3.5 Tons)	18	0.6%
	Bus	11	1.6%
Have you been involved in a driving crash?	No	1808	55.6%
	Yes	1441	44.4%

An initial screening aimed to discard participants with severe visual pathologies that may impair the results of the study showed that 71.9% of drivers composing the final sample could be considered as emmetropes (no significant refractive defects were detected), and 28.1% of participants present slight or non-severe visual ametropic deficiencies (i.e., either myopia or hyperopia, a fact that remains undetermined as a consequence of the lack of specificity of the tool). Of the subjects with visual refractive defects 42.5% reported often suffering blurred vision symptoms, while 41.8% of them reported suffering blurred vision quite frequently. The rest of the sociodemographic variables (sex, age, etc.), and the type of driver (professional driver, driving days per week, etc.) did not show significant differences.

2.2. Study Design and Procedure

For this cross-sectional study, we used a non-probabilistic (convenience) sampling method, that is commonly used for this type of research focused on specific populations, founded on the accessibility to the population of interest (i.e., Spanish drivers) and on their willingness to partake in the study. Specifically, data collection was performed through a face-to-face invitation to drivers using the services of a national-covering network of gas and service stations (Spanish Petroleum Company—CEPSA, Madrid, Spain), present in all the regions of Spain.

All them were invited to answer to a questionnaire and to perform a standardized vision test (see Section 2.3 for further information). The global response rate (completed and totally answered questionnaires) was approximately 65%, from a total of approximately 5000 drivers initially asked to participate throughout the national territory.

The sample is highly representative from the national census of licensed Spanish drivers, that was composed of approximately 26,853,754 individuals for the year 2018 [40]. Sample size was initially calculated through the Raosoft® sample size calculator (Raosoft Inc., Seattle, WA, USA), based on the total population and on the estimated sample needed to fulfill the basic parameters. The minimum sample size calculated was approximately 1843 subjects, assuming a confidence level of 99% and a maximum margin of error of 3%. The study sample was determined to be representative of the Spanish population considering not only its large size but also its concordance with the characteristics of the population and its geographical coverage. In this regard: (a) this study retrieved data from all the different 17 regions or autonomous communities (including two special jurisdictions outside the Iberic peninsula) of Spain; (b) a minimum quota, proportional to the population density of each one of the regions was established; and (c) subjects were invited to participate regardless their previous diagnosis in visual settings, avoiding selection bias for actively driving population.

As for procedural considerations, it is worth remarking that all the data were obtained from gas and service stations whose employees had been previously informed about the research project, and both the interviews and testing procedures were always performed by a trained member of the research team, especially considering the need of using advanced visual assessment tools, that need to be conducted by a professional in the field.

All the participants involved in the research were initially informed about the importance of answering honestly to all the questions raised in the interview, and to provide honest information for the performance of the vision test. Also important, participants were invited to enjoy a balanced snack of their choice, that could be picked up at the gas station store after completing the interview and visual test. However, the inexistence of potential monetary rewards as a consequence of their partaking in the study was explicitly emphasized before their participation.

2.3. Instruments

For this research, an assisted interview (conducted to complete a self-report-based questionnaire) and an applied vision test were performed. The average time required for answering to the questionnaire was approximately 10 min, and the vision test took approximately 5 min.

2.3.1. Self-Reported Information

The interview was performed in Spanish and consisted of two main sections: The first part inquired about individual and demographic variables, such as age, sex, educational level, size of the town or city of residence, and occupation. It also contained a brief questionnaire about driving-related issues such as: crashes suffered while driving since they were licensed, driving tenure (years of experience as a licensed driver) and driving patterns/habits, that included: (a) the type of vehicle most frequently driven, (b) the approximate number of kilometers (km) driven every day, and (c) driving frequency (number of times they drive in a week), these last two measured with the objective of estimating mileage or driving intensity.

The second part of the interview was composed of a brief questionnaire aimed to assess attitudes and habits related to the vision in driving: perception of the risk of having poor vision and other risky scenarios for driving (ranging from 1 = not risky at all to 5 = very risky), self-perception of the quality of one's own vision (ranging from 1 = very poor to 5 = very good), use of glasses or contact lenses, habits of vision checking, and any previously suffered vision-related problems.

2.3.2. Visiosmart® Vision Test

For the vision assessment, the Visiosmart® 500 C87001 Automatic Vision Screener tool for vision assessment developed by Essilor Instruments (Chicago, IL, USA, 2018) was used. This is a standalone self-directed digital vision screener that can allow for automatic vision checks, which has been widely tested and certified according to ISO 8596 standard for this purpose. Visiosmart® allows one to assess three key vision-related factors, that were strategically selected following the recommendations provided by the International Commission for Driver Testing [26]:

Visual acuity, i.e., a measure of the ability of the eye to distinguish shapes and the details of objects at a given distance [41]. Visual acuity is also one of the most used tests for driver licensing worldwide [42]. In this case, visual acuity was measured under two different lighting situations: (a) *Photopic acuity*—the user's visual quality in daylight conditions, and (b) *Mesopic acuity*—the user's visual quality under low-light conditions. The visual acuity values used in the Visiosmart® test are represented on a continuous scale, in which the minimum possible value is 1 (very poor visual acuity) and the maximum 12 (maximum visual acuity) for both the photopic and mesopic acuity assessments. Based on this, the following guidance intervals are presented: [1–3] Very poor; [4–7] Poor; [8–12] Good.

Visual field campimetry, that objectively allows measuring the visual field by analyzing the pupil response to perimetric stimuli [30]. The Visiosmart® test performs a repeated-measures assessment using different peripheral visual field amplitudes: 45°, 60°, 70°, 80°, 90° and 100°, in order to establish the cut-off point for each subject. For the interpretation of results, and in accordance to the specialized literature [18], 80° is suggested to be the cut-off criterion (adequate/inadequate), so that any subject who obtains a negative result at 80° or below, could be considered as with "deficiencies" in pupil campimetry, while those who do not have negative results or these are only at 80° or higher, can be considered as subjects presenting normal results in this test.

Glare recovery time, i.e., the extent it takes to a person to fully recover visual parameters and functionality after a certain time looking at a light, as it can also happen when a driver is glared when driving at night by another vehicle coming from the front with the high beams on. Thus, the temporary blinding effect from headlights is followed by a period of time required to fully recover vision, in which involuntary risky behaviors may take place. For this study, the criterion time of exposure to a light stimulus of 4 lux was established as 10 s, in accordance to the most common standards used in applied driving studies [43].

2.4. *Statistical Analysis (Data Processing)*

After a careful data curation, study variables were calculated. In the case of demographics, the data were rigorously coded and labelled, in order to categorize drivers by (e.g.,) sex, age and type of driver (professional/non-professional). The self-reported section of the interview (i.e., risk perception and importance attributed to vision in driving performance) were analyzed through descriptive statistics (mean, standard deviations, standardized errors). Each one of the four visual issues addressed by the Visiosmart® test were scored and categorized according to the interpretation guidelines the tool. Additionally, mean comparisons (ANOVA and Brown-Forshyte's robust tests for mean differences) were performed with the aim of assessing sex-based differences in the test sections providing continuous measures, for which confidence intervals [CI = 95%] were also calculated. As the sample was largely disproportional in regard to drivers' sex (70.3% males and 29.7% females), the sample was weighted to a rebalanced distribution (54.2% male and 45.8% female drivers), more useful and adequate for carrying out sex-based comparisons without affecting means, standard deviations/errors, or confidence intervals of the contrasted variables. Frequency analyses were used to determine the age-based proportionality of sample segments (principally age groups). Bivariate (Pearson) correlations were used to examine the measures of association between visual parameters (when continuous) and demographic variables. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS), version 26.0 software (IBM, Armonk, NY, USA, 2019).

2.5. Ethics

This study was assessed and approved by the Ethics Committee of the Spanish Foundation for Road Safety (IRB HE2019003ESP), thus certifying that the research subject to analysis and its methods responded to the general ethical principles addressed in the Declaration of Helsinki for research with human subjects. This study did not perform any intervention and/or clinical trial on participants.

3. Results

3.1. Drivers' Self-Rated Vision Sight and Road-Risk Perception

In order to assess the importance attributed to visual health in driving safety, drivers were asked to rate in a 0–5 scale (0 = no perceived risk at all; 5 = too much risk perceived) to what extent do they consider five different situations, that are generally conceivable as hazardous, may imply a risk for their driving performance, finding that "driving with an impaired vision" ranks on the first place with a mean of M= 4.84 (SD = 0.50), as shown in Figure 1, where females (M = 4.87, SD = 0.43) perceive a significantly higher risk perception on *driving with poor vision* ($F_{(13,247)}$ = 12.532; p < 0.001) when compared to males (M = 4.82, SD = 0.52), but without significant differences between professional and non-professional drivers ($F_{(13,247)}$ = 0.101; p = 0.751). Also, there was a significant bivariate correlation (r = 0.121; p < 0.001) between the age of drivers and the risk perceived in driving with an impaired vision; in other words, the higher is the age of the driver, the greater is the importance attributed to visual conditions for driving performance.

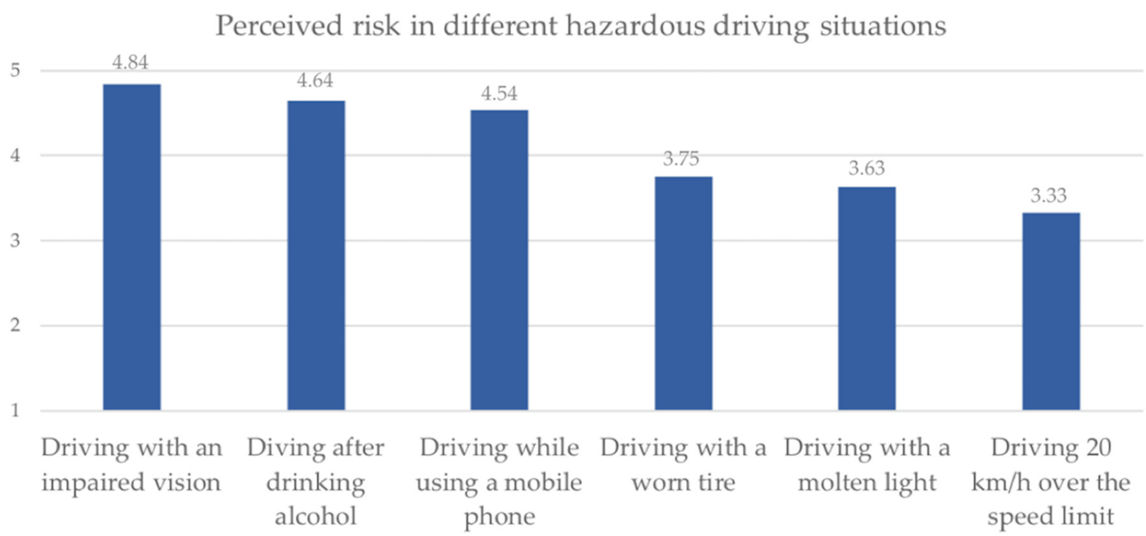

Figure 1. Average level of risk attributed to different potentially impairing driving situations (scale 1–5).

Drivers were also asked about their self-rated visual health. In this regard, 61.0% of them consider their vision is either very good (17.3%) or good (43.7%). 20.7% assess their vision as normal (not optimal but with no significant defects or impairments). Nevertheless, 12.9% of participants consider their vision as poor, and 5.4% as very poor. Non-significant sex-based differences ($F_{(13,247)}$ = 0.003; p = 0.956) were found for self-rated vision between males and females, nor in comparisons between professional and non-professional drivers ($F_{(13,246)}$ = 1.583; p = 0.208).

3.2. Visual Acuity

The categorical analysis of the obtained results indicated that 15.4% of Spanish drivers have a "poor" (15.1%) or "very poor" (0.3%) *photopic* visual acuity, even considering the optimal conditions of luminosity provided by the Visiosmart® tool. The remaining 84.6% of drivers have an adequate visual acuity under daylight conditions. As for the low-luminosity condition, that is comparable to night driving, *mesopic* visual acuity was scored as "poor" (38.7%) or "very poor" (1.1%) for 39.4% of the participants of the study, while only 60.6% present acceptable values in this regard.

The average score for photopic visual acuity (under normal/high light conditions) was $M = 9.95$ for the full sample, and significantly different ($F_{(13,247)} = 6.755$, $p < 0.001$) when comparing between males (higher) and females (lower), as shown in Table 2. The mean found for the low light condition, i.e., mesopic visual acuity, was $M = 7.82$, without significant sex-based differences between male and female drivers.

Table 2. Results from visual acuity tests (photopic and mesopic) by age group, sex and overall sample.

Variable	Age Group	N	Total		Male		Female		Sex Differences
			M [1]	*SD*	*M* [1]	*SD*	*M* [1]	*SD*	
Photopic visual acuity	<25 years	409	10.15	2.48	10.32	2.47	9.90	2.48	N/S
	26–35 years	775	10.34	2.33	10.40	2.28	10.22	2.42	N/S
	36–45 years	902	10.43	2.22	10.52	2.21	10.19	2.26	*
	46–55 years	717	9.68	2.53	9.78	2.54	9.05	2.49	N/S
	56–65 years	310	8.84	2.56	8.87	2.55	8.73	2.59	N/S
	>65 years	136	7.82	2.44	7.82	2.37	7.81	2.67	N/S
	Total	3249	9.95	2.48	10.01	2.47	9.81	2.49	*
Mesopic visual acuity	<25 years	409	8.26	2.61	8.34	2.66	8.14	2.55	N/S
	26–35 years	775	8.29	2.55	8.34	2.60	8.21	2.43	N/S
	36–45 years	902	8.37	2.48	8.46	2.50	8.12	2.39	N/S
	46–55 years	717	7.42	2.30	7.49	2.30	7.25	2.31	N/S
	56–65 years	310	6.35	2.07	6.37	2.05	6.30	2.13	N/S
	>65 years	136	5.46	1.76	5.53	1.70	5.25	1.97	N/S
	Total	3249	7.82	2.54	7.85	2.56	7.74	2.49	N/S

Notes: [1] Values ranging from 1 to 12; *SD* = Standard Deviation; N/S = mean difference is non-significant; * = mean difference is significant with $p < 0.05$.

Regarding types of driver (professional vs. non-professional), significant differences were found for both measures, being in both cases the means greater for the case of professional drivers: *photopic* visual acuity has shown significant differences with $M = 10.32$ ($SD = 2.27$) for professional and $M = 9.85$ ($SD = 2.52$) for non-professional drivers ($F_{(13,247)} = 9.365$; $p < 0.001$), and *mesopic* visual acuity has shown significant differences with $M = 8.18$ ($SD = 2.52$) for professional and $M = 7.71$ ($SD = 2.53$) for non-professional drivers ($F_{(13,247)} = 9.150$; $p < 0.001$).

Furthermore, the age group-based analysis has shown a lessening trend for both visual acuity measures. The mean of *photopic* visual acuity decreases from the range $M = [10.32–10.52]$ found for subjects younger than 45 years to $M = 7.81$ among individuals older than 65. Specifically, the Pearson correlation between age and photopic visual acuity was $r = -0.216$ ** (significant at the level 0.01). The mean values found for *mesopic* visual acuity -considerably lesser than the ones obtained by subjects in the photopic test- present also a decreasing trend with age, if the first three groups (ranging between $M = [8.12–8.21]$) are compared with adults over 65 ($M = 5.25$). Particularly, the Pearson correlation obtained between age and photopic visual acuity was $r = -0.278$ ** (significant at the level 0.01). Figure 2 displays the mean/dispersion-based distribution of the scores reported by both tests in subjects of different age groups.

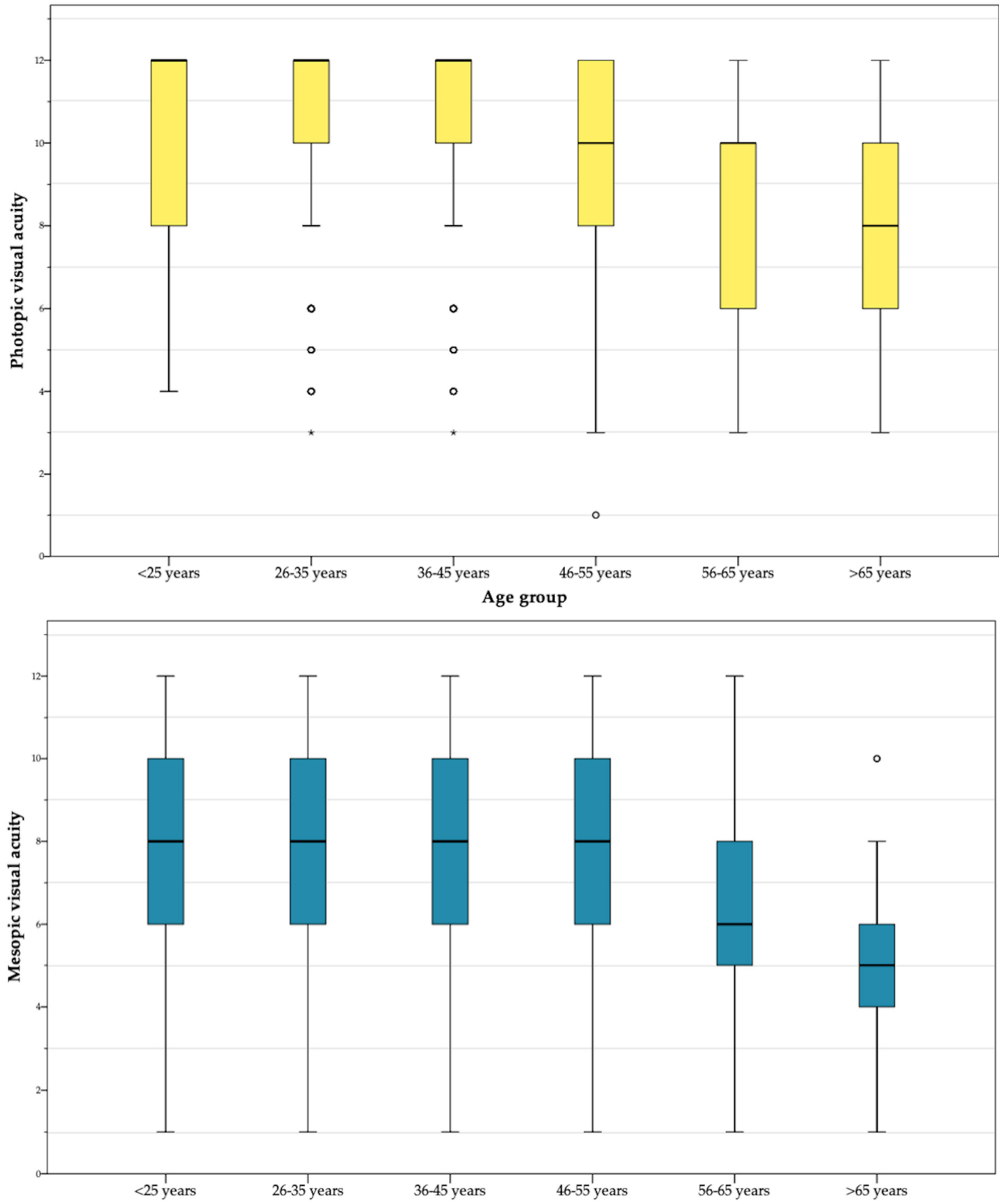

Figure 2. Boxplot-distribution of scores in photopic (high luminosity) and mesopic (low luminosity) visual acuity by age group (linear scale).

3.3. Visual Field Campimetry

The results of the pupil campimetry tests are shown at Table 3, where the different openness levels evaluated from 45° to 100° appear, both for the left eye and for the right eye. For this test, 80° of field amplitude is established as a cut-off point, so that any driver who obtains a negative result at 80° or below could be considered as a driver as with "deficiencies" in terms of peripheral visual field campimetry, while those who do not they have negative results or these occur above 80°, it is considered as a driver that presents "*good/normal*" results in this regard.

Table 3. Results of peripheral campimetry tests under different field amplitude angles [45° to 100°].

Left Eye	Percentage of Cases	Right Eye	Percentage of Cases
45°		*45°*	
Normal	89.1%	Normal	89.9%
Defective	10.9%	Defective	10.1%
60°		*60°*	
Normal	95.7%	Normal	96.3%
Defective	4.3%	Defective	3.7%
70°		*70°*	
Normal	95.5%	Normal	95.7%
Defective	4.5%	Defective	4.3%
80°		*80°*	
Normal	94.7%	Normal	93.5%
Defective	5.3%	Defective	6.5%
90°		*90°*	
Normal	81.8%	Normal	82.2%
Defective	18.2%	Defective	17.8%
100°		*100°*	
Normal	44.5%	Normal	44.9%
Defective	55.5%	Defective	55.1%

Based on these criteria, the results of this study indicate that almost one in four drivers (23.5%) seems to have "deficiencies" in peripheric visual field campimetry. Further, 77.5% of males and 74.2% of females presented good/normal values in the campimetry test, with no significant sex-related differences found in this regard. Also, no significant differences as for the results obtained when measuring campimetry in the left and right eye were observed, being the percentage of right eye's normal cases just slightly higher at critical values of 90° and 100°.

Drivers with good/normal results in campimetry are younger than those with poor results. The percentage of subjects with poor results increases especially after age 45, reaching 47.7% among drivers over 65 years. The average age of drivers with normal test results is $M = 39.9$ (approximately 40) years, while those with a defect in the campimetry test have an average age of $M = 44.6$ years. Figure 3 shows the graphical trends in terms of normal/defective cases across all age groups of drivers.

3.4. Glare Recovery Time

The glare test, as above indicated, measures the seconds it takes to a person to recover central vision after looking at a light for a certain amount of time. In this case, the criterion time for glare exposition was 10 s, i.e., the most common standard used worldwide for this type of test. The glare test has shown how, in 44.2% of cases, drivers need more than 20 s to fully recover normal vision parameters. Furthermore, of subjects 9.4% needed more than 60 s for full visual recovery, implying an excessive time driving under an impaired (partially functional) vision if a hypothetical driving scenario is considered. (Table 4)

Regarding the continuous measure (seconds) provided by the test, the average time required for full-visual recovery (considering all the sample) was $M = 27.05$ ($SD = 26.86$) seconds. In this regard, sex differences were also analyzed, finding marked significant differences between males and females. The average full-vision recovery time for males was $M = 26.16$ ($SD = 27.22$; $IC_{95\%}$ = [25.04–27.28]) seconds, while females needed $M = 29.14$ ($SD = 25.89$; $IC_{95\%}$ = [27.50–30.78]) seconds, and significantly different ($F_{(13,247)} = 6.755$, $p < 0.001$) when comparing the weighted samples. Summarizing the sex-based analysis outcomes, the glare recovery after a 10-s exposition takes in average 3 s more to female drivers. In other words, a male driver glared circulating at an assumed constant speed of 80 km/h may travel up to approximately 507 m. before fully recovering vision, and this figure could raise up to the 565 m. for the case of a female driver.

Table 4. Time required for full-vision recovery after glare exposition (total sample).

Recovery Time	Percentage	Accumulated Percentage
<20 s	55.8%	55.8%
21–30 s	16.1%	71.9%
31–40 s	9.4%	81.3%
41–50 s	5.4%	86.7%
51–60 s	4.0%	90.7%
>60 s	9.3%	100%

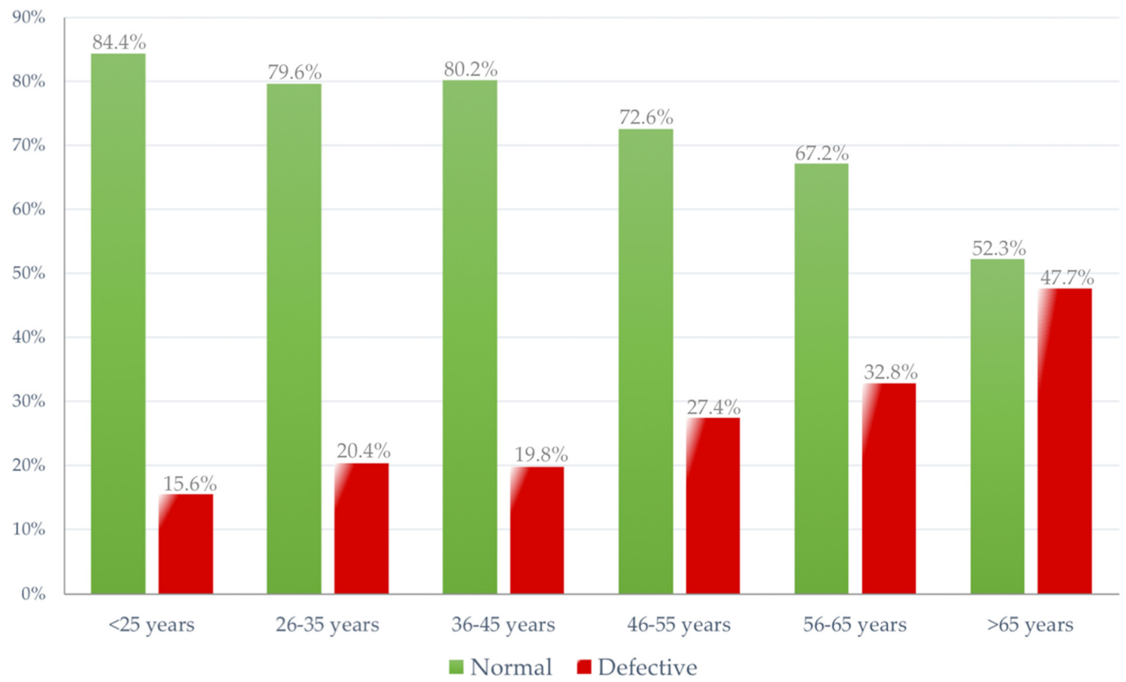

Figure 3. Distribution of normal and deficient cases for visual field screening (80° campimetry) by age group (percentages).

As for age-based analysis of glare recovery times, it ranged from $M = 24.90$ ($SD = 24.06$) seconds shown by drivers between 36–45 years [minimum] and the $M = 38.39$ ($SD = 33.50$) seconds needed to fully recover vision by drivers aged older than 65 [maximum], as shown in Figure 4 that graphically displays the distribution of recovery times in different age groups. Also, a significant Pearson' correlation between driver's age and recovery times (measured in seconds) was found, with r = 0.074 ** (significant at the level 0.01); in other words, the higher is the age of the driver, the greater is the visual recovery time needed after a glare. Going back to the previously described example, while full-vision recovery may take up to 482 m. to a driver ranged between 36–45 years, this travel distance can be increased up to 744 m. in an older driver.

Regarding comparisons between professional and non-professional groups of drivers, it was found that significant differences at the level $p < 0.05$ exist in the recovery time, being the $M = 25.38$ ($SD = 25.22$; $IC_{95\%} = [23.58–27.18]$) seconds for professional drivers, and $M = 27.55$ ($SD = 27.33$; $IC_{95\%} = [26.48–28.63]$) seconds for non-professional drivers ($F_{(13,243)} = 4.158$; $p = 0.042$).

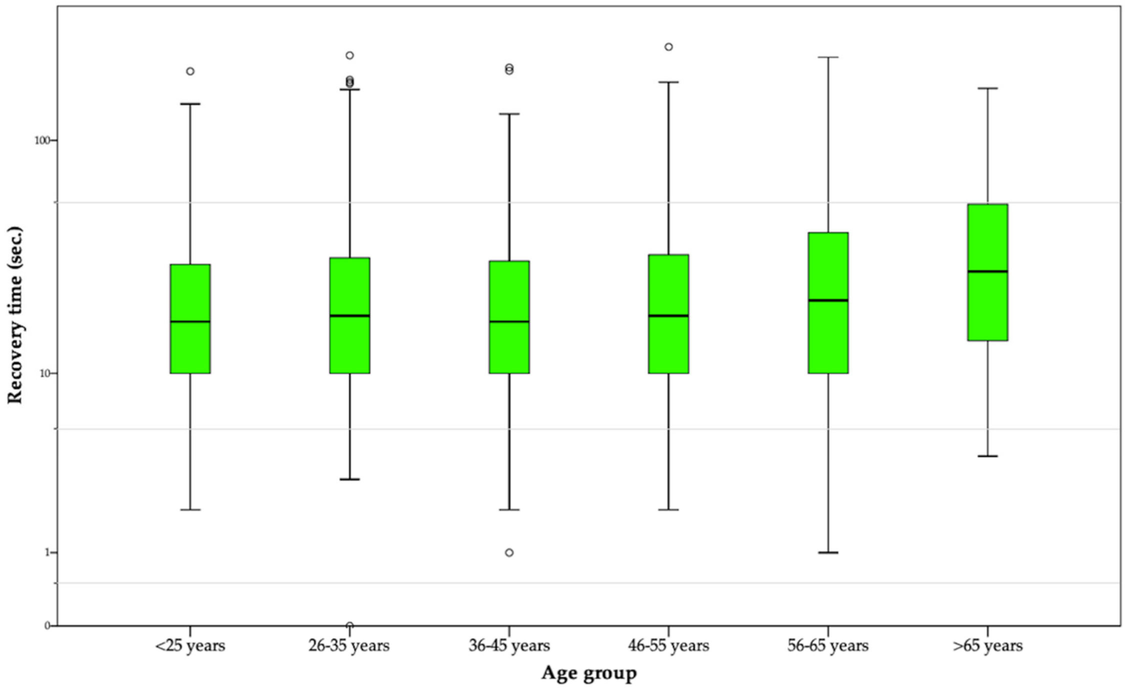

Figure 4. Boxplot—distribution of scores in full-vision recovery time after a 10-s exposition to glare, by age group (logarithmic/base-10 scale).

4. Discussion

The purpose of this cross-sectional study was to assess three key issues (i.e., visual acuity, field campimetry and glare recovery tests) related to the visual health of the Spanish driving population, in order to assess its implications and formulate possible guidelines to enhance road safety.

The figures found in this national-coverage empirical experience, although showing an overall adequate set of visual parameters among the Spanish driving population, raise some concerning issues related to the visual health status and the road risk of subjects suffering visual conditions that may impair their driving performance.

A first positive aspect to highlight is the fact that, regardless their visual fitness, Spanish drivers (especially women) report a considerably high awareness on the relevance of visual health for both driving performance and road safety, that is a major concern for public health practitioners. In brief, the risk perceived in driving with visual impairments was greater than the risk attributed to other generic situations typically increasing crash risk, such as alcohol-impaired driving [44,45], problematic used of mobile phones in driving [46], and driving over the speed limits [47]. However, and although studies dealing with this and different other issues equally relevant to human-based crash prediction (such as fatigue, health and risky behavior) have endorsed the value of public awareness as a first step to take actions aimed at reducing road risks, further evidences support the idea that awareness in road safety issues is not sufficient to prevent drivers from having road traffic crashes, but foster actions, tools and focused interventions are needed to strengthen road safety figures [48,49].

In this regard, it is worth mentioning that, in vision settings, intra-subject awareness can be a matter whose reliability is arguable. For this study, 19% of Spanish drivers self-reported having any vision impairment, a figure that, when compared to the data retrieved from the three objective tests performed, raises several implications for strengthening driving safety through strategic actions aimed at improving the visual care and fitness of drivers.

Visual acuity tests under two different light conditions (first objective measure of this study) have not only shown that approximately 38% of Spanish drivers present considerable deficiencies in this regard, but that there are significant sex-related differences under normal light conditions. In other words, male drivers have a considerably better photopic vision than females, that is coherently with the results found by Shaqiri et al. [50] for a cohort of more than 600 adult participants. Furthermore, and according to the expected, age-group analyses show that both photopic and mesopic acuity are significantly lesser as the age of drivers increases, and older drivers are a primary focus of attention in this regard [42].

A similar result was found for visual field campimetry and glare recovery tests: in the first, age-based analyses made possible to establish, coherently to other studies in the field [51,52], an ascending slope in the percentage of defective cases that range between the 15.6% of deficient cases found in drivers aged under 25, up to the 47.7% of elderly drivers (over 65 years) having an insufficient peripheral visual field, in which no significant sex-based differences were observed.

As for the second, the recovery periods of male and female drivers were significantly different, indicating almost three additional seconds for the latter to recuperate full vision after being exposed to a light overstimulation, as might happen when driving in a two-way road and being glared by the headlights of another oncoming car that is circulating with the high beams on. Recent studies suggest that sex differences should be considered along with the driving patterns, such as the frequency of night driving and the type of trips performed across sexes; for instance, the percentage of males with poor vision that continue to drive at night is substantially greater than for female drivers [53]. In this regard, different studies have speculated about the higher incidence of different visual impairments among women, remarking that, given the biological origins of the great majority, they cannot be currently prevented but rather addressed through proper follow-up and treatment [50,54]. Given this gap, it would be interesting to wonder if something else, apart from the traditional restrictions (e.g., using glasses, not driving by night, that could be attended or not by drivers) might be done. For instance, and based on the previous fitness testing, periodic assessments among vision-impaired drivers could be performed with greater frequency, in order to gather accurate information on the evolution and potential treatment of these risk conditions, as happens with various pathologies in the case of the Spanish General Regulation of Drivers [55]. Although this potential follow-up is not a gendered strategy, it could contribute to protect the higher proportion of women presenting visual issues, since the current 10 years interval between obligatory assessments is a period that seems to be excessively long if a visual impairment is detected.

Furthermore and also related to specific groups of the sample, age differences seem to be one of the most generalized problem found in the three study variables addressed in this research, including the findings obtained for glare recovery tests, in which the time needed for full-vision recovery among older adults was almost 14 s greater than the time interval needed by young and adult drivers. This result is coherent to what was found by studies such as the performed by Schieber [56] and Gupta et al. [57], in which recovery times after a prolonged glare exposure were substantially longer for older adults, when compared to both young and middle-aged populations. In this regard, some previous sources have supported the idea that dynamic components of glare effects should be considered at the designing of different environments (including road scenarios) in which older population is involved [53,58,59].

However, it is worth stating that visual impairments are not exclusively an age-related matter. Evidences support that in the case of the most common visual illnesses among the adult population, including myopia and hyperopia, the highest prevalence is expectable between the second and third decades of life [34], being an early diagnosis and treatment crucial for preventing driving impairments or causalities attributable to visual lacks or deficiencies. Further, and as we pointed before, although key visual parameters seem to inherently fit better among young and middle-aged drivers, other potential factors such as fatigue, alcohol and drugs may substantially impair (temporarily or permanently) their visual fitness. For instance, previous studies have demonstrated how glare recovery times are considerably longer after risky behaviors such as alcohol consumption [57,60], that (although not exclusively) are more frequently observed in younger segments of the driving population [61].

4.1. Visual Health, Non-Professional driving and Driver Licensing: does the Current Model Need to be Re-Evaluated?

Another interesting finding of this study was that professional drivers tended to report better outcomes in visual acuity tests (both for photopic and mesopic conditions) than or non-professional drivers. This makes sense if it we bear in mind that, at least in most European countries, more regular check-ups of visual acuity are needed for a professional driver's license, enhancing the early detection and treatment of potential impairments among high-intensity drivers [62,63], whose driving exposure and latent risk tend to be greater than in the case of non-professional drivers with less mileage.

This fact makes even more sense if it is considered that professional drivers are generally covered by regulated occupational health strategies and more systematic fitness testing, while non-professionals remain (outside the licensure and re-licensure context) conditioned to the performance of voluntary and extra-institutional visual revisions and controls, whose coverage is much less, if several social gaps in regard to the access to different healthcare resources are taken into account. However, the driver licensure system constitutes a universal process to what periodically all drivers (professionals or not) are subjected, and in which it is important to consider the need to carry out appropriate assessments that suitably diagnose the state of visual health of all road users [64]. As visual acuity, field campimetry and glare-recovery (tests that have shown good discrimination and interesting results in this study) are already assessed in most countries during driver's fitness testing, the solution could pass through revising the frequency of these assessments. Thus, it is worth considering it as an ideal scenario for improving driving fitness through a more frequent revision of both visual and other relevant settings of physical fitness; whereas (as aforementioned) Spanish drivers need to perform medical fitness tests every 10 years (5 for those aged over 65), in some countries, elderly drivers must undergo a revision every year, strengthening the timely detection of potential impairments [65]. Also, previous studies have suggested the loss of driving privileges, i.e., the restriction to drive under certain conditions such as low luminosity, highways and high-risk paths, and the need of a more frequent assessment to monitor progressive eye diseases among visually impaired drivers [5]. Nevertheless, different barriers and gaps related to accessibility, information and economic issues in visual healthcare, expressed in (e.g.,) the lack of campaigns, public health strategies and interventions for at-risk population segments [66], remain pending to be solved.

4.2. Limitations of the Study

Although this study comprised the use of a large and representative sample of the Spanish driving population and advanced testing tools, there are some limitations to be acknowledged. Firstly, due to the convenience sampling method used, the sex distribution was dissimilar. However, sex-based comparisons were possible under optimum statistical parameters thanks to sample weighting, which is recommended when sub-sample groups substantially differ in proportion within a full sample. Secondly, this was not a clinical study; thus, and even though visual health professionals participated in our research staff and the basic settings (e.g., luminosity, noise, time to carry out tests) were controlled, we cannot make any clinical diagnosis based on the tests performed, since that would require several other tests and specialized procedures performed by professionals in individual assessment environments under conditions that cannot be replicated for our study population. Also, the number of vision-related study variables tested among participants was considerably limited and based in the advice of visual health professionals from an initial list of 15, considering the technical/logistic limitations that such massive data collection processes imply.

5. Conclusions

The results of this descriptive study support a relationship between visual health (assessed through four key skills) and driving fitness issues, including the risks perceived by subjects in the fact of driving with impaired vision.

Further, the existence of key age and sex-based differences suggests the need to target and address the higher-risk segments of the driving population, for both the performance of preventive and interventive actions on visual health, as well as in the revision of the current vision-related standards used for driving assessment and licensure.

This study endorses the value of healthcare practices for the development of behavioral skills to strengthen the prevention of human factor-related traffic crashes involving children and young people, under assumptions of well-designed programs, systematic interventions, continuous evaluation and improvement approaches.

Practical Implications

Finally, three key practical applications of the study findings should also be discussed: Firstly, and although the panorama suggests attention to all drivers is necessary, sex comparisons highlighted a greater prevalence of visual issues among women. Concretely, female drivers have: (*i*) lesser visual acuity under daylight conditions than males and (*ii*) considerably longer glare recovery periods, that could compromise even more their driving safety, and actions are needed to reduce this gap. On the other hand, females have shown a greater risk perception while driving with impaired vision than males, a fact that could enhance their receptiveness to policies aimed at performing more regular vision assessments among "at visual-risk" drivers.

Secondly, age differences clearly point to drivers over 65 years as the most vulnerable group in regard to visual deficiencies, and particular attention must be shown on them, especially when their over-representation in traffic fatalities is considered [16]. Although in recent years elderly driver's re-licensing criteria have been relatively improved, the European Commission still forecasts that, linked to the population ageing, for 2050 one out of three traffic fatalities will be an older person, which means an increase of 13% compared to the current rate [63]. Thus, more regular assessments could strengthen the proper detection and treatment of impaired visual conditions among elderly drivers.

Thirdly, more research efforts and practical actions aimed at improving the design of policies and strategic interventions in visual health and driving should consider not only the visual health-related attitudes and practices of the population, but the existence of key differences [66] in terms of visual health, information and accessibility to eye healthcare among age, region and income-based groups. Also, the authors would like to highlight the importance of developing inferential models for assessing the actual impact of visual impairments on road safety figures of drivers.

Author Contributions: For this study, S.A.U., L.M., I.L., and J.L. conceived and designed the research and performed the data collection; S.A.U. and L.M. cured and analyzed the data; I.L., S.A.U., and J.L. contributed reagents/materials/analysis tools; S.A.U. and L.M. wrote and S.A.U., L.M., I.L. and J.L. revised the paper. All authors have read and agreed to the published version of the manuscript.

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9.4. Artículo 4

Lijarcio, I., Llamazares, Francisco J., Valle, Eliseo, Montoro, L., & Useche, S., (2022). Assessing risk perception over recidivist traffic offenders from a multigroup approach: How gendered could it be? *The European Journal of Psychology Applied to Legal Context, 14*(1), 33-41. https://doi.org/10.5093/ejpalc2022a4

[Evaluación de la percepción del riesgo en infractores de tráfico reincidentes desde un enfoque multigrupo y el efecto moderador del género]

Resumen

Introducción: Existen diferentes estudios que apelan a la necesidad de abordar las conductas infractoras reincidentes de la población conductora con intervenciones sensibilizadoras y programas de reeducación. Ciertamente estas intervenciones, se diseñan sin conocer las variables ni las características de la reincidencia, sabiendo por diferentes estudios, que el género es determinante en la comisión de infracciones de tráfico como en la delincuencia general, siendo los hombres los que comenten más infracciones y delitos. Es de vital importancia conocer cómo se percibe esta reincidencia vial por parte de la población conductora y cuáles son las características determinantes para poder desarrollar intervenciones de éxito.

Objetivos: El objetivo de este estudio era conceptualizar la reincidencia vial y determinar la percepción de riesgo que, sobre los infractores reincidentes tienen los conductores españoles, apoyándonos en rol predictivo de las características sociodemográficas, psicosociales y de conducción, analizando el género como factor diferenciador clave.

Métodos: En este estudio transversal se construyó un cuestionario con tres secciones. La primera de ellas, recogía datos sociodemográficos. La segunda, recogía información sobre hábitos de conducción (tipo de vehículo, número de días de conducción, kilómetros recorridos diariamente, horas en desplazamientos, siniestros sufridos, infracciones cometidas, etc.). La tercera sección, se componía de variables más relacionadas con la reincidencia como conocimiento de las norma y programas de reeducación, percepción de riesgo sobre conductores reincidentes, etc. La muestra estaba compuesta por 1.711 conductores españoles de las 17 comunidades autónomas. Se analizaron comparativamente las variables sociodemográficas, psicosociales y las relativas a la conducción a través de pruebas robustas y modelos multigrupo de ecuaciones estructurales (MGSEM).

Resultados: Los resultados de este estudio indican que el riesgo que percibe la población conductora sobre los reincidentes de tráfico, se explica y varía en función de: la edad de los conductores, su exposición al riesgo, su conocimiento de las normas de tráfico, sus creencias sobre la aplicación de la sanción y los programas de reeducación vial, así como el número de multas que han tenido. Además, hombres y mujeres perciben la reincidencia de forma diferente en función de las variables relacionadas con la conducción como la frecuencia de conducción semanal, el valor del cumplimiento y el conocimiento de la norma.

Conclusión: Es importante destacar que la variable de género es determinante en el riesgo percibido en la población conductora reincidente. Además, las características psicosociales y las relacionadas con la conducción determinan la percepción de riesgo existente sobre los reincidentes de tráfico entre hombres y mujeres. Estos resultados nos indican la necesidad de poner el énfasis en el género y en las variables relacionadas con la conducción y el conocimiento de la norma para mejorar, tanto la formación de conductores como los programas reeducación vial, al objeto de prevenir la reincidencia en el campo del tráfico y de la movilidad.

Palabras clave: reincidentes viales, conductores españoles, percepción del riesgo, diferencias de género, seguridad vial.

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Assessing Risk Perception over Recidivist Traffic Offenders from a Multi-group Approach: How Gendered Could It Be?

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A B S T R A C T

Objective: The core aim of this study was to examine the predictive role of demographic, psychosocial and driving features of Spanish drivers on their risk perception over recidivist traffic offenders, focusing on gender as a key differentiating factor. *Method:* For this cross-sectional study, it was analyzed the data gathered from a nationwide sample of 1,711 licensed drivers from the 17 regions of Spain (49% females, 51% males) with a mean age of 40.07 years, responding to a telephone-based interview on road safety issues. Demographic, driving-related and psychosocial factors were comparatively analyzed through robust tests and a bias-corrected MGSEM (Multi-Group Structural Equation Modeling) approach. *Results:* The findings of this study indicate that drivers' age, driving exposure, traffic law knowledge, their assessment of both enforcement and reeducation, and the number of traffic fines they have received, explain the risk perceived in recidivist traffic offenders. Secondly, and in regard to structural differences, three study variables, i.e., driving exposure, need for enforcement and traffic law knowledge, have shown to exert a differential influence on risk perception according to drivers' gender. *Conclusion:* The findings of this study suggest that both psychosocial and driving-related features differentially predict drivers' risk perception over recidivist traffic offenders between male and female drivers. This research supports the need of fostering the emphasis on gender, in order to strengthen driving education, re-education, and training processes aimed at facing and preventing recidivism in the field of traffic and mobility.

Evaluación de la percepción del riesgo en infractores de tráfico reincidentes desde un enfoque multigrupo y el efecto moderador del género

Palabras clave:
Infractores de tráfico reincidentes
Conductores españoles
Percepción del riesgo
Diferencias de género
Seguridad en el tráfico

R E S U M E N

Objetivo: El objetivo principal de este estudio es analizar el papel predictor que juegan las características demográficas, psicosociales y de conducción de los conductores españoles en la percepción del riesgo en comparación con los infractores reincidentes, centrándose en el género como factor clave diferenciador. *Método:* En este estudio transversal se han analizado datos de una muestra nacional compuesta de 1,711 conductores de las 17 regiones españolas (el 49% mujeres y el 51% hombres), con una media de edad de 40.07 años, que respondieron a una entrevista telefónica sobre temas relacionados con la seguridad vial. Se analizaron comparativamente los factores demográficos, los relativos a la conducción y los psicosociales por medio de pruebas robustas y de modelos multigrupo de ecuaciones estructurales (MGSEM). *Resultados:* Los resultados de este estudio indican que la edad de los conductores, su exposición al riesgo, su conocimiento de las normas de tráfico, su valoración de la aplicación de la ley y de los programas de reeducación vial, así como el número de multas de tráfico que han recibido, explican el riesgo que estos perciben en los infractores de tráfico reincidentes. En segundo lugar, en lo que se refiere a las diferencias estructurales, tres de las variables del estudio (la exposición a la conducción, la necesidad de cumplir las normas y los conocimientos de las normas de tráfico) parecen ejercer una influencia diferencial en la percepción del riesgo de acuerdo con el género de los conductores.

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Conclusión: Los resultados indican que tanto las características psicosociales como las referidas a la conducción predicen la percepción del riesgo de los conductores en relación a los infractores de tráfico reincidentes entre hombres y mujeres conductores. Esta investigación abunda en la necesidad de poner el énfasis en el género para potenciar los procesos de educación en la conducción, reeducación y entrenamiento dirigidos a abordar y prevenir la reincidencia en el campo del tráfico y de la movilidad.

Traffic crashes, understood as a latent threat for both road safety and public health, remain a great concern worldwide. In brief, the latest figures available estimate that 1.35 million people die, while 50 million more result seriously injured each year as a result of road crashes (World Health Organization, 2018). Also, and although some improvements have taken place during the last decade, about 25,600 people lost their lives on European roads during the year 2018, and more than 1.4 million suffered serious injuries in road crashes. More locally, Spain has registered a traffic crash average of 102,000 traffic accidents during the last five years, causing 1,800 deaths and 8,900 serious injuries (Dirección General de Tráfico, 2020). These data suggest that, regardless of where the figures come from, this trend continues to rise, remaining at a worrying level for public authorities, researchers and – of course – the road users themselves.

Precisely, and with the aim of preventing these crashes, governments usually implement road safety actions and measures of different natures and approaches, based on their resources, priorities, and contextual features. In this regard, key issues such as law enforcement and police supervision, substance use-related measures, speeding, vehicle technical inspections and infrastructural road improvements have raised the interest of policymakers during recent years (Staton et al., 2016). However, so far, some topics remain underrepresented in terms of actions and measures taken by public authorities. This is, for instance, the case of recidivist traffic offenders that, despite the great risks they can pose to road safety, do not constitute a crucial focus of action in most countries, even though key preliminary systematic measures and programs (many of them still in a 'pilot' phase) are beginning to be developed in some countries, including Spain (Bautista-Ortuño & Miró-Llinares, 2014; Marti-Belda et al., 2019).

Facing Offending (and Reoffending) Drivers

Many of the interventions and measures for offending drivers are based on reeducation and rehabilitation programs consisting of systematic measures for preventing further road offences – typically among drunk drivers and speed offenders – aiming at fostering positive behavioral modifications through their participation in these actions, as a condition to keep, or to recover, their driving status (Bartl et al., 2002; Turner & Mitra 2021). For instance, a recent macro-study analyzing thoroughly the data of almost 60,000 convicted drivers in Canada concluded that it seems possible to reduce recidivism risk through well-structured programs, even though this remains a substantially difficult task, given the many constraints involved in facing a widespread problem on the basis of considerably little empirical evidence and serious technical and institutional flaws (Wickens et al., 2016).

Further, it is worth remarking that the effectiveness of most programs developed for facing traffic-related problems is relative, and that – in many cases – actions developed to prevent risky road behaviors are not followed up over time (Ouimet et al., 2013), as well as commonly lack systematicity and sufficient contextual knowledge to efficiently face specific challenges, including the troublesome case of recidivist drivers (Baltruschat et al., 2021; Bamford et al., 2007; Clark et al., 2015; McKnight & Tippetts, 1997; Michael, 2004; Senserrick & Watson 2021; Struckman-Johnson et al., 1989). In this regard, most of the available interventions follow "Demerit Point Systems" (DPSs), grounded on behavioral "token economies", as developed by Ayllon and Azrin (1986), and point recovery systems. Depending on the severity, infractions are associated with a series of points, being the most dangerous and the ones that produce the greatest damage those penalizing the most. In this way, it is expected that recidivist traffic offenders will be the ones getting penalized and unable to keep (at least legally) driving a motor vehicle in the shortest term (Goldenbeld et al., 2012).

So far, 21 European countries have incorporated Demerit Point Systems (DPSs). However, there are certain differences among them. For instance, in most of these countries drivers start with a balance of 0 points and every sanctioned traffic violation adds some points, while in other cases (including the Spanish) drivers get between 12-15 points that can be withdrawn as a consequence of such road misbehaviors. In both cases, anyway, the recurrence of offending behaviors causes the total loss of their points and undergo both economic sanctions and license withdrawal. Once this happens, it is necessary to undergo reeducation programs and/or driving qualification tests to regain a driving license (Bestpoint, 2012). However, understanding the relationship between recidivism and drivers' faculty to legally drive a vehicle (or the absence of it), at least in a population level, makes it necessary to approach the concept from both its theoretical and legal roots.

"Recidivism" as a Concept: Insights and Constraints from Literature

Perhaps, the most commonly accepted definition of the concept of "recidivism" from a legal approach is the one proposed by Maltz (1984), according to which it can be understood as "the reversion of an individual to criminal behaviour after he or she has been convicted of a prior offense, sentenced, and (presumably) corrected", despite the fact that, of course, the ways of controlling recidivism in traffic are often limited to conducts sanctioned through fines or "tickets", or the occurrence of (generally severe) crashes making them manifest (Hunt & Dumville, 2016; King & Elderbroon, 2014).

However, and although there exists a relative consensus for understanding "recidivism" in the field of traffic, there are no homogeneous criteria over the type of behaviors to be punished and, e.g., their severity, frequency, aggravating, and mitigating circumstances (Lijarcio et al., 2015; Payne, 2007). This implies that the legal approach to recidivist drivers may vary depending on the legislation or regulatory framework of each country, and their ability to detect offenders' law bypassing through traffic control actions. In fact, many decades ago Blumstein and Larson (1971) already elaborated about the several difficulties to establish "true" recidivism rates, as – same as with many other law bypassing behaviors – they remain largely dependent on criminal records commonly prone to data underreporting and multiple other biases, especially when the behavior does not involve administrative sanctions, arrests, and/or police recording procedures (DeMichele & Payne, 2013; Loinaz & Sousa, 2019; Ruggero et al., 2015).

In addition to the pointed above, there are different authors using concepts such as 'multi-recidivism', in cases in which the frequency of the offending behavior is repeated twice or more, especially in offenses related to alcohol or substance use, which are the ones detected and sanctioned several times over time in most cases (Beck et al., 1999; McMillen et al., 1992; Reis, 1982). In this regard, and beyond the already troublesome low effectiveness of recidivism detection systems, some of the biggest shortcomings to address the problem of 'multi-recidivism' among drivers are: (i) the excessive ambiguity and implicitly poor operationalization of the term across diverse legal contexts, (ii) their often-differential understanding of the concept, and (iii) its fluctuating legal configurations worldwide.

The Legal Framework of Recidivism in Spain

In legal terms, recidivism is classified, specifically in the Spanish context, as an aggravation of a previous criminal responsibility. According to the Spanish Organic Act 10/1995 (Ley Orgánica 10/1995), it is considered that there is recidivism when an offender has been enforceable for a crime of the same nature. In the context of road safety, however, the case of recidivist traffic offenders is only mentioned in the Article 81 of the Royal Legislative Decree 6/2015 (Real Decreto Legislativo 6/2015), stating that the penalties for recidivist offenders must be higher, in view of (i) the seriousness and significance of the event, (ii) the offender's criminal background, (iii) the potential danger created for both himself and other road users, and (iv) the 'criterion of proportionality', i.e., a correct balance between the corrective measure and the severity of the offense. In this regard, recidivism acquires a criterion of temporality on the basis of a one-year term (Ley 40/2015).

Finally, in Act 17/2005 (Ley 17/2005), the concept of multi-recidivism is briefly developed, although vaguely, and lacking from a fairly operational definition. Notwithstanding, it should be noted that this is the first time that the concept of multi-recidivism has been used in legislation in reference to traffic and safety. Given this excessive ambiguity for differentiating recidivism from multi-recidivism, in most cases the literature interchangeably uses them, rather referring to repeat traffic offenders in a broader context (Lijarcio et al., 2015; Payne, 2007).

Psychosocial Correlates of Recidivism: The Need of Public Awareness

Once we have contextualized the legal framework of recidivism, it is important to highlight that, with the aim of enhancing the development of preventive and rehabilitative measures, some studies have claimed about the need to know what the most usually associated variables (or 'correlates') of the repetition of the offending behavior in the field of traffic (DeMichele & Payne, 2013; Nagin & Pogarsky, 2001) are. Although the evidence is still scarce in this regard, it seems clear that sanctions and other enforcement-related measures keep a certain efficacy, but psychosocial issues (such as law knowledge, risk perception, and attitudes towards road safety) may also play a relevant role in explaining a greater or lesser involvement in certain risky driving behaviors commonly performed by recidivist offenders (Goncalves & Mello, 2017; Wieczorek, 2013).

In addition, and according to different international studies on crime in the field of traffic, it is common to find how the criminal population performs more offending and criminal behaviors (Broughton, 2007; Ross, 1992), even with a three or four times higher frequency than the general population (Middendorff, 1981), leaving many serious or fatal injuries among different groups of road users as a result (Brace et al., 2009). Broughton (2007) also identified that male drivers having committed crimes other than those in the sphere of traffic were more likely to commit alcohol-related offenses than non-criminals. In the same way, Bautista-Ortuño and Miró-Llinares (2014) established a 'generic' profile for road offenders in the Mediterranean region of Spain (specifically in the Valencian Region), finding that traffic recidivists were typically men in their 30s, frequently having a prior crime on their personal record.

Notwithstanding, and even though these few existing studies already provide some good insights about recidivist drivers, their public perception remains considerably understudied. For instance, there are really few studies assessing road users' awareness of recidivism, the prevalence of recidivism in traffic, or (even more specifically) to what extent these recidivists are considered as risky for road safety, and how much these perceptions could vary as a function of road users' demographic features, such as age or gender.

Study Aim and Hypotheses

Bearing in mind the aforementioned considerations, the aim of this study was to assess the predictive role of demographic, psychosocial, and driving-related features of Spanish drivers in their risk perception over recidivist traffic offenders, focusing on gender as a key differentiating factor. In this regard, it was hypothesized that: (i) demographic and psychosocial variables would significantly explain the risk perceived in recidivist drivers and (ii) these variables would have a differential influence on risk perception when considering gender as an analytical category, i.e., there are structural differences in the explanation of risk perception between females and males.

Method

Sample

This study analyzed the data obtained from a nationwide sample of n = 1,711 Spanish drivers from all the 17 Regions of the country, with a mean age of 40.07 (SD = 14.17) years. From the study sample group, 48.7% of the drivers surveyed were females and 51.3% were males. Table 1 presents some further demographic characteristics of the study's participants.

Table 1. Sociodemographic Information and Basic Driving Features of the Partakers

Feature	Category	Frequency	Percentage
Gender	Female	834	48.7%
	Male	877	51.3%
Age Group	< 25	396	23.0%
	25-34	309	18.1%
	35-44	273	16.0%
	45-54	451	26.4%
	>54	282	16.5%
Educational level	Primary studies or lower	8	0.5%
	Secondary-high school	832	48.6%
	University studies	734	42.9%
	Post-graduate studies	137	8.0%
Type of vehicle (most driven)	Car	1601	93.6%
	Motorcycle	51	3.0%
	Van	34	2.0%
	Bus	16	0.9%
	Truck	9	0.5%
Driving frequency (weekly basis)	Daily	751	43.9%
	5-6 days a week	345	20.2%
	3-4 days a week	288	16.8%
	1-2 days a week	221	12.9%
	Occasionally	106	6.2%

Study Setting

This empirical research was based on a phone-conducted interview that was applied following a random dialing method, sampling that constitutes a pseudo-probabilistic method, given that it allows researchers to quickly access the population of interest under a fixed selection criteria, even though potential partakers remain limited to those using phone services (Hoffmeyer-Zlotnik, 2003). Participants were first involved in the study during the data-collection stage, getting contacted by a member of the research staff in order to invite them to partake in the research, and being informed about the research purposes and ethical issues related.

In order to achieve an acceptable degree of representativeness, an a priori number of about 680 subjects proportionally distributed by sex and age was determined as minimum sample, considering a confidence interval of 95% and a margin of error of 5%, at the least favorable case as $p = q = 50\%$. Notwithstanding, and as partakers were quite responsive, the sample size reached more than 1,700 responses.

The interview took an average time of about 12 minutes. In order to avoid potentially biased responses, before starting the process it was emphasized that the data would be exclusively used for statistical research purposes and their participation was anonymous. All partakers verbally agreed with an informed consent (agreement read by the surveying researcher) containing information on the research purpose and anonymization of personal data. No economic rewards and/or incentives were offered to participants. The response rate (i.e., accepted and responded interviews) was about 60%.

Description of the Questionnaire

The research questionnaire was composed of three main parts or sections:

- The first section of the interview inquired about demographic data, including gender (male/female/other; "other" was never chosen as a response, so the variable was dichotomized), educational level, city of residence, and driving status (having/not having a driving license).

- The second part comprised general driving features and outcomes of participants, such as type of vehicle usually driven, driving frequency (number of days driving in an average week), and hourly intensity (number of hours most commonly spent at the wheel in a driving day) used to calculate the driving exposure. The number of traffic fines received in the last 2 years was used as a "traffic offense index" among participants in order to assess the number of times they had been sanctioned for committing traffic violations. It results accurate, given that – uniformly with recidivists' assessment criteria – they correspond to actually sanctioned traffic violations (instead of behaviors that could be remembered, or not, at the moment of responding to the question; Montoro et al., 2018), thus resulting pertinent for the purpose of this study.

Finally, the third part of the interview addressed road safety issues: self-reported knowledge of traffic laws and risk perceived in recidivists were measured through an adapted version of the RPRS (Risk Perception and Regulation Scale; Useche et al., 2021), in which the degree of perceived risk (7 items, α = .820) and general knowledge – some of the most universal road regulations (5 items, α = .813) – are assessed in a 1-5 scale, i.e., from 1 (*no knowledge/risk perceived*) to 5 (*highest knowledge/risk perceived*). Both the assessment (or 'valuation') of driving reeducation programs and the perceived need for enforcement of traffic laws were assessed through single items using the same 1-5 scale in order to make them descriptively comparable to the aforementioned latent factors (i.e., law knowledge and risk perception in recidivists).

Ethics

To perform this study, the Ethics Committee of the Spanish Foundation for Road Safety was consulted, certifying that it complies with the general ethical principles applicable to research involving human subjects and the Declaration of Helsinki (IRB 0120201129HR). Since personal data were not used, the participation was anonymous, and it did not asked about sensitive/confidential information, the risk level for partakers was determined as "minimum". Moreover, an informed consent statement containing ethical principles and data treatment details was read to participants (and agreed by them) before responding to the interview.

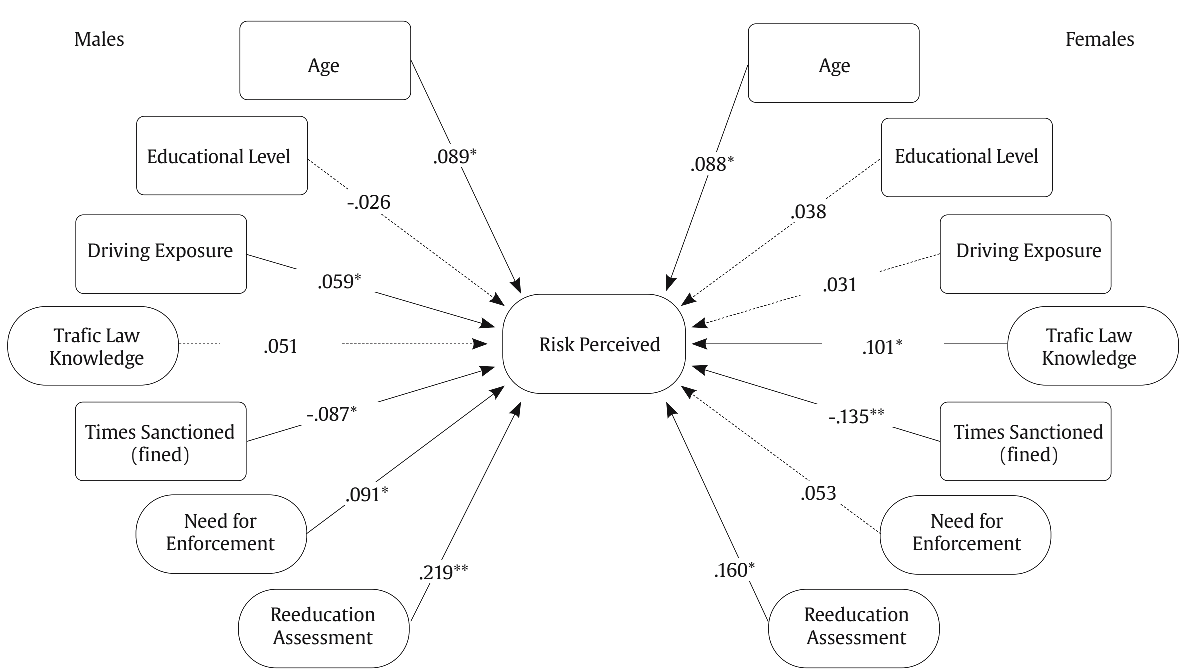

Figure 1. Two-group Structural Model Showing Standardized Path Coefficients for Risk Perception in Recidivists: Men (left) and Women (right).
$^{*}p < .05$, $^{**}p < .01$.

Data Analysis

After performing basic statistical procedures, i.e., descriptive statistics, bivariate Spearman's rho correlations, and mean comparisons (robust tests, as basic normality and homoscedasticity-related assumptions were not met), a gender-based multi-group structural equation model (MGSEM) was built up. For this purpose, bootstrap-based robust maximum likelihood estimations (i.e., 10,000 bootstrap samples and 95% confidence intervals) were used in order to handle non-normality issues, as most of study variables did not meet the basic assumption of univariate normality and multivariate normality was not met either, as usually happens in self-report-based studies (Byrne, 2010). The model fit was evaluated by using chi-square (χ^2), minimum discrepancy ratio (CMIN/*df*), normed fit index (NFI), Tucker-Lewis index (TLI), incremental fit index (IFI), and root mean square error of approximation (RMSEA).

Estimators were calculated controlling for age, education, and driving exposure. According to the specialized literature led by Hu and Bentler (1999), it is commonly accepted, as rules of thumb, that a set of CFI/NFI/TLI/IFI coefficients greater than .900 and a root mean square error of approximation lower than .080 (better if < .060), plus the coherence of the model data with its theoretical assumptions, constitute insights of an acceptable model fit to the data. When possible, the model's fit was improved taking into account the largest and more theoretically parsimonious modification indexes.

As for the punctual features of the model used to test the hypothesized structural relationships among measured variables, the multivariate relationships between female and male drivers' demographic/psychosocial factors and risk perceptions over recidivist traffic offenders, it was composed of the seven exogenous variables (educational level was excluded due to its collinearity with age, and type of vehicle was not considered given its nominal nature) and one endogenous factor (i.e., risk perceived in recidivists) shown in Figure 1. This is statistically more accurate than separately testing genders as separate populations, since it considers the full sample parameters for fitting the models. The direct effects of the model, their confidence intervals (at the level 95%), and significance levels were calculated following the bootstrap method, specifically through a Monte Carlo (parametric) procedure, favoring that (e.g.) the results of the estimates can be bias-corrected, do not present problems of normality, and type I errors (*false positives*) in regression paths can be avoided, and constitutes a reasonable alternative to other estimation methods such as Satorra-Bentler or weighted least square mean and variance adjusted (WLSMV), that cannot be performed with AMOS software (Version 26.0; IBM Corp.), as done in this research for SEM modeling tasks.

Results

Table 2 shows the mean values and bivariate correlations of the variables measured in the study, divided in three groups: demographic data, driving factors and outcomes, and road safety-related perceptions. Overall, demographic variables, and especially age, have shown certain associations with road safety-related perceptions. For instance, drivers' age has been found positively and significantly associated with the assessment given to driver reeducation programs, as well as with a greater risk perception towards recidivist traffic offenders over road safety.

Also, driving-related factors, especially drivers' self-reported knowledge of traffic laws and the number of fines they have received in two years, have been found significantly associated with road safety perceptions, as follows: drivers' knowledge of traffic laws is positively associated to both (i) their perceived need for enforcement and (ii) their risk perception in relation to recidivist traffic offenders. On the other hand, the more drivers commit (sanctioned) road risky behaviors, the least they perceive that recidivist drivers constitute a risk for road safety.

Finally, risk perception in recidivists was positively and significantly correlated to both participants' assessment of driver reeducation strategies and their perceived need for enforcing traffic laws.

Gender Differences

After assessing the bivariate correlations (Spearman's rhos) between these three groups of variables, gender differences were explored through mean comparison tests. Given that the assumption of normality was not met in the case of most variables used in the study, especially as for those having an ordinal nature, and variances were rather heteroscedastic, robust (Brown-Forshythe) tests were used for this purpose. Unlike traditional ANOVA tests, this technique uses a different denominator for the '*F*' equation, adjusting the mean square through the observed variances of each group, instead of dividing by the mean square of the error. The results of mean comparison tests are fully available in Table 3, being readable and interpretable in the same way than one-way analysis of variance tests.

Overall, not many significant differences could be established between both genders in regard to most of the study variables. For instance, the average self-reported traffic law knowledge, the assessment of reeducation programs for drivers, and the level of risk perceived in recidivist traffic offenders did not report significant differences, being rather almost invariable between males and females. On the other hand, this analysis suggests two relevant figures related to female drivers: firstly, they had a greater driving exposure than

Table 2. Descriptive Data and Bivariate (Spearman rho) Correlations between Study Variables

	Variable	Mean / %	*SD*[3]	1	2	3	4	5	6	7	8
Demographic data											
1	Gender[1]	51.3%	--	--							
2	Age (years)	40.07	14.17	.422**	--						
3	Educational level	--	--	-.130**	-.092**	--					
Driving factors and outcomes											
4	Driving exposure	2.17	1.29	-.122**	-.082**	.078**	--				
5	Traffic law knowledge[2]	4.66	1.88	.032	-.116**	.059*	-.045	--			
6	Times sanctioned (fined)	0.12	0.40	.066**	.011	.010	-.071**	.008	--		
Road safety perceptions											
7	Need for enforcement[2]	2.01	0.40	-.070**	-.010	-.016	.029	.110**	-.072**	--	
8	Driver reeducation assessment[2]	3.89	0.75	-.028	.075**	-.008	-.039	.029	-.051*	.037	--
9	Risk perceived in recidivists[2]	3.74	0.55	.007	.083**	.007	.039	.052*	-.102**	.091**	.171**

Note. [1]Categorical variable (ref = male); [2]variable measured in a 1-5 scale; [3]*SD* = standard deviation.
**p* < .05 (2-tailed), ***p* < .01 (2-tailed).

Table 3. Descriptive Statistics and Mean Comparisons between Genders

Variable	Group	Descriptives		Brown-Forshythe test			
		Mean	*SD*	Statistic[1]	*df*1	*df*2	*p*
Driving exposure	Males	2.01	1.19	30.591	1	1651.373	< .001
	Females	2.35	1.36				
Traffic law knowledge	Males	4.71	1.97	1.103	1	1704.784	.294
	Females	4.61	1.78				
Times sanctioned (fined)	Males	0.14	0.41	3.425	1	1708.808	.064
	Females	0.10	0.39				
Need for enforcement	Males	1.97	0.41	8.334	1	1708.972	.004
	Females	2.02	0.39				
Reeducation assessment	Males	3.86	0.77	1.738	1	1708.994	.188
	Females	3.91	0.73				
Risk perceived in recidivists	Males	3.74	0.55	0.009	1	1705.459	.923
	Females	3.73	0.54				

Note. [1]Asymptotically *F* distributed.

males, with $F(1, 1651.373) = 30.591$, $p < .001$ (highlighting the need of controlling for this variable for structural analyses) and secondly, they were also the ones attributing a larger importance to enforcement to prevent overall risky behaviors of road users, with $F(1, 1708.972) = 8.334$, $p = .004$.

The Structural Model

Based on the aforementioned theoretical assumptions of the study, the effect of gender over the extent to which Spanish drivers consider recidivist drivers constitute a risk for road safety was examined through a MGSEM (multi-group structural equation modeling) approach that differs from using gender as a dummy category within a structural model encompassing other predictive variables, whose effects can be hypothesized to differ in nature according to drivers' gender. Instead, it allows differentially assessing the effect of the exogenous factors on the dependent variable for each group, making it possible to compare the "mechanisms" by which these relations can be explained for the case of each gender.

In this sense, data were split into two gender-based groups (i.e., reference categories): a group of 834 (48.7%) female and a group of 877 (51.3%) male drivers, both of them with acceptable sample size and proportionality for the comparative exploration. Using the SPSS AMOS multi-group (MGSEM) analysis, the hypothesized structural model was adjusted to control for demographic and driving-related differences and to fit the data according to gender, at the same time considering the parameters of the full sample.

The resulting structural equation model, simultaneously fitted for both gender groups or categories, $\chi^2(18) = 44.547$, $p < .001$; CMIN/df = 1.485; NFI = .942; CFI = .935; TLI = .909; IFI = .942; RMSEA = .017, IC 90% [.003, .017], is presented through two merged graphical models in Figure 1. Qualitatively, the magnitude and significance levels of paths from exogenous variables to risk perception rates show differential trends between male and female individuals. The standardized path coefficients (see Table 4 and values next to solid lines in Figure 1) of the bias-corrected MGSEM suggest that there are significant structural similarities, but also key differences, as follows:

In regard to structural similarities, it was found that:

(i) Age exerts a positive effect on the risk perception for the case of both genders, showing magnitudes and significance levels alike.

(ii) The number of traffic fines received in the last 2 years had a similar negative effect among all study participants, i.e., the greater

Table 4. Multi-group SEM Model to Predict Risk Perceived in Recidivist Traffic Offenders

Path			SPC[1]	*SE*[2]	CR[3]	*p*	Bootstrap Bias-corrected Coefficients[4]			
							SE[2]	95% CI[5]		*p*
Group 1: Males										
Age	→	Risk perceived	.089	.001	2.583	.009	.002	.002	.007	.046
Educational level	→	Risk perceived	-.026	.026	-0.781	.435	.022	-.056	.013	.318
Driving exposure	→	Risk perceived	.059	.015	2.113	.041	.013	.003	.050	.046
Traffic law knowledge	→	Risk perceived	.051	.009	1.497	.134	.009	-.001	.031	.127
Times sanctioned (fined)	→	Risk perceived	-.087	.043	-2.695	.007	.053	-.218	-.030	.030
Need for enforcement	→	Risk perceived	.091	.044	2.774	.006	.056	.023	.204	.043
Reeducation assessment	→	Risk perceived	.219	.023	6.715	< .001	.03	.111	.210	.007
Group 2: Females										
Age	→	Risk perceived	.088	.002	2.576	.009	.001	.001	.006	.048
Educational level	→	Risk perceived	.038	.030	1.132	.258	.037	-.024	.091	.406
Driving exposure	→	Risk perceived	.031	.013	0.929	.353	.013	-.013	.034	.416
Traffic law knowledge	→	Risk perceived	.101	.010	2.956	.003	.012	.009	.050	.012
Times sanctioned (fined)	→	Risk perceived	-.135	.046	-4.023	< .001	.069	-.295	-.075	.008
Need for enforcement	→	Risk perceived	.053	.047	1.572	.116	.060	-.043	.167	.197
Reeducation assessment	→	Risk perceived	.160	.025	4.762	< .001	.031	.066	.167	.019

Note. [1]SPC = standardized path coefficients (can be interpreted as b-linear regression weights); [2]*SE* = standard error; [3]CR = critical ratio; [4]bootstrapped (bias-corrected) model; [5]confidence interval at the level 95% (lower bound – left; upper bound – right).

the number of sanctioned risky behaviors they commit, the least their risk perception in recidivist traffic offending.

(iii) Also, the assessment given to reeducation programs for drivers has, in both cases, a positive effect, whose magnitude is slightly larger for males when compared to females. In other words, it can be assumed that reeducation assessment influences risk perception among male and female drivers, but this effect is greater for the first.

(iv) Finally, the educational level had a non-significant effect on risk perception among both males and females.

As for structural differences, it was found that: (i) driving exposure has a significant effect on risk perception only for the case of male drivers; in other words, the greater the exposure, the more risks they perceive in regard to recidivist traffic offending; (ii) also, only among males, the need for enforcement has a significant path to the endogenous variable, i.e., the fact of perceiving law enforcement as a more/less important matter seems to affect only the risk perception of male drivers; (iii) on the other hand, traffic law knowledge only had a significant effect over risk perception among female drivers, being this relationship positive and significant, as graphically shown in Figure 1. Additional information on the model's statistical parameters is presented in Table 4.

Discussion

Based on the data gathered from a nationwide sample of n = 1,711 Spanish drivers, this paper examined the relationships among demographic, psychosocial, and driving features of Spanish drivers, and their risk perceptions over recidivist traffic offenders, focusing on gender as a key factor possibly influencing them. Through the multi-group structural equation modeling approach, we found empirical evidence supporting the hypothesis that there are key gender-related differences in the explanation of recidivist-related risk perceptions, i.e., finding how demographic, driving-related, and perceptual factors may differentially influence this outcome between genders.

In this regard, and although this technique had never been applied to the study of recidivist traffic offenders, previous studies have already analyzed the role of gender as a key potential mediator between, on the one hand, demographic and psychosocial factors and, on the other hand, perceptual and behavioral outcomes of road users. Furthermore, gender differences have also been studied in diverse fields addressing both risk-related perceptions and law-related issues.

However, evidences in these regards remain very limited. Actually, pioneer studies such as Gustaffson's (1998) offer good highlights in regard to gender differences in risk perceptions, arguing that, apart from being of different kinds, they may require both quantitative, qualitative, and innovative approaches to be holistically depicted. This is, precisely, one of the strengths of this study: although in a first moment no significant differences were found through mean comparison tests, structural analyses allowed to determine that (beyond mean values) risk perception-related mechanisms and dynamics might substantially vary between male and female drivers, serving as a starting point for further research.

Also, other recent studies addressing risk perceptions in regards to both traditional and emerging issues for public health such as COVID-19, chronic diseases and natural disasters (McDowell et al., 2020) have concluded that, beyond the average outcomes potentially observable between genders, the way that males and females develop risk-related appraisals of certain circumstances and individuals can largely vary in terms of nature, structure, and dynamics (Rhodes & Pivik, 2011; Useche et al., 2021). Indeed, various studies performed from the perspective of legal psychology in relation to other risk-related issues, such as violence and aggression, do not only show how (from the earliest stages of development) gender may explain key behavioral differences, but how these discrepancies also apply to their attitudes and perceptions in regard to these risk-related behaviors (Del Hoyo-Bilbao et al., 2020; Loinaz & Sousa, 2019).

Overall, the aforementioned theoretical and empirical considerations, in addition to the study findings, suggest – in accordance to the study hypotheses – that: (i) demographic and psychosocial variables, as measured in the present study (except for the case of educational level), would significantly explain the risk perceived in recidivist traffic offenders, and that (ii) three of these variables have a differential influence on risk perception when considering gender as an analytical category, as described in detail in the next subsection.

Summary: Gender-based Structural Differences and Similarities in the Risk Perceived in Recidivist Traffic Offenders

The core analysis factor addressed in this study, as a split category, was gender. In this regard, our research aimed to study the structural differences (and similarities) between 877 male and 837 female Spanish drivers in many factors, theoretically influencing their risk perceptions over recidivist drivers. The two multi-group SEM models allowed us to determine that specifically for each independent variable:

- Age. This demographic variable significantly explains recidivist-related risk perception among both male and female drivers. In these two cases, the relationship is positive and similar in terms of magnitude. Therefore, no gender differences were found in the case of age, which appeared to have a similar influence in both cases. In other words, it can be assumed that the greater the driver's age, the higher the extent to which recidivist traffic offenders are perceived as risky road users, regardless of their gender.

- Educational level. This ordinal factor has shown to have a non-significant effect on risk perception amongst the two genders of participants addressed by this research. In other words, after controlling for demographics (especially as for the correlation between age and education), risk perception seems to be, rather, explained by the six other features used as independent variables.

- Driving exposure. One of the most interesting findings of this set of structural comparisons is that unlike females the weekly time spent at the wheel does significantly explain risk perception over recidivist drivers among male participants. In other words, the more a male driver is exposed to driving scenarios in terms of frequency and intensity, the greater his perception of recidivist traffic offenders as potentially risky for road safety.

- Traffic law knowledge. The self-reported degree of knowledge on traffic norms has shown to have a significant effect on risk perception of female drivers, but not in the case of males. In other words, and given the positive direction of the path, recidivist-related risk perception among women could be influenced by the extent to which they are actually familiarized with traffic norms and regulations, while it does not seem to influence male drivers significantly.

- Traffic fines. This indicator has been used as a "traffic offense index" among participants in order to assess the number of times they have been sanctioned for performing traffic violations. MGSEM results show how, apart from having a significant effect across genders, it keeps a negative relationship with risk perception, i.e., the greater the number of (sanctioned) traffic offenses performed by Spanish drivers, the lesser the extent to which they perceive recidivist traffic offenders as risky for road safety.

- Need for enforcement. The extent to which male individuals consider that actions related to law enforcement are needed for improving road safety significantly (and positively) predicts the degree of risk perceived in recidivist drivers. However, this association is not significant among female drivers.

- Reeducation assessment. Finally, the valuation given to drivers' reeducation actions and programs has shown to positively predict risk perception over recidivist drivers. In other words, both males and females tend to perceive greater risks in recidivist traffic offenders when their assessment of the effectiveness and importance of drivers' reeducation tends to be higher.

Limitations of the Study and Further Research

Although this research analyzed the data from a sample that can be considered as representative of the Spanish driving population in terms of age and gender, and the essential theoretical assumptions, analytic parameters and goodness-of-fit criteria were met, it is important to state some essential limitations and technical shortcomings that could have biased the study outcomes, so that they should be interpreted in consideration of them.

First of all, an anonymous interview does not fully deter common method biases (CMBs) in responses, especially if there are addressed topics related to their own behavior and other common socially stigmatized issues (Af Wåhlberg & Dorn, 2015). Secondly, and although based on a literature review, the set of variables measured by this study is partial, given that many further factors potentially affecting drivers' risk perception in regard to recidivist traffic offenders is more extensive and may cover many other spheres. However, and same as in most cross-sectional-based studies, the extension of the surveys and time spent by participants are limited, making it necessary to use relatively short sets of questions.

Likewise, and as previously suggested by Gustaffson (1998), it might be advisable to complementarily acquire further insights on this interesting issue by means of (e.g.) in-depth interviews and mixed research methods, with the aim to maximize the explanation of gender-based differences in regard to legal issues affecting traffic safety.

Conclusions

The findings of this study suggest that both psychosocial and driving-related features differentially predict drivers' risk perception over recidivist traffic offenders according to gender. In other words, the mechanisms by which these factors (i.e., driving exposure, traffic law knowledge, and perceived need for enforcement) affect risk perception seem to differ between male and female drivers.

Secondly, this research supports the influence of gender on risk perception of key safety issues such as recidivist traffic offenders, thus depicting the differential role of demographic and psychosocial factors on safety-related perceptions according to drivers' gender.

Finally, and as for the practical implications of this study, this research stands as the first approximation made so far to the matter from a gender-based MGSEM approach, these results being of potential interest for many stakeholders, even though in different ways. For instance:

- Road safety researchers can get from this study relevant insights about factors influencing drivers' risk perceptions, whose value for crash prevention is widely supported in the specialized literature.

- Policymakers might find it useful to count on: (i) a detailed problematization about the need to unify criteria to understand, face, and prevent recidivism in the field of traffic and mobility and (ii) recent and contextually specific empirical evidences endorsing the relevance of the problem and its state of the art in Spain.

- Practitioners' actions aimed at intervening in road safety problems related to human factors (including recidivism) might get benefitted from the described evidences and differences in order to enhance driving education, re-education, and training processes.

Conflict of Interest

The authors of this article declare no conflict of interest.

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