Messages beyond the phone:

Processing variable message signs while attending hands-free phone calls

Abstract

We examined the effects of different types of cognitive distraction coming from a hands-free phone conversation on the processing of information provided by variable message signs (VMS), on driving performance indicators, and on a physiological index of mental effort (heart rate). Participants drove a route in a driving simulator and had to respond to VMS messages under three conditions: no-distraction, visuospatial distraction (attending phone calls with questions inducing visuospatial processing), and conceptual distraction (attending phone calls with questions requiring semantic memory). Results showed more errors responding to VMS messages in the visuospatial distraction condition. In addition, both types of questions increased the intraindividual variability of response distances and the heart rate, as compared to the no-distraction condition. These results provide new evidence that talking on a hands-free phone entails costs in the processing of traffic information (in particular, text messages displayed on VMS) and it increases the driver's cognitive effort. Interestingly, the cognitive distraction had no effect on the driver's control of the vehicle speed or lateral position. Therefore, the effects of potential risk factors can critically vary among the different driving subtasks due to modulatory factors, such as the level of attentional task demands (relatively high in the processing of messages on VMS, but relatively low in controlling the speed and lateral position of the vehicle in quiet traffic conditions). In consequence, the current paper provides new evidence to discuss hands-free phone policies and highlights the importance of designing technological countermeasures to prevent drivers missing critical information displayed on VMS.

Keywords: Hands-free phone, Variable message signs, Cognitive distraction, Cognitive control, Cognitive effort, Driving performance.

1. Introduction

Results from European surveys show that one in three drivers thinks that it is acceptable talking on a hands-free mobile phone while driving, and one in two drivers does not think that this behaviour can have negative effects on traffic (e.g., Trigoso et al., 2016). Consistent with this popular view, road safety policies in many countries allow the use of a hands-free phone, while hand-held use is generally banned (World Health Organization, 2018). Still, it seems that most drivers would agree that such behaviour is risky if the conversation induces a mental activity that captures considerable attention. Experimental research, as well as our common experience, shows that the processing of information that is necessary to perform a primary attention-demanding task is harder and prone to fail, if we are concurrently engaged in a secondary task that is attention-demanding too. In particular, a person conversing on the phone becomes slower and less accurate in responding to specific visual tasks, such as the so-called multiple-object tracking task (Kunar et al., 2008), or visual search tasks (Gunnell et al., 2019, Kunar et al., 2018). There is also some evidence that a phone conversation increases the proportion of long responses in cognitive tasks, such as mental arithmetic, resulting in a higher variability of response times (Steinborn & Huestegge, 2017). Moreover, research on driving performance and road safety supports that talking on a hands-free mobile increases the risk of being involved in road accidents, by affecting relevant attentional mechanisms (for reviews, see Atchley et al., 2017; Strayer & Fisher, 2016; and Oviedo-Trespalacios et al., 2016). For example, studies have shown that, when drivers are distracted by attention-demanding phone conversations, they reduce the visual scanning of the driving environment (Briggs et al., 2016, Experiment 1), become worse at detecting unexpected events in such environment (Briggs et al., 2018; Horberry et al., 2006), and react worse to a sudden brake of the preceding vehicle (Benedetto et al, 2012).

The present driving simulator study assessed the effects of different types of cognitive distraction (i.e., a phone conversation requiring either visuospatial or conceptual processing) on the processing of traffic messages provided by variable message signs (VMS), on driving performance indicators, and on a physiological index of mental effort (heart rate). Considering the previous literature, the current study would attempt to achieve the following three objectives: (1) analyse the impact of a phone conversation, specifically, on the processing of traffic information provided by text messages in VMS, (2) evaluate whether such impact would be a consequence of loading domain-general or specific attentional resources, and (3) examine if a phone conversation would selectively affect non-automatic and/or more automatic driving subtasks.

1.1. Objective 1: processing information on VMS under cognitive distraction

A search in the relevant academic literature indicated that, as far as we are concerned, no previous studies have directly examined the effects of phone conversations on the processing of traffic information provided by VMS. Different to other traffic signs, by means of text messages and/or pictograms displayed on VMS, drivers are informed of dynamic, special circumstances in the driving environment, such as congestions, traffic diversions, accidents, or adverse weather conditions, among others. This information is usually critical to make driving decisions, such as lane changes, route choices, or hazard anticipation.

In the present work, participants were asked to drive a simulated route and decide, for each VMS they encountered, whether a text message was recommending to take a driving action (i.e., *warning messages,* such as 'ATTENTION PEDESTRIANS IN TUNNEL'), or was demanding no immediate action (i.e., *informative messages*, such as 'ATTENTION INSPECT TYRES'). It seems plausible that such decisions would be made with the help of central attention, i.e., the variety of attention by which we select (i.e., initiate, prioritize, or inhibit) some central (i.e., high-level, non-peripheral) mental processes, in order to achieve the current goals efficiently (Johnston, McCann, & Remington, 1995; Tamber-Rosenau & Marois, 2016). Such a variety of attention has been also studied using the constructs of mental effort (Kahneman, 1973), executive attention (Petersen & Posner, 2012), and cognitive control (Botvinick et al., 2001). Driving decisions based on VMS involve high-level mental functions such as reading comprehension, memory retrieval, and response selection; and it is well known that attention can enhance these functions. However, central attention is capacity-limited, and thus a process that demands central attention can be affected by a concurrent process using this resource (Pashler, 1994; Souza & Oberauer, 2017; Tombu & Jolicoeur, 2003). Therefore, a concurrent attention-demanding phone conversation can compete with the decision-making process based on a VMS message. Moreover, verbal processing is involved in both processing the VMS and listening to the conversation partner speech, and thus central attention would also be needed to efficiently switch between these two overlapping tasks. Therefore, if the driver is concurrently involved in a demanding phone conversation, in comparison to a no-distraction condition, delayed decisions and/or more errors responding to VMS messages would be expected. In addition, as the effects of attentional lapses in cognitive tasks can be better reflected in trial-to-trial intraindividual variability (e.g., Garret et al., 2012), higher variability of response distances will be observed. Finally, as mental effort would increase in a driver trying to process a VMS text message while talking on the phone, physiological indexes, such as a rise in heart rate, can be used to obtain a more objective, independent measure of such effect (for recent reviews of literature proposing that cardiac activity is sensitive to the mental effort level, see Borghini et al., 2014; Charles & Nixon, 2019; Hughes et al., 2019).

1.2. Objective 2: domain-general vs specific attentional resources

The rationale in the previous objective is consistent with a domain-general view of the effects of cognitive distraction on a primary attention-demanding task. Previous studies have followed a similar domain-general view to interpret results relevant to the current study. For example, Gunnell et al. (2019; see also Kunar et al., 2018) analysed the effects of a phone conversation in visual search tasks, and found that the conversation made the participants generally slower at finding the target stimulus across the different tasks. Still, their performance indicated that they used the specific mechanisms that commonly operate in these tasks, such as spatial learning and visual selective attention.

In addition, there is also a multiple, specific-resources view of attention (Navon & Gopher, 1979; Wickens, 2002) proposing that irrelevant, secondary tasks that demand some specific resources interfere more intensely with tasks involving just the same types of resources. For example, a spatial task such as tapping fingers in a specific order interferes more with tracking multiple moving vehicles than articulating syllables in a specific order (Trick et al., 2006). This specific-resources view would predict different effects of a demanding phone call, depending on the type of processing induced by the conversation. In particular, as visuospatial resources are needed to identify the message displayed on the VMS, a phone conversation requiring visuospatial resources would generate a relevant interference. Indeed, there is evidence that the processing of speech with salient visuospatial content affects the performance of tasks involving visual perception more than speech without such content (e.g., Bergen, 2007). Critically, Bergen et al. (2013) found that performance in a car following task was worse when the participant had to concurrently verify the veracity of sentences with salient visual content than relatively more abstract sentences. Briggs et al. (2016; Experiment 1) found consistent results for the detection of hazards in films of driving situations.

In conclusion, different predictions can be made for the current study considering either a domain-general or a specific-resources point of view. From a domain-general view, no significant differences would be expected between conversations inducing high- and low-demanding visuospatial processing. On the contrary, from a specific-resources approach, a phone conversation requiring visuospatial processing would be particularly detrimental to the processing of VMS messages, as compared to other conversations, in which visuospatial resources are not particularly required, such as answering conceptual questions. Beyond the implications for the theory of driver distraction, this issue can also have some practical implications. For example, if research supports that the effects of a phone conversation on driving are specifically negative if the conversation induces visuospatial processing (i.e., the type of processing involved in most driving subtasks), drivers could be instructed to avoid engaging in such content. Otherwise, if research supports that a phone conversation produces a driving performance loss, no matter the type of processing induced by the conversation, arguments in favor of banning hands-free phone use would gain more strength.

1.3. Objective 3: non-automatic vs more automatic driving sub-tasks

The last objective of the current study was to study the effects of cognitive distraction due to a phone call on the lateral control of the vehicle (lane position variability) and on the longitudinal control (speed variability). The aim was to compare the effects observed on the attention-demanding VMS task with other aspects of driving that are more automatic (i.e.

driving sub-tasks that experienced drivers can successfully perform with little or no attention, because these tasks have become proceduralised with practice; see Charlton & Starkey, 2011, for a review of automaticity and attention in driving). Thus, the experiment was set to make the lateral and longitudinal control of the vehicle easy for the driver during the approach to the VMS -at least, in the absence of phone distraction-, minimizing the attentional demands of these sub-tasks, so that the driver could perform them automatically. The route ran in a highway environment with very quiet traffic conditions, the VMS were posted on relatively straight road sections, the participants completed a practice session beforehand, and they were just asked to maintain the vehicle in lane and drive at a constant speed respecting speed limits. Adopting the theoretical framework proposed by Charlton & Starkey (2011), the lateral position and speed of the vehicle in such circumstances can be controlled by unconscious monitoring processes that are relatively independent from active attention. In contrast, the VMS task involves high-level, time-limited cognitive processes (reading comprehension, memory retrieval, and decision-making) and, therefore, it cannot be correctly and efficiently performed without conscious processes that are supported by active attention.

The extent to which a task depends on attention is thought to be crucial to modulate the effects of cognitive distraction on task performance. Accordingly to the cognitive control hypothesis stated by Engström et al. (2017; see also the implementation in a simulation model in Engström et al., 2018b), having a phone conversation while driving can increase the driver's cognitive load, though the increase would only have negative consequences on some specific driving sub-tasks. In particular, the affected tasks would be those that rely on cognitive control (i.e., tasks that are novel, unpredictable, or intrinsically difficult for the driver), whereas tasks that can be performed in a more automatic way would be unaffected or even improved. To support this idea, on the one hand, these authors cite studies showing that having a phone conversation impacts on tasks depending on cognitive control, such as the visual scanning of the driving environment (e.g., Reimer et al., 2012), braking in response to the onset of the brake lights of the preceding vehicle (e.g., Bergen et al., 2013), maintaining the lane in windy conditions (e.g., Medeiros-Ward, et al., 2014), controlling the vehicle speed accordingly to explicit speed restrictions (e.g., Recarte & Nunes, 2002), or deciding whether it is safe to perform a turn across the path of oncoming vehicles (e.g., Cooper et al., 2003). On the other hand, there are also studies suggesting that having a phone conversation does not alter more automatic tasks, such as braking to avoid an impending, unexpected collision (e.g., Horrey & Wickens, 2006), maintaining the vehicle in lane in good weather conditions (e.g., Cooper et al., 2013), or controlling the preferred speed (e.g., Recarte & Nunes, 2002).

Engström et al. (2018a) conducted a study to test this cognitive control hypothesis, examining how participants responded to a critical traffic event -an oncoming vehicle suddenly interfering the participant's path- that occurred in the same way a number of times along a simulated route. The cognitive load only was detrimental to respond to the traffic event on the first trials. In their opinion, these results supported their hypothesis, arguing that participants were not able to predict the event on these initial trials yet, and thus their responses were mostly automatic reactions to the traffic event. In contrast, the participants would have learned to anticipate the traffic event in the subsequent trials, and thus their responses would be more controlled. There have been other recent studies that, without explicitly mentioning the cognitive control hypothesis, have produced results consistent to it. For example, Ward et al. (2018) found that an increase in the driver's cognitive load affected their ability to process the orientation of visual stimuli presented at different places of the simulated driving environment, and their ability to keep a constant distance to a leading car –

tasks which seem to rely on attentional control-; but not their control of the vehicle in lane –a task which experienced drivers can automatically perform in good conditions-.

Thus, accordingly to the cognitive control hypothesis, the effects of the phone cognitive distraction on the lateral and longitudinal control of the vehicle would be absent, unlike the effects on the VMS task. Finally, it should be noted that we used a VMS reading task for evaluating the cognitive control hypothesis, instead of other more common driving indexes that may even require a greater amount of cognitive control. We chose this task because drivers' interactions with VMS have not been comprehensively studied in the previous literature, and, as described in Objective 1, we expected a significant interference, considering that verbal processing is involved in both the processing the VMS and listening to the phone conversation.

2. Method

2.1. Participants

Eighteen adult drivers (four male) participated. To collect this sample, people who had responded to an online recruitment questionnaire available at the website of the ERI-Lectura (University of Valencia, Spain) were contacted. Volunteers were interviewed and assessed to exclude (a) those who were non-native in Spanish, (b) those who did not show normal reading performance in the word and pseudoword reading tests of the PROLEC-SE-R battery (Cuetos, Arribas, & Ramos, 2016); (c) those who did not have normal or corrected-to-normal vision in an E chart; (d) those who reported in a clinical interview any sensory, cognitive, neurological or health disorder that can affect heart rate, or (d) those who did not hold a B category driving licence (which allows driving motor vehicles with a maximum authorised mass up to 3500 kg and transporting no more than eight passengers plus the driver). Twenty-five people were tested, but six of them were excluded for not holding the required driving licence and one more for showing reading difficulties. Table 1 shows descriptive statistics of the sample.

The participants were asked to abstain from alcoholic drinks, exceeding the usual amount of stimulant drinks, or performing intense physical activity for a 24-hour period before the experiment. They were also asked to abstain from stimulant drinks or copious meals 2 hours before the experiment. In addition, they were asked to have a good rest the night before the experiment. The study was approved by the research ethics committee of the University of Valencia.

Table 1. Participant characteristics and performance on the reading and visual tests.

Measures	*Lowest*	*Highest*	*M*	*SD*
Age (years)	20.00	51.00	27.17	7.96
Driving experience (years)	0.80	32.36	8.01	8.31
Formal Education (years)	14.00	18.00	15.61	1.72
Word reading (PROLEC-SE-R LP)	147.69	240.00	184.54	25.31
Pseudoword reading (PROLEC-SE-R PS)	71.67	135.29	108.53	17.23
Visual Acuity (LogMar)	-0.20	0.00	-0.06	0.08

2.2. Instruments and stimuli

The participants were tested in a Carnetsoft driving simulator (https://www.rijschool-simulator.nl/). The simulator, housed in a light- and sound-attenuated room of the Faculty of Psychology at the University of Valencia, included a comfortable seat, three 24-inch monitors

(Benq GL2450), an operator interface monitor, and a set of driving controls (Logitech G2: a steering wheel, a steering gear box, and three pedals). The central monitor was located at 38 cm from the participant's eyes, so that the visual angle of the screen was 70º (on the horizontal axis) by 43º (on the vertical axis). The height of the seat was adjusted so that the line of sight of the participant fell on the focal point on the apparent horizon line in the driving environment displayed on this monitor. The other two simulation monitors were placed right next to the central one, one at each side. The simulator gave auditory feedback about the vehicle engine and tyres. The simulation software ran on a personal computer (Intel Core i7-3770 3.4 GHz with a Nvidia GTX770 2GB graphic card). The participant's actions on the vehicle controls, as well as speed and horizontal position on the road lane, were processed at a sample rate of 120 Hz, although continuous variables were downsampled by the simulator and recorded at 20 Hz.

We used a 28-km route in a motorway environment. A number of VMS showing text messages were embedded in the simulation (see Table 2), all of them posted on relatively straight 120-km/h sections of the road. The VMS were 3-D models of one of the most commonly used VMS on the Spanish roads, allowing to display up to three lines of text, 12 or fewer characters each line. The design features followed the specifications of the standard norm UNE-EN 12966 (*Asociación Española de Normalización y Certificación*, 2015). To represent the characters, we used the patterns available in CarDim (I.P.S. Vial, S.L.), a computer application aimed at creating sign models for traffic engineering projects.

The participant's ECG was recorded during the whole driving experiment at a sample rate of 1000 Hz, using a MP100 BIOPAC system (www.biopac.com), with three Ag–AgCl electrodes (the ground electrode was placed on the participant's left shoulder, the positive on the left ankle, and the negative on the right shoulder). ECG data were visually inspected offline for detecting artifacts, and corrected using the AcqKnowledge software. After correction, we obtained the average participant's heart rate (beats/minute) during the approach to each VMS, from the beginning of the audio message (300 m to the VMS) until response. Finally, we calculated the mean corrected heart rate per participant and condition (no-distraction, visuospatial questions, conceptual questions).

Table 2. The text messages on variable message signs used in this study. An English approximate translation is provided below. Two different types of messages (i.e., warning and informative) were presented (see section 2.3. for further information).

Warning messages

Attention pedestrians in tunnel	Flooded lane 2 km ahead	Hazard: broken down vehicle

Informative messages

Attention inspect tyres	Access to tunnels 2 km ahead	Extreme fire hazard

2.3. Task and design

Participants were asked to drive in the right lane at a constant speed, as closely as possible to the posted limit (120 km/h in most of the route, 80 km/h in only two short sections at the extreme of the circuit). In addition, they had to complete two simultaneous tasks along the route: a VMS reading task and a phone questions task.

VMS reading task. Participants were instructed to read silently the VMS they encountered to discriminate between *warning messages* (i.e., potentially dangerous circumstances on the road that would demand an immediate action from the driver) and *informative messages* (i.e., other circumstances that would not demand an immediate action). They were encouraged to respond as soon as possible, without neglecting driving, by using one of two levers placed behind the steering wheel: a left lever for warning messages and a right lever for informative messages. Six different VMS were used (three warning and three informative messages; see Table 2), which were repeated three times in each distraction condition (see Phone questions task). Therefore, 18 experimental trials were presented in a random order for each participant and condition, with the only restriction of no presenting the same VMS on two subsequent trials.

Phone questions task. To manipulate distraction, every participant completed the route at the driving simulator three times (no-distraction condition, visuospatial questions, and conceptual questions), separated by a 5-minute break to rest. The first time was a 'no-distraction condition', in which the participant just drove and responded to the VMS reading task. During the other two times, the participants were presented with audios simulating incoming calls through a hands-free cell phone. The calls began with a ringtone, then a female voice asked the driver a question, and gave two response choices. The calls sounded at a moderate volume level, so that the participants would not be startled by the initial ringtone. The participants were asked to say aloud the correct response after the second choice was heard. They were encouraged to respond as soon as possible, without neglecting the driving, nor the VMS reading tasks. In one of the distraction conditions, we used questions aimed at engaging visuospatial cognitive resources (i.e., visuospatial questions, e.g., '*Which number has the shape of a tie: Eight or four?*'). In the other distraction condition, we used questions demanding semantic memory, in which visuospatial resources would have a relatively minor role (i.e., conceptual questions, e.g., '*Which word is related to holiday: tribunal or cruise*?') –see the Appendix for the Spanish wording and an English translation of the questions that were used in the experiment-.

During the simulation, each phone call started when the participant's vehicle was at a distance of 300 m to the VMS, with a total duration ranging from 6874 to 7739 ms (from the beginning of the ringtone to the end of the second response choice). At the required speed of 120 km/h, such duration involved travelling between 229 and 258 m (see Figure 1). During this period, the participant had also to attempt to read the VMS, which was already visible –but not yet legible- when the phone call began. No instructions were given regarding the priority of the responses to either the VMS or the phone task.

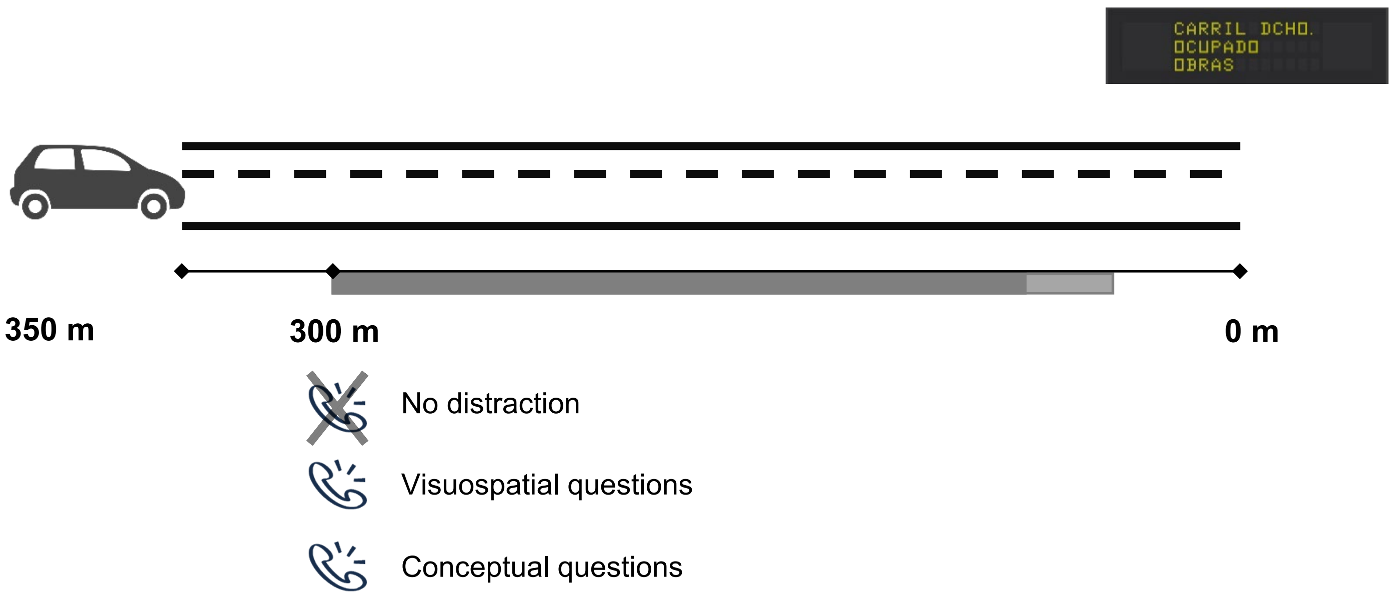

Figure 1: Schematic representation of an experimental trial. Phone calls started when the participant's vehicle was at 300 m to the variable message sign in the visuospatial and

conceptual conditions. The grey bar represent the minimum (dark grey) and maximum (light grey) distance driven at 120 km/h while listening to the visuospatial or conceptual questions.

2.3.1. *Pilot testing of the visuospatial and conceptual questions*

A pilot experiment was performed to test if there were intrinsic, significant differences between the two types of questions in accuracy or response latencies. In this single-task experiment, we asked participants to listen to and answer the oral questions, with no concurrent driving, nor the VMS task. We recruited an independent sample of volunteers (N = 21; five male) for the pilot experiment, who matched the participants in the driving experiment in age (ranging from 19 to 53, M = 26.4, SD = 8.2), and years of formal education (ranging from 14 to 18 years, M = 15.6, SD = 1.5). The visuospatial and conceptual questions were presented randomly intermixed.

First, the percentages of correct answers to the two types of questions were compared using a generalised linear mixed model (GLMM) with a binomial (logit) distribution (see Measures and analyses subsection for further information on this analysis). The results did not support significant differences between the two types of questions (visuospatial = 93.39 %, SD = 7.15; conceptual = 96.03 %, SD = 6.78; z = -1.632, p = 0.103; GLMM = accuracy ~ condition + 1 | participant). Second, we performed a one-way analysis of variance (ANOVA) on the response latencies, measured from the end of the second response choice to the beginning of the answer, using IBM SPSS Statistics 24 (IBM Corp., 2016). No significant differences between the two types of questions were found in this analysis either (visuospatial: M = 921.21 ms, SD = 60.38; conceptual: M = 817.13 ms, SD = 282.70; $F(1,20)$ = 3.17, p = .090, η_p^2 = .14).

After answering all the questions, the participants in the pilot experiment were asked to recall as many words as they could from those given as response choices, in free order. This unexpected recall task was used to test if the words given as response choices in the visuospatial questions were better recalled than the ones given in the conceptual questions, under the assumption that words in the visuospatial questions will arouse mental images more easily. Accordingly to Paivio (1991), words encoded using more than one type of processing (e.g., verbal and visual imagery processes) are better recalled than words encoded using a single type. As expected, more target words were recalled from the visuospatial questions (M = 13.81, SD = 5.86) than from the conceptual questions (M = 8.38, SD = 4.64), and a one-way ANOVA indicated that the differences were statistically significant $F(1,20) = 11.159$, $p = .003$, $\eta_p^2 = .358$.

2.4. Procedure

Figure 2 shows a diagram representing the experimental session. First, the participant signed an informed consent. Then, s/he was presented the six different VMS messages and completed a number of practice trials of the VMS task to learn the correct response associated to each message. No driving was required, and no oral phone questions were asked during this initial briefing. Second, the participant began the experiment in the driving simulator. All participants completed first the no-distraction condition, and then the two conditions with phone questions in a counterbalanced order by participant, separated by a 5-minute break to rest. In the conditions with questions (visuospatial or conceptual), two practice questions were also presented during the practice trials. The participants completed a total of 54 experimental trials (6 different VMS × 3 repetitions in each condition × 3 conditions).

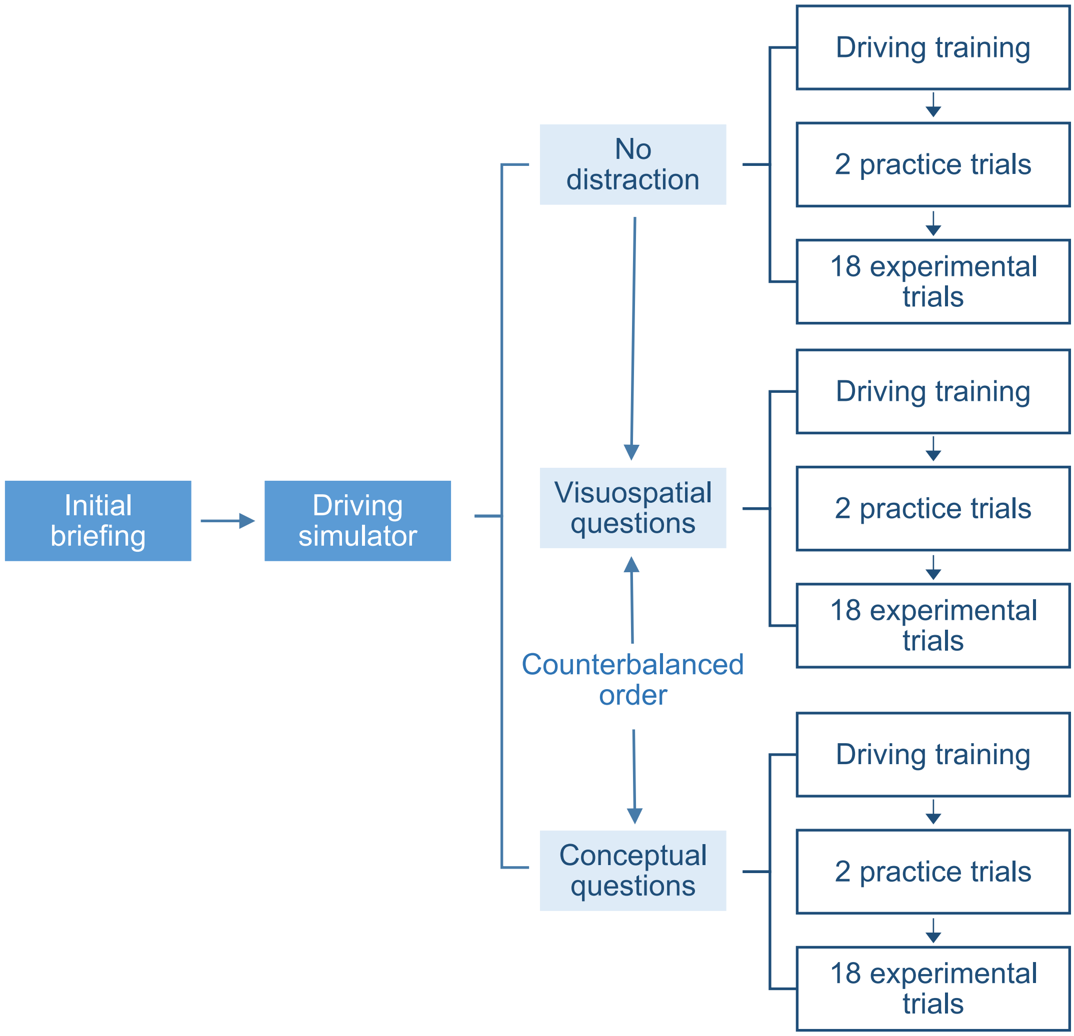

Figure 2: Diagram representing the experimental session

2.5. Measures

Table 3 shows the measures taken to analyse the VMS reading task, the driving performance, the heart rate, and the phone task. Each measure was computed by participant and distraction condition (no-distraction, visuospatial questions, conceptual questions). The trials on which the participant gave an incorrect response to the phone task (4.4% of the total number of trials for all participants) and/or the VMS task (4.6 %) were excluded from analyses. Only trials with correct answers in both tasks were allowed, assuming that in these trials: (a) the participant had paid enough attention to the whole question in the phone task (which was a requirement for the experimental manipulation of cognitive distraction), and (b) the participant had fully read the message displayed on the VMS (which was a requirement for assessing the processing of the VMS information).

Table 3. Name and definition of the measures taken in the study.

VMS reading task		
a	VMS accuracy	Percentage of correct responses to the VMS
b	Response distance	Mean distance (m) to the VMS
c	Variability of the response distance	Standard deviation of the distance (m) to the VMS
Driving performance		
d	Variability of speed	Standard deviation of the vehicle speed (km/h), as a measure of the participant's ability to keep a steady speed
e	Variability of the lateral position	Standard deviation of the lateral position of the vehicle (SDLP), as a measure of the participant's ability to keep a stable control of the vehicle direction
Heart rate		
f	Beats per minute at baseline	Mean heart rate during the initial sections of the route preceding the first experimental trial (baseline period)
g	Beats per minute during the trials	Mean heart rate during the approach to each VMS (i.e., during the experimental trials).
Phone questions task		
h	Phone questions	Percentage of correct answers to the phone questions

	accuracy	
i	Phone questions latency	Latency of the correct answers to the phone questions, computed since the end of each question until the beginning of the response

2.6. Data analysis

We performed one-way ANOVA on continuous variables (b, c, d, e, f, g, & i; as described in Table 3), with distraction condition as a within-subject factor (no-distraction, visuospatial questions, conceptual questions). IBM SPSS Statistics 24 (IBM Corp., 2016) was used in these analyses. Greenhouse–Geisser corrections were applied to *p*-values when sphericity was violated. When the results supported the statistical significance of the main effect of Condition, post-hoc analyses with Bonferroni correction were performed to test the significance of the differences between conditions. We estimated that a sample size of 18 participants was required to observe significant results of at least an effect size about $\eta_p^2 = .20$ in the current experiment, which was the minimum effect size reported in previous studies with similar driving tasks (Roca et al., 2018; Tejero et al., 2018, 2019) and is in line with common criteria (Cohen, 1988).

In addition, following methodological recommendations for the analysis of categorical data (e.g., Jaeger, 2008), we used generalised linear mixed models (GLMM) with a binomial distribution (logit) to compare the effect of the distraction condition on percentage measures (a & h; as described in Table 3). These models were analysed with the lme4 package v1.1–21 (Bates et al., 2015) implemented in R 3.5.1 (R Core Team, 2018). We considered the following model: accuracy ~ condition + 1 | participant. An alternative model including random slopes was tested, accuracy ~ condition + (1 + condition | participant), but provided similar results with no better fit, and therefore we only report the results of the simple model for simplicity. All the reported models converged successfully.

Finally, some of the hypotheses described in Section 1.3. (Objective 3) involved accepting the null hypothesis (H_0: no differences in driving performance between the visuospatial and conceptual questions conditions). It could be argued that the absence of statistically significant differences in an ANOVA cannot be taken as evidence of the actual absence of such differences (e.g., Dienes, 2014), and thus a non-significant result can mean either that the null hypothesis is true or that the data are insensitive to provide such result. In contrast, differently to the traditional frequentist analysis performed with ANOVA, the Bayesian approach is more suitable to test the strength of the evidence supporting null hypotheses. Therefore, we performed complementary Bayesian ANOVAs with JASP software (JASP Team, 2020) to test such hypotheses. In these analyses, we computed the Bayes Factor (BF_{10}) of the effect of the distraction condition on the driving performance measures. According to usual methodological guidelines (e.g., van Doorn et al., 2019), the Bayes Factor could be interpreted as follows: a) lower than 1/10, strong evidence supporting the null hypothesis (H_0), b) between 1/10 and 1/3, moderate evidence supporting H_0, c) between 1/3 and 1, weak or inconclusive evidence supporting H_0, d) between 1 and 3, weak or inconclusive evidence supporting the alternative hypothesis (H_1), e) between 3 and 10 moderate evidence supporting H_1, and f) greater than 10, strong evidence supporting H_1..

3. Results

The dataset of the experiment can be downloaded from Open Science Framework (Tejero & Roca, 2020). Table 4 shows some descriptive statistics of the measures in each distraction condition.

Table 4. Percentage of correct responses to the VMS, and mean values across participants of continuous measures (standard deviation between parentheses), by distraction condition (no-distraction, visuospatial questions, conceptual questions).

		Distraction condition		
	Measure	**No-distraction**	**Visuospatial questions**	**Conceptual questions**
Correct responses to the VMS	Percentage	95.37 (4.76)	90.74 (6.60)	95.68 (5.89)
	Distance to the VMS (m)	101.49 (16.09)	100.11 (29.24)	97.94 (29.89)
	Variability (*SD*) of the distance to the VMS (m)	18.13 (4.75)	23.61 (7.76)	23.16 (6.39)
Driving performance	Variability (*SD*) of the speed (km/h)	0.49 (0.35)	0.50 (0.23)	0.55 (0.27)
	Variability (*SD*) of the lateral position (m)	0.16 (0.06)	0.16 (0.07)	0.16 (0.07)
Heart rate	Beats per minute at baseline	82.42 (12.64)	80.50 (14.04)	80.20 (13.10)

Beats per minute during the trials	81.32 (13.08)	83.93 (13.63)	83.81 (12.97)

3.1. Correct responses to the VMS

The results of the GLMM (accuracy ~ condition + 1 | participant) supported the statistical significance of the differences between the condition with visuospatial questions and the no-distraction condition (z = -2.426, p = 0.015) and between the conditions with visuospatial and conceptual questions (z = -2.543, p = .011), whereas not so regarding the differences between the condition with conceptual questions and the no-distraction condition (z = 0.200, p = 0.841).

As for the mean distance at which the participants gave correct responses to the VMS, the ANOVA did not support an effect of the distraction condition on this measure (F(2,34) = 0.416, p = .595, η_p^2= .024). However, the distraction condition did have an effect on the intraindividual variability of the response distance (F(2,34) = 6.495, p = .004, η_p^2 = .276). The variability was smaller in the condition with no distraction than when visuospatial questions were presented (F(1,17) = 10.307, p = .005, η_p^2 = .377) or when conceptual questions were presented (F(1,17) = 9.494, p = .007, η_p^2 = .358), whereas there were not significant differences between the two conditions presenting questions (F(1,17) = 0.069, p = .796, η_p^2 = .004).

Focusing on the two conditions with phone questions, we found that the participants gave the responses to the VMS generally earlier than answering the phone question, with no differences between the two types of questions in the analyses of the percentage of trials on which the VMS response was given before answering the question (visuospatial = 97.28, %, SD = 3.12; conceptual = 95.48 %, SD = 4.61; z = 1.265, p = .205; GLMM = VMS first response ~ condition + 1 | participant).

3.2. Driving performance

The ANOVAs did not support any significant effects of the distraction condition on the driving performance measures, neither on the standard deviation of speed variability ($F(2,34) = .619$, $p = .544$, $\eta_p^2 = .035$), nor the lateral position of the vehicle ($F(2,34) = .213$, $p = .809$, $\eta_p^2 = .012$). In addition to the traditional ANOVA, we computed the Bayes Factor for the effects of the distraction condition on both the standard deviation of the vehicle speed ($BF_{10} = 0.23$) and the standard deviation of the lateral position of the vehicle ($BF_{10} = 0.17$). Therefore, the Bayes analyses provided moderate evidence for the absence of a condition effect on the driving performance measures.

3.3. Heart rate

The ANOVA of the mean heart rate during the baseline in each condition did not support any significant differences ($F(2,34) = 2.131$, $p = .134$, $\eta_p^2 = .111$), whereas we found significant differences in the ANOVA of the mean heart rate during the approach to the VMS ($F(2,34) = 12.059$, $p < .001$, $\eta_p^2 = .415$). In particular, in comparison to the condition with no phone distraction, the mean heart rate increased when visuospatial questions were presented ($F(1,17) = 13.820$, $p = .002$, $\eta_p^2 = .448$), and also when conceptual questions were presented ($F(1,17) = 25.123$, $p < .001$, $\eta_p^2 = .596$). No differences were found in the mean heart between the two conditions with phone questions ($F(1,17) = .046$, $p = .833$, $\eta_p^2 = .003$).

3.4. Answering the phone questions

The participants' accuracy in the phone task was very high and, like in the single-task experiment, no significant differences were found between the two types of questions (correct answers to visuospatial questions = 96.60 %, *SD* = 4.72; conceptual = 98.77 %, *SD* = 2.38; $z = -1.754$, $p = 0.079$; GLMM = accuracy ~ condition + 1 | participant). Nevertheless, unlike the single-task experiment, the participants were slower in initiating the answer to the visuospatial questions (*M* = 733.40 ms, *SD* = 307.07) than the conceptual questions (*M* = 541.61 ms, *SD* = 232.25), and the ANOVA supported that these differences were statistically significant ($F(1,17) = 17.10$, $p = .001$, $\eta_p^2 = .502$).

4. Discussion

Overall, the results reported in the current study suggest that the cognitive distraction coming from a conversation on a hands-free phone while driving can hinder the processing of relevant traffic information, such as text messages presented on a VMS, and increase the driver's cognitive effort. As further elaborated in the following paragraphs, when the drivers were engaged in a phone conversation during the approach to a VMS, we observed higher intraindividual variability of the response distances in the VMS task and an increase in the heart rate. In addition, we also observed more errors in the VMS task when the drivers were engaged in a particular type of phone conversation (i.e., requiring visuospatial resources). Therefore, the reported results are generally consistent with the predictions made regarding the first objective of the current study, and highlight the importance of considering the effects of phone conversations on the processing of the traffic information provided by text messages in VMS. In addition, regarding the second and third objectives of the current study, a diverging pattern of results was reported when considering the specific cognitive resources required by the phone conversation (i.e., visuospatial or conceptual processing) or the kind of task required to perform (i.e., low-demanding, automatized driving sub-tasks or a higher-demanding, non-automatic VMS reading task). Therefore, the current study provides new evidence to further discuss previous studies reporting significant or absent effects of cognitive distraction coming from a phone conversation on different aspects of driving.

4.1. Effects on central attention capacity

Being involved in a hands-free phone call, demanding either visuospatial or semantic processing, affected the distance at which the text message on the VMS was identified. Although there were no significant differences in the mean distance, the intraindividual standard deviation of the distance was significantly higher in the two conditions with phone calls than in the no-distraction condition, i.e., the driver's response distance was less consistent if a phone call was going on during the approach to the VMS. It has been argued that attentional lapses on the continuous performance of a cognitive task can be better reflected as higher intraindividual variability than in measures of central tendency (e.g., Garret et al., 2012), and there is some evidence that a phone conversation affects the performance stability of a cognitive task. For example, Steinborn & Huestegge (2017) found that participants performing mental arithmetic showed more instability in their response times when they were concurrently engaged in a phone conversation. Similarly, the results in our study suggest that the phone calls actually captured the participant's attention, provoking attentional lapses in the VMS task, as it can be expected if the effects of a phone conversation are actually affecting the driver's central attention capacity.

Physiological measures, such as the cardiac activity, can provide more objective, independent evidence of cognitive effort, as compared to other self-reported or performance-based additional tasks (see, for example, Hughes et al., 2019). In the present study, the heart rate results suggest that the driver's cognitive effort during the approach to the VMS increased when the driver was being asked a question on the phone. The mean heart rate was higher in the trials with questions (either conceptual or visuospatial) as compared to the condition with no questions, whereas no difference was found in the baseline measures taken at the beginning of each condition. Therefore, the heart rate results support the interpretation that the reported poor performance in the VMS reading task under cognitive distraction would be associated with an increased cognitive effort. Our results are in agreement with Mehler et al. (2009), who found that the heart rate increased in a stepwise manner from single-task driving through three increasingly demanding levels of an auditory cognitive task. Finally, it should be noted that the heart rate was recorded while the participant was listening to the question until the participant gave the response to the VMS. Since the response to the VMS was generally earlier than the answer to the question (over 95% of all trials), this measure of cognitive effort would not additionally reflect the effect of the answer production, which, accordingly to research, would be even greater than the effect of just listening to speech (Bergen et al., 2013; Coleman et al., 2016).

4.2. Effects on specific attentional resources

The results regarding the VMS task suggest that the decision-making processes related to text messages displayed on VMS could be affected if the driver is involved in hands-free phone calls inducing visuospatial processing of information. We found that the percentage of correct responses to the VMS was lower when answering questions inducing visuospatial processing than with no questions or questions demanding semantic memory. These results are consistent with studies on the specific effects of the processing type triggered by a phone call on the driving task. For example, Bergen et al. (2013) found that the mean distance to the preceding vehicle was altered if the phone call involved the processing of language with salient visual content, but not if the language was relatively more abstract. Briggs et al. (2016; Experiment 1) found that the processing of language impaired the sensitivity to detect hazards in films of real driving situations, as well as the reaction time for hazards, being the effects greater if the language was aimed at inducing mental imagery. The present results suggest that the visuospatial questions competed with the VMS task for visuospatial resources, which were not required to process the semantic questions.

On the other hand, the results regarding the phone task suggest that the participants processed the different types of questions in the multitasking conditions of the driving simulation experiment with some differences with respect to the single-task pilot experiment, with no driving, nor reading VMS. The time taken to initiate the answer to a question while driving was longer in the visuospatial than in the semantic memory questions, whereas no differences were found between the two types of questions in the single-task experiment. Thus, either the VMS task, the driving task, or both, given their visuospatial components, affected the processing of the visuospatial questions more than the processing of the semantic questions. These results differ from those obtained by Bergen et al. (2013), who did not find clear evidence that language inducing different types of processing was differentially affected by simultaneous performance of a car following task. However, these authors left the door open for research to show these differences, stating that "it may well be the case that language was in fact differentially affected by concurrent driving" (p. 124). Moreover, the present results are consistent with studies related on the specific effects of tasks involving visuomotor components on cognitive tasks demanding visuospatial processing. Baddeley et al. (1975) already showed that tracking a light moving on a screen only affected the performance of a short-term memory task only when this task was designed to induce some visuospatial processing.

4.3. Effects on low-demanding, automatized driving sub-tasks

In Mehler et al. (2009), physiological measures were sensitive to changes in mental workload with no significant decrements in driving performance. The present study produced a similar pattern of results, because the simulated phone calls had no detrimental effects on the control of the vehicle speed or the lateral position during the approach to the

VMS. Importantly, regarding the cognitive control hypothesis (Engström et al., 2017), the demands of driving task in both Mehler et al.'s (2009) and the present study were very low, considering the road and traffic conditions, as well as the task requirements. Other researchers have reported a significant deterioration of driving performance as a consequence of listening to a mobile phone, but this has generally been in more demanding driving circumstances. For example, Horberry et al. (2006) found significant deviations from the posted speed limit when driving while listening to phone questions. In their study, the posted speed limit randomly varied between 60, 70, and 80 km/h every kilometre on a route of 6 km, whereas in the present study, the participants had to keep a steady speed of 120 km/h for most of the route, except for two short 80 km/h sections.

Taken together, the present results regarding the performance of the driving task (with low demands on central attention) and the VMS task (with relatively higher demands on central attention) support the cognitive control hypothesis stated by Engström et al. (2017) too. When the drivers were cognitively distracted by phone questions in good road and traffic conditions, they showed worse performance in the VMS task and an increased mental effort, but they could still keep the basic control of the vehicle. The absence of significant effects of the distraction condition on the driving performance measures was supported by non-significant results in a traditional frequentist ANOVA and, importantly, by Bayes Factors providing moderate evidence in favour of the null hypotheses. Therefore, the reported results would not be better explained by a lack of sensitivity of our data to report such results (e.g., Dienes, 2014).

A main concern in the design of this experiment was whether the timing of the phone task and the VMS task actually overlapped. As said in the Methods section, the phone question began when the participant was at 300 m to the VMS, the questions lasted from

6874 to 7739 ms, and the instructed speed on the road sections with VMS was 120 km/h. The reported results supported that these settings were valid to generate the required overlap. We found that the participants' mean speed during the VMS approach was about 122 km/h in the three distraction conditions, with a very low variability across participants and trials. Thus, for the shortest question, we can estimate that the participants were at a distance of 67 m to the VMS when they still had to answer, after travelling at least 233 m while listening to the question. At that distance, it is highly plausible that the driver had being attempting to read the message, considering that, in the condition with no phone calls, the longest (i.e., the best) mean distance to the VMS at which the participants gave the response to the message was 129.9 m, and the shortest (i.e., the worst) was 71.4 m. Indeed, the participants generally (>95%) gave the correct response to the VMS before answering the phone question. Moreover, the level of accuracy of the answers to the phone questions (>96%) indicated that the participants were really committed to the phone call during the VMS approach. In our view, altogether, these results showed that the participants were actually processing the contents of the VMS while listening to the phone question, which supported the validity of the design of the study for the present objectives.

We did not instruct the participants to give priority to neither the VMS task nor the phone question task. However, we expected that they would respond to the VMS first, due to the study design, and actually, they mostly did so. We cannot conclude from this that they gave priority to the VMS task up to that moment, but if they did it so, we can speculate that the effects of the phone distraction on the processing of VMS might have been worse if the phone call had been prioritized. Further research can examine this issue. In any case, the results from a study conducted by Miller & Durst (2014) suggested that the performance of a 'primary' task suffers from the simultaneous performance of a 'secondary' task even when we are allowed to give absolute priority to the former. Therefore, even if we want to give absolute priority to be aware of the traffic message, a concurrent phone conversation will divert us from this goal.

Drivers can adapt their behaviour when they are talking on the mobile phone, e.g., reducing the vehicle speed. This may be a strategy to compensate the increase of risk due to phone distraction, i.e., self-regulation (Christoph, Wesseling & van Nes, 2019; Oviedo-Trespalacios, Haque, King, & Demmel, 2018). In the present study, the participants were asked to complete the route, driving at a constant speed and respecting the speed limits, which might have worked against the use of such strategy. Therefore, the results obtained are limited to driving situations such as the one we studied, or others in which driving requires attention demands to the same extent, at best. Further research can extend the present results examining the effects of cognitive distraction due to a phone call on the processing of VMS in other driving circumstances, for example, allowing the drivers to control the vehicle speed as they prefer.

4.4. Conclusion

To conclude, being engaged on a hands-free phone call while driving might have no significant impact on the control of the vehicle speed or the lateral position in relatively quiet traffic circumstances, but it can still impair the processing of text messages displayed on VMS, and it would increase the driver's cognitive effort even in such low-demanding circumstances. In addition, the processing of VMS messages can be particularly affected by cognitive distraction requiring visuospatial processing. In our opinion, these results have important implications and provide new evidence to further discuss hands-free phone policies. We believe that any loss in the processing of messages on VMS are worthy of particular consideration, because VMS are often used by road and traffic authorities for providing critical information about unexpected events (such as immediate traffic congestion or on-road obstacles). Missing or misunderstanding such information, as well as having to dedicate an extra reading time, can potentially lead to serious consequences. Furthermore, considering that the participants engaged in a phone call managed to identify the text message on the VMS with the cost of investing more cognitive effort (as our heart rate results suggest), less attentional capacity would be available to deal with sudden, potential risks demanding their attention.

In consequence, considering that many countries still allow the use of hands-free phones while driving (e.g., World Health Organization, 2018), our results suggest that new technological countermeasures must be designed, specifically to prevent drivers missing critical information provided by road and traffic authorities through VMS. In our opinion, a promising strategy to achieve such countermeasures involves the redesign of traffic information systems by integrating the driver' cell phone. For example, we have developed a mobile application, known as READit VMS (Roca & Tejero, 2019; see also Tejero, Pi-Ruano, & Roca, in press), which is able to provide in-vehicle oral versions of the messages shown on VMS during real driving conditions. This application is currently functional in most of the Spanish motorways (https://go.uv.es/lectura/readitvms).

4.4.1. ***Limitations***

The present study has some limitations. To begin with, the control condition (no-distraction) was completed first by all participants. By doing so, we aimed to avoid that the effects of distraction were enlarged if the VMS task got easier with practice. However, it could be argued that not counterbalancing the control condition would allow that the effects of distraction were partially explained by the driver's fatigue or boredom. To this respect, heart rate data shows a lack of significant differences between the three baseline measures (which were taken at the beginning of each condition), which provides no evidence of a hypothetical performance decrement because of fatigue or boredom. In addition, the accuracy in the message identification in the two conditions with questions, which were actually presented after the control condition in a counterbalanced order across participants, showed significant differences between the two distraction conditions, thus suggesting that these results were not better explained by such confounding factors.

The participants did not have to manipulate any device to take the simulated call, as it often happens in real settings. We think that the effects of the phone calls on the processing of VMS would have been even greater in our experiment if a manual action had been required, because looking at the device and/or acting on it would have also interfered with the VMS task. Further research is needed to test this hypothesis. In addition, our study only tested the effects of processing phone questions and giving short answers to them. We also find it interesting to test the effects of conversational situations, in which the driver speaks for longer times. We think that the effects on the processing of VMS would be greater in these circumstances, considering the evidence that the driver's mental workload is higher when speaking than when listening to speech (Bergen et al., 2013; Coleman et al., 2016). Even more, future research can also examine the impact of using a phone or other devices to text, navigate, or perform other activities on the processing of VMS (see Strayer, 2015; Strayer et al., 2019).

We acknowledge that the use of a phone by drivers in many real world situations does not necessarily entail a high level of cognitive distraction, and thus the present results are limited to the situations in which the driver's processing of information is actually loaded by the phone conversation. In any case, further real-driving experiments and naturalistic studies would be necessary to estimate the true impact of cognitive distraction in real-life situations.

The messages displayed on the VMS in the current study only included text. Current practice in Europe and other geographic areas is combining text and pictograms to provide traffic information on VMS (see, for example, Arbaiza & Lucas-Alba, 2012). Still, it seems reasonable to claim that identifying pictogram-based messages while approaching a VMS would also require visuospatial resources similarly to text messages (if not more intensely). In contrast, having a phone conversation might interfere to a greater extent reading verbal messages, such as text or pictograms that are easy to verbalise. Therefore, further research would be useful to clarify the impact and the modulatory factors of cognitive distraction on pictogram-only or mixed messages including text and pictograms.

The VMS were placed above the road in the current study, because this is the most common location of VMS at Spanish roads. Further research can test whether similar results are also found when the VMS are placed at the side of the road, a location that would demand peripheral vision to a greater degree in either the VMS task, the driving task, or both. As an anonymous reviewer pointed out, the VMS location can be crucial, because previous research has demonstrated that talking on a mobile phone impairs peripheral vision (e.g., Haque & Washington, 2014). Thus, we can expect that, with roadside VMS, the effects of distraction on task performance would be even stronger.

The VMS were placed at fixed locations along the road. It can be argued that this procedure could help participants anticipate the location of VMS, thus making easier the message classification task overall. Still, we decided to use fixed locations for the following reasons: a) VMS are actually placed at fixed locations in real settings, and b) the same locations were used in each of the three distraction conditions, and thus no systematic bias could be attributed to this procedure when comparing the experimental conditions. Nonetheless, we cannot rule out that the effect of cognitive distraction was more intense if messages would have been randomly presented along the road.

Regarding the sample composition, our study focused on drivers aged 20 to 51 years. Therefore, further research would be needed to examine if the effects of a phone conversation on reading VMS messages are different in older drivers, who might be more affected by attentional lapses than younger drivers. In addition, only four males completed the experiment. Therefore, further evidence would be required to confirm our results in samples including a higher proportion of male drivers. Finally, we support our results on a relatively small sample size (18 drivers), which was recruited by convenience sampling. Therefore, other studies with larger sample sizes would be more appropriate to generalize the conclusions of the current study to the broader population.

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Declarations of interest

Declarations of interest: none

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Appendix

Original questions used in the experiment and their approximate English translations (CPQ: Conceptual questions used in practice trials; CTQ: Conceptual questions used in test trials; VPQ: Visuospatial questions used in practice trials; VTQ: Visuospatial questions used in test trials).

Conceptual questions

CPQ1. ¿Qué palabra está asociada a vacaciones: tribunal o crucero? (Which word is related to holiday: tribunal or cruise?)

CPQ2. ¿Qué instrumento musical está hecho de madera: guitarra o batería? (Which musical instrument is made of wood: guitar or drums?)

CTQ1. ¿Cuál es el nombre del presidente de Estados Unidos: Donald o George? (Which is the president name of the U.S.A.: Donald or George?)

CTQ2. ¿Cuál es el nombre del futbolista de apellido Ronaldo: Leo o Cristiano? (Which is the name of the football player whose last name is Ronaldo: Leo or Cristiano?)

CTQ3. ¿Cuántos años debes tener para votar en España: 18 o 20? (How old do you have to be to vote in Spain: 18 or 20?)

CTQ4. ¿Cuántos años debes tener para beber alcohol en España: 14 o 18? (How old do you have to be to drink alcohol in Spain: 18 or 20?)

CTQ5. ¿Cuál es la lengua oficial en Dinamarca: inglés o danés? (Which is the official language in Denmark: English or Danish?)

CTQ6. ¿Cuál es la lengua oficial en Islandia: islandés o alemán? (Which is the official language in Iceland: Icelandic or German?)

CTQ7. ¿Qué vehículo necesita gasolina: camión o patines? (Which vehicle needs gasoline: a truck or skates?)

CTQ8. ¿Qué vehículo necesita gasolina: bicicleta o autobús? (Which vehicle needs gasoline: a bike or a bus?)

CTQ9. ¿Qué animal se considera doméstico: gato o león? (Which animal is considered a domestic animal: a cat or a lion?)

CTQ10. ¿Qué animal se considera doméstico: tigre o perro? (Which animal is considered a domestic animal: a tiger or a dog?)

CTQ11. ¿Qué comida cuesta más dinero: plato combinado o bocadillo? (Which food costs more money: a combination meal or a sandwich?)

CTQ12. ¿Qué objeto cuesta más dinero: libreta u ordenador? (Which item costs more money: an exercise book or a computer?)

CTQ13. ¿Qué acción está relacionada con jardinería: resumir o podar? (Which action is related to gardening: doing a summary or pruning?)

CTQ14. ¿Qué palabra está relacionada con negocio: crédito o receta? (Which word is related to doing business: loan or recipe?)

CTQ15. ¿Qué receta es típica de Valencia: pizza o paella? (Which is a traditional recipe in Valencia: pizza or paella?)

CTQ16. ¿Qué bebida es típica de Valencia: horchata o gazpacho? (Which is a traditional drink in Valencia: horchata o gazpacho?)

CTQ17. ¿Qué objeto sirve para hacer deporte: raqueta o persiana? (Which object is useful for playing sports: a racket or window blinds?)

CTQ18. ¿Qué objeto sirve para hacer deporte: tijeras o zapatillas? (Which object is useful for playing sports: scissors or sneakers?)

Visuospatial questions

VPQ1. ¿Qué número tiene forma de lazo: 8 o 4? (Which number has the shape of a tie: eight or four?

VPQ2. ¿Qué forma tiene una zapatilla de deporte: redonda u ovalada? (Which is the shape of a sneaker: round or oval?)

VTQ1. ¿De qué color es el billete de 10 euros: rosa o verde? (Which color is a 10-euro bill: pink or green?)

VTQ2. ¿De qué color es el billete de 20 euros: marrón o azul? (Which color is a 20-euro bill: brown or blue?)

VTQ3. ¿Qué fruta cabe dentro de un paquete de tabaco: plátano o nuez? (Which fruit fits in a pack of cigarettes: a banana or a walnut?)

VTQ4. ¿Qué hortaliza cabe dentro de una funda de gafas: judía o berenjena? (Which vegetable fits in a glasses case: beans or an eggplant?)

VTQ5. ¿Qué objeto tiene mayor circunferencia: 1 euro o pelota de tenis? (Which object has longer circumference: a 1-euro coin or a tennis ball?)

VTQ6. ¿Qué objeto tiene mayor circunferencia: 5 céntimos o lenteja? (Which object has longer circumference: a 5-cent coin or a lentil?)

VTQ7. ¿Qué alimento es más pequeño: grano de arroz o garbanzo? (Which food is smaller: a grain of rice or a chickpea?)

VTQ8. ¿Qué objeto es más pequeño: sacapuntas o chincheta? (Which object is smaller: a pencil sharpener or a pin?)

VTQ9. ¿Qué objeto está más abajo en un autocar: ruedas o faros? (Which object is lower in a bus: tyres or headlights?)

VTQ10. ¿Qué parte está más abajo en una bicicleta: manillar o pedales? (Which component is lower in a bicycle: handlebars or pedals?)

VTQ11. ¿Qué parte está más arriba en el cuerpo humano: cintura o nuca? (Which part is higher in human body: waist or nape?)

VTQ12. ¿Qué parte está más arriba en el cuerpo humano: rodilla o tobillo? (Which part is higher in human body: knees or ankles?)

VTQ13. ¿A qué letra se parece el perfil de unas montañas: M o G? (Which letter looks like the shape of some mountains: M or G?)

VTQ14. ¿A qué fruta se parece la forma de la letra O: pera o mandarina? (Which fruit looks like the shape of letter O: pear or tangerine?)

VTQ15. ¿Qué objeto tiene forma cuadrada: balón o tablero de ajedrez? (Which object is square shaped: a ball or a chessboard?)

VTQ16. ¿Qué forma tienen las orejas de un gato: triangular u ovalada? (Which is the shape of the ears' cat: triangular or oval?)

VTQ17. ¿Qué objeto tiene más altura: lavadora o paragüero? (Which object is higher: a washing machine or an umbrella stand?)

VTQ18. ¿Qué objeto tiene más altura: nevera o canasta de baloncesto? (Which object is higher: a fridge or the baskets in a basketball court?)