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# Driven to distraction: A systematic literature review on the role of the driving context in mobile phone use

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ABSTRACT

Mobile phone use is one of the most frequent causes of distraction among drivers. While there have been a significant number of studies that have examined individuals' intentions to use a mobile phone while driving, the influence of individuals' in-situ judgement of driving conditions has received considerably less attention. The aim of this investigation was to provide a systematic understanding of how factors associated with the driving context and environment influence a driver's decision to engage in mobile phone use while driving. Following a systematic classification scheme, 41 research articles from the years 2011 to 2020 were reviewed and synthesised to identify the contextual determinants of mobile phone distraction. Overall, the findings provided support for the role that contextual features play in influencing individuals' mobile phone use engagement. This finding was particularly the case in instances where mobile phone tasks required relatively high cognitive and physical demands on an individual, such as texting and/or reading mails. The findings also indicated that as contextual complexity increases, mobile phone use decreases as well. A deeper understanding of the relationship between contextual factors and phone use while driving may aid in the design of more efficient driver support systems and the development of distraction-sensitive road design guides. This understanding can also assist in the identification of mobile phone use hotspots and the improvement of law enforcement and educational strategies to prevent the behaviour.

## 1. Introduction

Mobile phone use has long been recognised as a major contributor to driver distraction. A prior systematic review on secondary task management while driving reported an evident trend of increased mobile phone use over the years, including conversations, app use, and texting (Huemer et al., 2018). In Australia, in a sample of drivers aged 15 to 60 years, 61 % (n = 1500) admitted to talking or texting on a mobile phone while driving (Petroulias, 2014), and a survey indicated that one in every two drivers used handheld devices to talk, text, or browse on a regular day (Oviedo-Trespalacios et al., 2017). Similarly, a study conducted in the United States (n = 1211) showed that nearly 60 % of drivers admitted engaging in at least one mobile phone-related activity within the previous 30 days

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(Gliklich et al., 2016). Similar patterns of mobile phone use while driving have been reported in low- and middle-income countries, including Chile (CONASET, 2015), Poland (Przepiorka et al., 2018), Ukraine (Hill et al., 2019), Iran (Pouyakian et al., 2012) and Uruguay (UNASEV, 2016), to name but a few.

The constant use of mobile phones and potential adverse side effects constitute a pressing concern for road transport authorities worldwide. The literature on the topic confirms that heightened crash risk has been consistently linked to mobile phone use while driving. Indeed, some authors have reported between two to six-fold increases in crash risk being associated with phone use while driving (e.g., Bakhit et al., 2018; McEvoy et al., 2005). This reported increase in risk has been linked to the interference of the mobile phone task with driving. A *meta*-analysis by Simmons et al., (2016) concluded that tasks requiring drivers to take their eyes off the road, such as dialling or texting, increased the risk of a safety–critical event (SCE) to a greater extent than tasks where fewer off-road glances were required. In accordance, evidence suggests that the greater the amount of off-road glance time of the task required, the higher the associated crash risk (Oviedo-Trespalacios et al., 2016; Simons-Morton et al., 2014). Regarding mobile phone conversations, as distinct from other mobile phone tasks such as dialling and texting, a systematic review conducted by Oviedo-Trespalacios et al., (2016) found a lack of evidence linking this activity to changes in crash likelihood. Nonetheless, there was evidence that mobile phone conversations interfere with peripheral awareness and object detection sensitivity.

Understanding the decision-making process behind a driver’s choice to engage in mobile phone-related activities is necessary to reduce distracted driving. According to Michon (1985), driver behaviour involves three decision-making levels: strategic (planning), tactical (manoeuvring) and operational (control). Oviedo-Trespalacios et al. (2018a) adapted this model to the behaviour of mobile phone use while driving. According to Oviedo-Trespalacios and colleagues’ conceptualisation, at a strategic level, the individual establishes their intentions or plans as to whether they would use their phone or not while driving. At a tactical level, during the ongoing driving task, an individual is largely constrained by the exigencies of the actual situation (Michon, 1985). At this level, environmental complexity and task demands, both from the driving task and any secondary tasks, determine where and when a driver deems it feasible to engage in mobile phone-related activities. Lastly, at an operational level, using a mobile phone can influence driving performance measures such as lane-keeping and speed once the secondary activity is already underway.

To comprehensively understand and devise interventions to prevent the behaviour of mobile phone use while driving, attention must be directed towards the strategic and tactical decision-making levels, as they precede the manifestation of the behaviour. Much of the literature studying factors related to the decision to use a mobile phone while driving has focused on the strategic level. For example, the Theory of Planned Behaviour (TPB) has been used multiple times in studies which have sought to investigate a driver’s intention to engage in mobile phone use as a determinant of the behaviour (e.g., Oviedo-Trespalacios et al., 2018a; White et al., 2010). In 2001, a *meta*-analysis by Armitage & Conner found that the standard TPB accounted for 39 % of the variance in intention to perform a behaviour and 27 % of the variance in explaining the behaviour. Extensive research has consistently supported the predictive capacity of the TPB framework, particularly in anticipating behaviours such as dieting and exercise, which are typically characterised by intention, premeditation, and logical decision-making (Gibbons et al., 1998). However, it is crucial to acknowledge that not all behaviours conform to these principles, especially those that may be perceived as risky, or counter to one’s well-being. In fact, several studies have underscored the significant disparities between intention and subsequent behaviour across various case studies (Hasssan et al., 2014; Sheeran & Webb, 2016). Moreover, Preece et al. (2018) indicated that intention does not consistently serve as the sole or most accurate predictor of behaviour when it comes to risky behaviours and substantiated this assertion by prior research demonstrating inconsistencies between individuals’ reported intentions and their actual future behaviours. While it could be argued that models like the TPB should not be confined only to a strategic or intentional framework as various modifications have been made to these models in an attempt to also account for tactical considerations, the model still relies heavily on intention, and the temporal gap between forming an intention and translating it into action must be acknowledged. The existence of this intention-behaviour gap has been documented in the research, and it is apparent that intentions do not always translate to behavioural enactment (Sniehotta et al., 2005).

Moreover, when exploring mobile phone use while driving using the TPB, researchers primarily rely on self-report methods, such as surveys. Participants are asked to report their intentions to engage in specific behaviours within defined contexts, incorporating a tactical aspect. However, this approach predominantly relies on individuals’ anticipations of their future actions and lacks exposure to real driving situations.

To gain a deeper understanding of the influences on mobile phone use while driving, it is imperative to consider drivers’ decisions not only from a strategic perspective, as exemplified by such TPB-based studies, but also from a tactical, in-situ perspective. Adapting Michon’s multi-layered decision model for mobile phone use while driving offers a framework that more effectively differentiates intentions from actual behavioural enactment. At the tactical level, individuals are placed in real-world scenarios, emphasising tactical considerations, including contextual factors and the expected demands of the mobile phone task at hand. This shift away from the more traditional, primarily strategic-centric approach aims to bridge the gap between intention and action, providing a more comprehensive understanding of an individual’s definitive decision that takes place mere seconds before engagement and, in essence, ultimately determines behavioural enactment.

From a tactical perspective, many contextual factors might be present while an individual performs the driving task. Previous research has shown that drivers are less likely to use a mobile phone where road traffic conditions are perceived as more demanding such as in urban areas, where there are roundabouts, heavy traffic or when the driver needs to navigate curved roads (Kidd et al., 2016; Kujala & Mäkelä, 2018, Oviedo-Trespalacios et al., 2018a). A naturalistic study in the Netherlands found that driving speed was an important factor in influencing individuals’ decisions whether to use mobile phones while driving. Specifically, drivers were more likely to use a mobile phone while driving at a low speed or while stationary (Christoph et al., 2019).

Despite the evidence pointing to the influence of road traffic conditions on mobile phone engagement, there is a lack of systematic understanding of how features associated with the driving context and environment influence a driver's tactical decision to engage in mobile phone distraction while driving. This study conducted a systematic review to summarise and critically appraise the literature on the subject and determine the role of contextual features as determinants of individuals' mobile phone engagement while driving. The literature analysis identified contextual features influencing phone use while driving and described their effect on mobile phone engagement. In doing so, the review sought to provide insight into other influencing factors besides those associated with the more traditional intention-based approach.

More profound knowledge of the relationship between the road traffic environment and a driver's attention-diverting decisions can lead to the design of more targeted interventions. For instance, it may help to inform efficient driver support systems, the development of distraction-sensitive road design guides, identification of mobile phone use hotspots, optimisation of law enforcement, and development of education strategies. Any efforts to optimise the effects of such interventions are significant to the extent that they may contribute to reductions in individuals' phone use while driving and, in turn, its role in causing distraction and distraction-related road trauma.

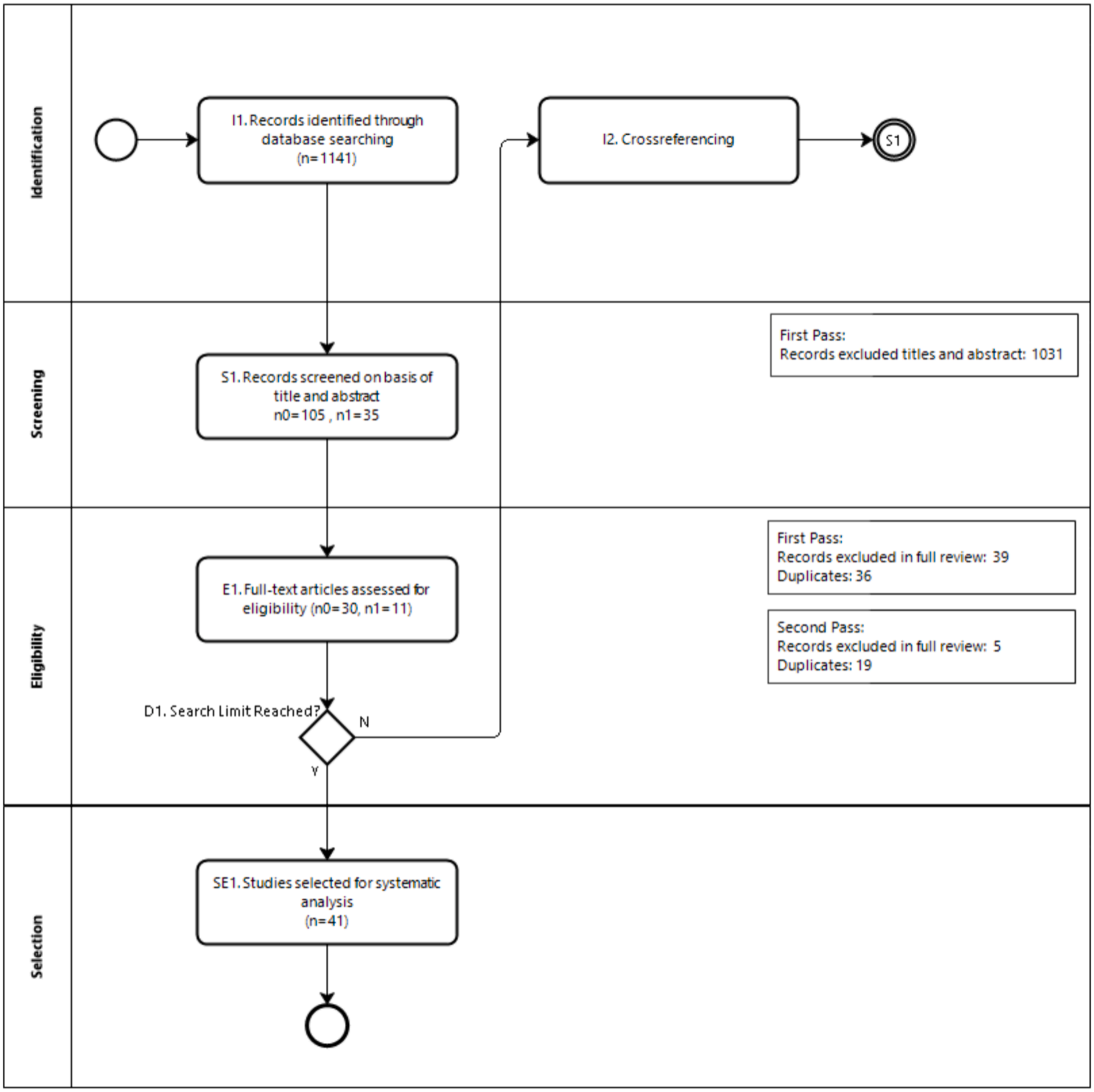

**Fig. 1.** PRISMA methodology.

## 2. Methods

### 2.1. *A systematic classification scheme (SCS) to review the literature*

A systematic literature review was conducted to understand the extent to which context features influence an individual's decision to engage in mobile phone use while driving. The review utilises a systematic approach that follows a systematic classification scheme (SCS) methodology introduced by Hachicha and Ghorbel (2012) and applied mainly in road safety to analyse impaired driver behaviour (Oviedo-Trespalacios et al., 2016; Vaezipour et al., 2021). The first three analysis questions focused on data collection techniques and theoretical confounders (e.g., driver characteristics and mobile phone task type) that are often included alongside contextual factors as determinants of mobile phone use. The remaining questions focused on contextual features and the methods used to assess their effect. The proposed SCS consisted of the following questions:

- What was the data collection method? (e.g., simulator study, naturalistic study, observational, survey).
- What was the demographic target of the study?
- Which mobile phone activity types and modes of use were studied? (e.g., talking, texting, manipulating, holding).
- Which contextual/environmental features were analysed in relation to mobile phone engagement?
- What method was used to explore the relationship between environmental features and mobile phone engagement?

### 2.2. *Search strategy*

The search strategy is depicted in Fig. 1. An initial literature search was conducted to identify peer-reviewed papers in several academic databases, including Science Direct, ProQuest, Scopus, and TRID (I1). The search period was limited from the years 2011 to 2020 since extending this time frame would not accurately reflect recent mobile phone engagement tendencies. Mobile devices have undergone a radical transformation over the years, initially covering basic tasks, such as calling and texting, and currently offering a variety of other functions, such as internet navigation, social media and games (Oviedo-Trespalacios et al., 2019a). Thus, mobile phone use habits are expected to change noticeably over time.

The keywords "(cell phone OR mobile phone OR secondary task) AND (driving OR driver) AND (context OR environment OR scenarios OR infrastructure OR situational OR contextual OR roadside or intersections)" served as the search statement in accordance with the search syntax of each database. Term inclusion for the search statement was based on maintaining a specificity level that allowed for an all-inclusive range of context/environmental features.

For the purpose of the search, the driving context referred to all the variables that make up the immediate driving environment a driver experiences while operating a vehicle on the road at any given moment. These factors include variables that define the landscape or geodemographic features of the area (e.g., area type, population density, socioeconomic status, etc.), temporal aspects (e.g., time of day, weather, etc.), physical layout and features of the road network (e.g., number of lanes, road classification, etc.), and dynamic traffic conditions that reflect the changing state of traffic. This includes context features related to how drivers navigate the road network and interact with other vehicles (e.g., speed, traffic density, manoeuvres).

The search process was initiated by the terms being sought in the document's title and/or abstract, depending on the database search capacity (I1). Retrieved manuscripts were screened based on title and abstract (S1), followed by a full review of the manuscripts of interest to confirm eligibility (E1). For both S1 and E1 stages, the following inclusion and exclusion criteria were applied:

- The manuscript was included if the analysis was conducted on original empirical data.
- The manuscript was included if its publication date was restricted to 2011–2020, and the publication language was restricted to English.
- The manuscript included studies where the driver decided to initiate or respond to an incoming phone-related interaction without being obligated to do so.
- The manuscript was excluded if considered off-topic. For instance, manuscripts were excluded if the effect of contextual factors was not directly analysed. Also, manuscripts were excluded if mobile phone engagement was not assessed independently of other secondary tasks, such as working on a laptop or eating in the vehicle.
- The manuscript was excluded if considered a duplicate of another manuscript (i.e., appeared in previous search results).
- Peer-review filters were applied if available in the database search engine.

Subsequently, eligible manuscripts were subjected to cross-referencing to identify additional articles of interest (I2). All new items identified by cross-referencing followed the same eligibility check process as the initial search, starting from E1. A final set of articles was obtained for systematic classification at this stage.

## 3. Results and discussion

A total of 41 articles were selected for systematic analysis based on the PRISMA methodology (Fig. 1). The initial database search yielded 30 eligible manuscripts, while the subsequent cross-referencing procedure yielded an additional 11 manuscripts, totalling 41 articles. The resulting systematic classification of articles is presented in Appendix A.

### 3.1. *What was the data collection method?*

In the literature, several data collection approaches have been used to investigate driver distraction. The systematic review identified five main types of design which were classified as (i) naturalistic, (ii) observational, (iii) driving simulator, (iv) video clips, and/or (v) self-reported data.

The most common study methodology was observational, with over half of the studies implementing this approach (51.2 %). In a roadside observational study, drivers' behaviour is generally recorded from outside the vehicle by trained observers at one or more locations during short periods. This data collection method allows for the observation of a driver's behaviour in its natural environment without issues related to self-reporting errors or biases, or the alteration of behaviours while being monitored (Huisingh et al., 2015). Observational data is often preferred when the study's scope targets specific traffic scenarios such as intersections. Conditions in which vehicles are stopped or moving at low speeds are optimal for gathering observational data, as trained observers are subjected to less visibility and time restrictions. In fact, most of the observational studies included in the classification framework were found to be intersection-focused (e.g., Cooper et al., 2013, Huisingh et al., 2015, Huth et al., 2015, Kidd et al., 2016, etc.).

However, despite their popularity in this area of research, observational studies have some significant limitations that need to be considered. For example, drivers may conceal their behaviour to avoid detection if performing an illegal activity, such as using the phone in handheld mode (Prat et al., 2015). Additionally, activity identification may pose a challenge since specific tasks are more difficult to identify accurately than others. Therefore, several activities need to be grouped together into more general categories. For instance, a broader category of visual-manual interactions might be selected for analysis encompassing activities such as dialling, texting, browsing, etcetera. Collapsing mobile phone tasks facilitates identification when there is no certainty about the specific phone activity performed; however, doing so restricts the possibility of providing a more detailed assessment based on task differentiation. For all cases, careful assessment of inter-observer agreement is required to have greater confidence in the reliability of the results.

The second most common data collection methodology was found to be naturalistic driving studies (29.2 %). In a naturalistic study, data is collected by placing sensors and video cameras inside volunteers' vehicles and recording their behaviour, typically for long periods. The main advantage of naturalistic studies is the ability to record driving behaviour in real traffic conditions without the intrusion of artificial elements from experimental settings such as experimenters, protocols and pre-defined tasks (Tivesten & Dozza 2014; Tivesten & Dozza 2015). The continuous recording of detailed information for whole trips and more extended time periods allows the assessment of a broader range of real-world driving scenarios and increases the power of statistical tests (Tivesten & Dozza 2014; Tivesten & Dozza 2015). However, naturalistic studies have some key disadvantages. Participants' awareness of being recorded may impact their decision-making process and displayed behaviour. In addition, most studies employing naturalistic data in this review preferred to use existing datasets. The main reason for doing this is that instrumentation can be costly and lengthy, even for relatively small sample sizes. Using an existing dataset means that the analysis must align with its scope. Consequently, there may be limitations due to geographical factors (e.g., country, region), insufficient inclusion of seasonal variables (e.g., exploring a behaviour during adverse weather conditions such as rain or snow), or constraints related to the time period (i.e., the years covered by the study). Upon examination of the reviewed naturalistic studies, it is noticeable that naturalistic datasets mainly included data from the United States and some European countries, with some studies of a more relatively limited-scale nature from South America (Bastos et al., 2020).

An alternative to the analysis of driver behaviour in real environments is driving simulator studies (9.8 %). In such studies, drivers are placed in an artificial environment equipped with components that are believed to provide a valid substitute for an actual driving experience. The drivers are observed under controlled experimental conditions while experiencing programmed scenarios. Driving simulator studies provide the ideal mechanism to reproduce any scenario combination and overcome time, weather, and task identification constraints. Complete control of experimental conditions allows for assessing the effects of any roadway characteristics or combinations of roadway characteristics as desired. As a result, scenarios that are deemed unethical, infeasible, unsafe or too costly to be evaluated in real-life scenarios can be assessed within a driving simulator. Moreover, the study may include sensor data necessary to collect cognitive and physical performance measurements from the participants that could not be used in real driving. Despite these advantages, driving simulator studies accounted for only 9.8 % of the reviewed studies. Possible explanations include restricted access to facilities with driving simulators and high programming costs. Another consideration when conducting driving simulator studies is that participants are aware, even more so than in the case of naturalistic studies, that they are being observed and may behave unnaturally or differently.

Given the above, there has been ongoing debate about whether simulators can serve as valid and reliable alternatives to on-road studies. A recent systematic review aimed to assess the accuracy of driving simulators when compared to real-world driving experiences. Despite the differences in the types and quality of simulators used, the results showed that in approximately half of the studies, simulators demonstrated either absolute or relative validity (Wynne et al., 2019).

A more simplistic experimental approach to driving simulator studies is the use of desktop-based experiments using video clips (9.8 %). Under this modality, drivers are shown clips of simulated or real road traffic conditions without performing any driving tasks. The participants may even be placed inside a driving simulator to achieve a more realistic experience (e.g., Pouyakian et al., 2012; Pouyakian et al., 2013); however, participants are not actively operating any vehicles during the duration of the experiment. It can be argued that video clips could be a more viable, less expensive option relative to a driving simulator study. However, it is uncertain how valid the results are when the participant is not interacting with the vehicle or experiencing driving task demands in a manner similar to operating a vehicle (as can be done in a driving simulator).

Finally, self-reported data is another alternative to gathering data about individuals' mobile phone use while driving. Self-reported data involves participants directly reporting on their behaviour in various ways, such as surveys, interviews, focus groups, questionnaires, or think-aloud sessions (verbalising thoughts while going through questions/scenarios). In most cases, information collected from self-reported data is concerned with the intentional nature of a driver's conduct. As such, few studies containing self-reported data surpassed the exclusion criteria (9.8 %). The studies that were included for classification containing self-reported data were those that paired exposure to driving scenarios with questionnaires or think-aloud sessions to gain more insight into the internal thought processes underpinning individuals' decisions (e.g., Hancox et al., 2013, Parnell et al., 2018). Collecting self-reported data during exposure to the driving scenarios or immediately after allows gathering data on tactical decisions as opposed to other techniques, such as focus groups or surveys, which may discuss a driving context and seek individuals' responses about it but are retrospective and neither simulated nor actual in-situ driving situations.

## 3.2. *What was the demographic target of the study?*

### 3.2.1. *Country*

Most reviewed studies included data collected in European countries (31.7 %) and North America, and in the latter, it was mainly the United States (36.6 %). European studies were primarily conducted using naturalistic, observational and survey data, and the span of countries was quite extensive (Germany, UK, Spain, Finland, Netherlands, Poland, France, and Sweden). Similarly, studies in the United States also included naturalistic, observational and survey data. Another cluster of interest for data collection encompassed countries of the Middle East (19.5 %), mainly Iran, with a single study covering other countries such as Saudi Arabia, Qatar, and Israel. Most of the studies in this region were observational, with some including simulated environments or video clips. A few studies were conducted in Australia (9.8 %) with various data collection methodologies, including naturalistic data, observational data, simulator data and video clips. There is a notable lack of studies on the topic in Central and South America, Africa, and a vast majority of Asian countries. As a result, it must be acknowledged from the outset that findings from this systematic review correspond mainly to European and American driving contexts.

### 3.2.2. *Gender*

Gender (only as male or female) has been considered numerous times as a potential factor influencing driver behaviour. Reviewed studies were classified according to the predominance of gender to assess their distribution. Predominance was defined as a 20-point prevalence in the percentage of the gender of either type. Results indicated that 39 % of studies had male predominance, 43.9 % had an even distribution, 2.4 % were predominantly female, and 14.6 % did not provide information on gender distribution. The literature has mixed findings regarding gender differences and mobile phone engagement while driving. Several studies have found that males are more likely to be observed using a mobile device while driving (e.g., Hallett et al., 2011; Narine et al., 2009; Pouyakian et al., 2013; Zhou et al., 2009); several others found no significant differences (e.g., Gras et al., 2012; Prat et al., 2015; Sullman, 2012; Sullman, 2010; Young & Lenne, 2010), while others indicated female prevalence (e.g., Oviedo-Trespalacios et al., 2018a). Regarding the influence of gender on decisions to engage in particular mobile phone activities, findings are not consistent either. Several authors found no significant differences between distributions of phone use modes and gender (e.g., Sullman, 2012; Townsend, 2006; Young et al., 2010). For texting, in particular, both Huisingh et al. (2015) and Struckman-Johnson. et al. (2015) found no differences in regularity. In contrast, Sullman et al. (2015) reported significantly more males engaging in handheld phone use, while Huisingh et al. (2015) and Farmer et al. (2015) reported significantly more female drivers talking on the phone compared to their male counterparts.

### 3.2.3. *Age*

To analyse age distribution, studies were classified into two categories: non-targeted, including data from two or more age groups, or targeted, including data from a single age group. Due to the lack of consistency in the definition of age groups among the reviewed studies, the following age groups are defined for analysis purposes: young drivers (16–25 years), middle-aged drivers (26–60 years) and older drivers (over 60 years). Results showed that 80.5 % of studies were non-targeted; only two studies (4.8 %) contained data from a single age group, one including solely middle-aged drivers and one targeting only older drivers. In 14.6 % of studies, the participants' age distribution was not specified. Even in studies with two or more age groups, a skewed distribution towards middle-aged and young drivers was noticeable.

Several studies have shown that mobile phone engagement while driving is more frequently observed among younger drivers (e.g., Bingham et al., 2015; Brusque & Alauzet, 2008; Cooper et al., 2013; Huisingh et al., 2015; NHTSA 2011; Pöysti et al., 2005; Prat et al., 2015; Sullman, 2012). Indeed, the younger the driver, the more they tend to perceive distracting activities as less risky and display overconfidence in their ability to perform multiple tasks simultaneously (Lerner et al., 2008; McEvoy et al., 2006). Risky activities such as talking on handheld mode and texting/dialling have been consistently reported as being more prevalent in drivers from young and middle-aged groups (Funkhouser & Sayer 2012; Huisingh et al., 2015; Kidd et al., 2016; Prat et al., 2015; Sullman 2012; Young & Lenne, 2010). Conversely, older drivers are more reluctant to engage in mobile phone distractions while driving (Langford & Koppel 2006; Lerner & Boyd 2005; Shinar et al., 2005). An interesting outcome in relation to age groups and context/environmental features seems to support the above findings. Tractinsky et al. (2013) found that young drivers answer and initiate calls regardless of driving demands, while experienced and older drivers tend to be more sensitive to road conditions and call context (incoming vs outgoing).

## 3.3. *Which mobile phone tasks were studied?*

Mobile phone functionalities have changed over the years. From the basic calling and texting functionalities offered in the early years of commercialisation, mobile phones have evolved to include internet browsing, photography, games, and social media interactions. Depending on the task at hand, the user may choose between performing the task by holding the phone in their hands (handheld mode) or with the aid of additional features (e.g., headset, dashboard/cradle, Bluetooth) to accommodate for hands-free use. When using a mobile phone while driving, both the driving task and the secondary task compete for the drivers' available cognitive and manual resources. Mobile phone tasks with a higher resource demand, particularly handheld mode activities involving parallel competition for cognitive, visual, and manual resources, have been consistently associated with an increased risk ()(Oviedo-Trespalacios, 2018). From the reviewed studies, 41.4 % included both hands-free and handheld functionalities in their assessment, and 41.4 % had only handheld functionalities. Adaptations mimicking phone use in dashboards or the steering wheel were used to study hands-free functionalities such as answering a call (9.8 %). Some studies (7.3 %) were classified as unspecified when phone functionalities were not clearly stated.

When studies compared the prevalence between different mobile phone functionalities, recent findings showed that drivers report more hands-free than handheld mobile phone interactions (Oviedo Trespalacios et al., 2019b). Indeed, Sullman et al. (2015) reported a decreasing trend in handheld mobile phone use over two years. However, earlier research by Young et al. (2010) reported higher use of the handheld mode among drivers in Australia. The change towards more frequent hands-free mobile phone use in recent studies could result from drivers trying to comply with stricter legislation and avoid hefty penalties or fines.

A relevant drawback when comparing the results of studies analysing the effect of contextual/environmental factors on mobile phone use is the discrepancy between the definition and grouping of mobile phone tasks. From the review of the literature, six different categories were identified comprising the most common granularities in which mobile phone activities are analysed in the reviewed studies (see Table 1). These categories provide a common ground for comparing findings and identifying influence patterns between contextual/environmental factors and mobile phone tasks. However, as evident by the definitions provided, these categories can overlap and are defined quite broadly to account for the variability in the groupings of each study.

### 3.4. *Which contextual features were analysed in relation to mobile phone engagement?*

The analysis of contextual features is separated into two sections. This first section comprises studies in which the effect of each feature on mobile phone engagement was independently assessed. This means that each feature studied is singled out to analyse its effect.

Features listed in this section comprise all features external to the vehicle that might influence the driver, as well as features describing the vehicle's movement with respect to the surrounding context.

The contextual features were categorised into four sub-categories to structure the presentation of the results according to the following definitions (Fig. 2):

- Geodemographics and Zoning Features: This subcategory encompasses features related to the demographics and area delineation where driving occurs.
- Temporal and weather-related features: This subcategory includes temporal and weather-related features.
- Road configuration: This subcategory involves the physical layout and features of the road network.
- Dynamic traffic conditions: This subcategory focuses on the features associated with the evolving state of traffic, influencing how drivers navigate the road network and interact with other vehicles.

#### 3.4.1. *Temporal and weather-related features*

*3.4.1.1. Time of Day.* Time of day was the most frequently investigated contextual/environmental variable in the distracted driving literature. With respect to general mobile engagement, studies were scarce, and results were mixed (Table 2). No trends are identifiable among the studies that provided evidence of a significant effect of time of day on mobile phone use. While Sullman et al. (2015) reported 50 % more engagement during afternoon periods compared to the morning period, Toole et al. (2013) reported more engagement between 2–3:59 AM compared to evening and morning periods. However, both studies are not comparable, as the latter focused on commercial motor vehicle drivers. It is possible that higher engagement rates during early morning hours could be a response from commercial motor vehicle drivers to deal with drowsiness caused by monotonous conditions of long drives during natural sleeping hours.

Regarding phone conversations, handheld talking drew the most attention compared to other phone function granularities (Table 3). Studies focusing on handheld/hands-free talking or solely on hands-free talking reported a trend of higher engagement

**Table 1**
Mobile phone task granularity identified within the N=41 articles reviewed.

| Mobile phone use | Definition |
|---|---|
| General Use | All tasks grouped together or not specified. (22 %) |
| Talking Handheld/Hands-free | Conversations using both handheld and hands-free modes. (19.5 %) |
| Talking Handheld | Handheld calls (i.e., phone held to the ear or with the phone held in the hand using the speaker). (34.1 %) |
| Talking Hands-free | Conversations held with any hands-free device such as a dashboard/console adaptation, an integrated car-kit, a Bluetooth ear set or headphones. (26.8 %) |
| Handheld Use | General handheld use combining calls and other visual/manual tasks. (22 %) |
| Visual/Manual Tasks (V/M tasks) | Visual and/or manual tasks apart from calls. (61 %) |

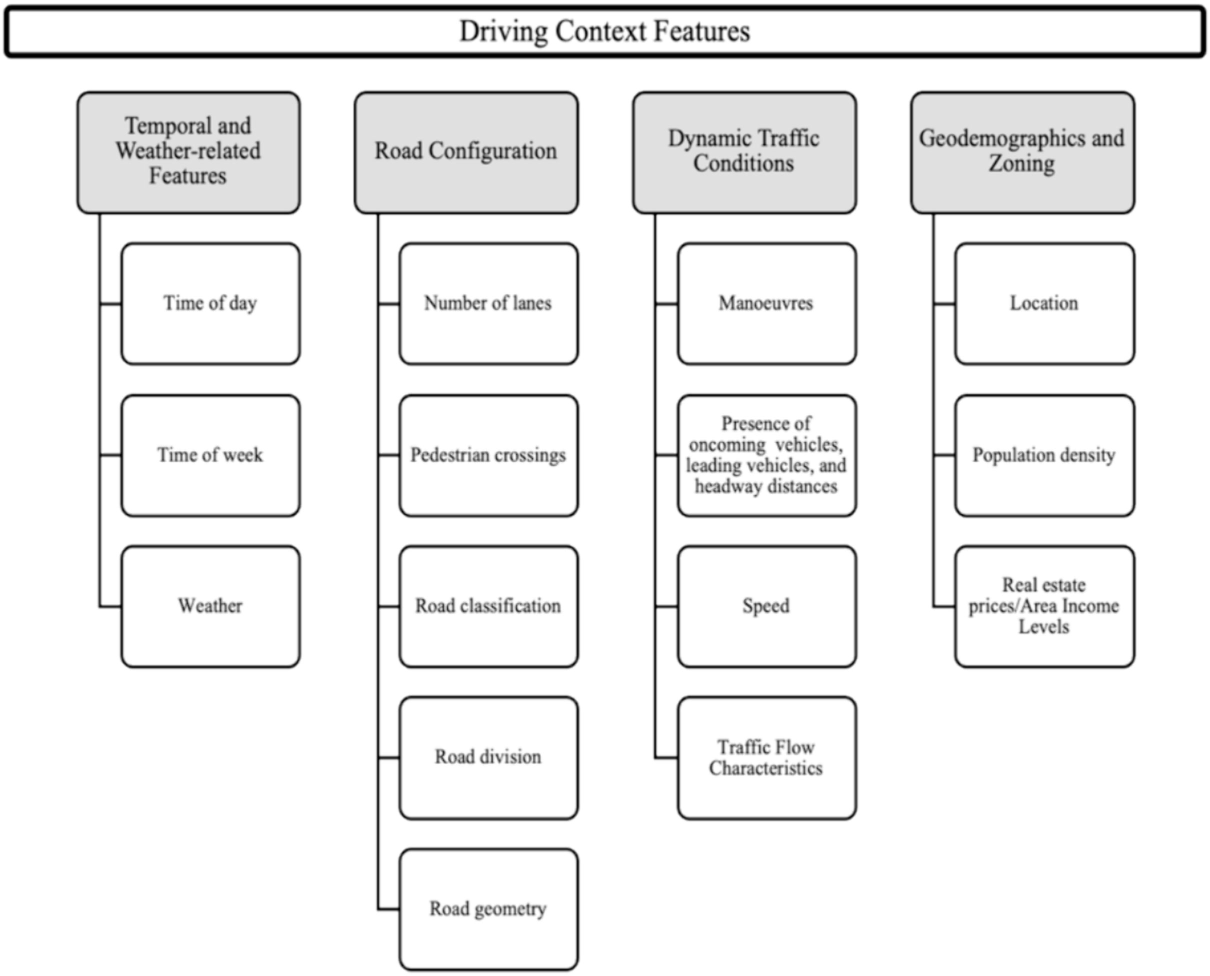

**Fig. 2.** Driving context features categories.

**Table 2**
Summary of the articles analysing time of day in relation to engagement in general mobile phone use.

| Author (Year) | Country | Time bins/periods | Phone Task | Results Summary |
|---|---|---|---|---|
| Sullman et al. (2015) | UK | 8–9 AM, 10–11 AM, 2–3 PM, 4:30–5:30 PM (including weekends) | General Phone Use | An increased occurrence of phone use of more than 50 % in the afternoon periods compared to the 8-9AM period. |
| Toole et al. (2013) | US | Low circadian rhythm (2–3:59 AM) high circadian rhythm (9–10:59 AM), low circadian rhythm (1:00 PM – 2:59 PM), high circadian rhythm (7–8:59 PM) | General Phone Use | The low circadian morning bin (2–3:59 AM) had a significantly higher percentage of engagement than all other bins. Moreover, engagement during the high evening bin (7–8:59 PM) was significantly higher when compared to the high morning bin (9–10:59 AM). |
| Vera-López et al. (2013) | Mexico | 8:35 AM-12–59 PM, 13:00 PM-15:59 PM, 16:00 PM – 18:50 PM (including weekends) | General Phone Use | Time of day had no association with mobile phone use. |

during afternoon periods when compared to morning periods. This might be a response to a higher communication demand after working hours to organise activities for the remainder of the day. A similar trend is discernible towards a higher rate of engagement during evening/afternoon periods when compared with morning periods for handheld talking. However, results were more mixed, with some studies reporting opposing results suggesting that time of day does not play a significant role in engagement in handheld talking (e.g., Prat et al., 2015; Wundersitz, 2014).

An interesting issue relates to engagement by time of day on weekends. Traffic dynamics on weekends generally differ when compared to weekdays. For instance, Vollrath et al. (2016) reported that the time of day was significantly different on weekends for the city of Berlin, which was the only city in their study to include observations on weekends. In contrast, other studies report no

**Table 3**
Summary of the articles analysing time of day in relation to mobile phone conversations while driving.

| Author (Year) | Country | Time bins/periods | Phone Task | Results Summary |
|---|---|---|---|---|
| Xiong et al. (2014) | US | Naturalistic Data (24 h) | Handheld/ hands-free talking | Regarding call starting time, 1.3 % of the calls started between midnight and 7:00 AM and 34.3 % of the calls started in the period between 4:00 and 7:00 PM |
| Funkhouser & Sayer (2012) | US | Daylight (i.e., the period when the solar altitude angle is equal to or greater than − 6 degrees), night-time | Handheld/ hands-free talking | No significant differences in time of engagement were found across lighting conditions. |
| Funkhouser & Sayer (2012) | US | One-hour observation periods | Handheld/ hands-free talking | The handheld/hands-free talking distribution of the frequency of engagement peaked between 4 and 5 PM., with almost no calls between 11 PM. and 6 AM. |
| Vollrath et al. (2016) | Germany | Morning period (8–9 AM), afternoon period (1–2 PM, 5–6 PM). Weekend observations only for Berlin. | Hands-free talking | Significant differences were reported for the city of Berlin with higher engagement during the afternoon periods in comparison with the morning period. No significant differences were found across time bins for the remaining cities (Hannover and Braunschweig). |
| Sullman et al. (2015) | UK | 8–9 AM, 10–11 AM, 2–3 PM, 4:30–5:30 PM (including weekends) | Hands-free talking | The odds of having a hands-free conversation were more than 70 % higher for the afternoon period between 4:30–5:30 PM compared to the 8–9 AM period used as a reference. |
| Fakhrmoosavi et al. (2020) | US | Observations ranging from 7AM to 7PM. Morning peak, evening peak, normal traffic conditions. | Handheld talking | When compared with off-peak periods, engagement was more common during the evening peak period and the frequency decreased during the morning peak. |
| Precht et al. (2017) | US | Dawn, daylight, dusk, darkness (SHRP2 data) | Handheld talking | Handheld talking was performed on average 2.87 times more during dusk when compared to daytime (dawn and daylight). |
| Vollrath et al. (2016) | Germany | Morning period (8–9 AM), afternoon period (1–2 PM, 5–6 PM). Weekend observations only for Berlin. | Handheld talking | Only in Berlin, time of day contributed significantly to handheld talking with higher engagement during the afternoon period. |
| Kidd et al. (2016) | US | Morning (6:30–10 AM), afternoon (11 AM–1 PM), evening (4:30–7 PM), night (9 PM–1 AM). Weekends not included. | Handheld talking | Drivers were more likely to be talking in handheld mode in the 9 PM-1AM period when compared with the 6:30–10 AM period. |
| Sullman et al. (2015) | UK | 8–9 AM, 10–11 AM, 2–3 PM, 4:30–5:30 PM (including weekends) | Handheld talking | The odds of engaging in handheld talking were significantly higher in the 2-3PM period when compared to the 8–9 AM period. |
| Wenners et al. (2013) | US | AM peak (7 AM-10 AM), midday (10 AM – 3 PM), PM peak (3 PM – 7 PM). Weekends were defined as any time on a Saturday or Sunday | Handheld talking | Significantly higher engagement rate during the PM peak when compared to the midday period and the AM peak. |
| Sabzevari et al. (2016) | Iran | Between Friday (Iranian weekend) and Monday (working day) from 9 to10:30 AM and 4–5:30 PM | Handheld talking | No significant differences in engagement were found across time bins. |
| Prat et al. (2015) | Spain | Nine one-hour observation periods, from 8 AM to 5 PM (included weekends) | Handheld talking | No significant differences in engagement were found across time bins. |
| Wundersitz (2014) | Australia | 7:00 AM-10:00 AM, 3:00 PM- 6:00 PM, Weekends 10:00 AM- 2:00 PM | Handheld talking | No significant differences in engagement were found across time bins. |

association of time of day with handheld talking, including on weekends. It is important to note that the results reported by Vollrath et al. (2016) could also be explained because observations in Berlin were conducted at a later date than the other two German cities. In any case, these results suggest that day of the week could be a confounding factor in the analysis of the effects of time of day on engagement in phone conversations.

Research also yielded mixed results for handheld use and V/M tasks (Table 4). It was not possible to establish any clear patterns of engagement from the studies that reported an association between time of day and engagement in handheld use or V/M tasks.

### *3.4.2. Time of the Week (Weekdays vs. Weekends)*

The relationship between time of the week and mobile phone engagement while driving was considered for a variety of function granularities, including general use, handheld use, handheld talking, hands-free talking and V/M tasks. Regarding general mobile phone use, an observational study conducted by Vera-López et al. (2013) in Mexico found that driving a car during weekdays was associated with a higher rate of mobile phone use. In contrast, an observational study conducted by Sullman et al. (2015) in the UK found no differences in patterns of engagement by time of week based on logistic regression modelling.

The study of engagement in hands-free talking, handheld use, handheld talking and V/M tasks by time of the week yielded mixed results. Observations in the UK and Germany, conducted by Sullman et al. (2015) and Vollrath et al. (2016) respectively, indicated time of the week is not associated with hands-free conversations. Opposing results were reported by Cooper et al. (2013) for observational locations in the US, indicating significantly higher engagement rates in hands-free talking on weekdays during peak hours compared to the weekend.

With respect to handheld talking, Wenners et al. (2013) and Fakhrmoosavi et al. (2020) indicated a higher engagement in handheld talking on weekdays compared to weekends. Prat et al. (2015) reported handheld talking being four times higher on weekdays than on

**Table 4**
Summary of the articles analysing time of day in relation to engagement in mobile handheld use and V/M tasks while driving.

| Author (Year) | Country | Time bins/periods | Phone Task | Results Summary |
|---|---|---|---|---|
| Arvin et al., (2017) | Iran | Observations ranging from 7 AM to 8 PM. Peak and off-peak periods. Weekend included. | Handheld use, V/M tasks (viewing, texting) | Significantly higher handheld use during peak hours when compared to off-peak hours. Statistical significance was not assessed for V/M tasks separately. |
| Sullman et al. (2015) | UK | 8–9 AM, 10–11 AM, 2–3 PM, 4:30–5:30 PM (including weekends) | Handheld use | Drivers were over two times more likely to engage in handheld use between 2 PM and 3 PM when compared to the morning period between 8 AM and 9 AM |
| Wenners et al. (2013) | US | AM peak (7 AM-10 AM), midday (10 AM – 3 PM), PM peak (3 PM – 7 PM). Weekends were defined as any time on a Saturday or Sunday | Handheld use | Significantly higher engagement during PM peak when compared to midday and the morning peak. The engagement rate at midday was also significantly higher than the engagement rate during the morning peak |
| Asgharabad et al. (2013) | Iran | After morning rush hour (8:30 AM – 9:30 AM), after mid-day rest (3:30 PM –4:30 PM). Weekdays only | Handheld use | Significantly higher engagement during the morning period when compared to the afternoon period. |
| Cooper et al. (2012) | US | Observations ranging from 7 AM to 6:30 PM. Rush hour (defined as weekdays 7–9 AM, 4–6 PM), weekends, all others. | Handheld use | Significantly higher engagement in handheld functionalities during weekdays non-rush hours (9 AM – 4 PM and 6 PM –6:30 PM) when compared with rush hours and weekends. |
| Cheema et al. (2014) | Qatar | One-hour observation periods between 7:00 AM and 5:00 PM (excluding 12:00 PM to 3:00 PM) | Handheld use | No significant differences in engagement were found across time bins. |
| Cooper et al. (2013) | US | Observations ranging from 7:00 AM to 6:30 PM. Morning peak (weekdays 7:00 to 9:30 AM), evening peak (weekdays 3:30 to 5:00 PM), weekend, all others | Handheld use | No significant differences in engagement were found across time bins. |
| Sullman (2012) | UK | 10–11 AM, 2–3 PM, 5–6 PM time bins. Only weekdays. | Handheld use | No significant differences in engagement were found across time bins. |
| Fakhrmoosavi et al. (2020) | US | Observations ranging from 7AM to 7PM. Morning peak, evening peak, normal traffic conditions. | V/M tasks (manipulating) | V/M tasks were more frequent during the off-peak periods and the difference was significant when compared to the evening peak period. |
| Kidd et al. (2016) | US | Morning (6:30–10 AM), afternoon (11 AM–1 PM), evening (4:30–7 PM), night (9 PM–1 AM). Weekends not included. | V/M tasks(holding) | The odds of just holding the phone registered significant differences between the night period and the morning and evening periods. |
| Xiong et al. (2014) | US | Naturalistic Data (24 h) | V/M tasks (all activities except conversations) | Overall, 33.8 % of V/M tasks started between 4:00 and 8:00 PM.; only 4.3 % started between 1:00 and 8:00 AM |
| Wenners et al. (2013) | US | AM peak (7 AM-10 AM), midday (10 AM – 3 PM), PM peak (3 PM – 7 PM). Weekends were defined as any time on a Saturday or Sunday | V/M tasks (texting) | Significant higher engagement rates during midday when compared to the morning peak and afternoon peak. |
| Funkhouser & Sayer (2012) | US | One-hour observation periods | V/M tasks (all activities except conversations) | The distribution of V/M tasks peaked between 4 and 5 PM., with almost no interactions between 11 PM and 6 AM. In the period of 1 week, 10 % of the tasks started between 4 and 5 PM, and close to 50 % started between 3 and 9 PM |
| Precht et al. (2017) | US | Dawn, daylight, dusk, darkness (SHRP2 dataset) | V/M tasks (texting, browsing, dialling) | No significant differences in engagement were found across lighting conditions. |
| Kidd et al. (2016) | US | Morning (6:30–10 AM), afternoon (11 AM–1 PM), evening (4:30–7 PM), night (9 PM–1 AM). Weekends not included. | V/M tasks (keying) | No significant differences in engagement were found across time bins. |
| Vollrath et al. (2016) | Germany | Morning period (8–9 AM), afternoon period (1–2 PM, 5–6 PM). Weekend observations only for Berlin. | V/M tasks (keying) | No significant differences in engagement were found across time bins. |
| Sabzevari et al. (2016) | Iran | Between Friday (Iranian weekend) and Monday (working day) from 9 to10:30 AM and 4–5:30 PM | V/M tasks (manipulating) | No significant differences in engagement were found across time bins. |
| Sullman et al. (2015) | UK | 8–9 AM, 10–11 AM, 2–3 PM, 4:30–5:30 PM (including weekends) | V/M tasks (texting, keying) | No significant differences in engagement were found across time bins. |
| Tivesten & Dozza (2015) | Sweden | Daylight, dusk, dark (EuroFOT dataset) | V/M tasks (dialling, reading, texting, texting/reading) | No significant differences in engagement were found across lighting conditions. |
| Prat et al. (2015) | Spain | Nine one-hour observation periods, from 8 AM to 5 PM.(included weekends) | V/M tasks (texting/ keying) | No significant differences in engagement were found across time bins. |
| Funkhouser & Sayer (2012) | US | Daylight (i.e., the period when the solar altitude angle is equal to or greater than – 6 degrees), night-time | V/M tasks (all activities except conversations) | No significant differences in time of engagement were found across lighting conditions. |

weekends. Conflicting outcomes were reported by Sabzevari et al. (2016), who found significant differences in only one out of three Iranian cities where the study took place. Lastly, Vollrath et al. (2016), Sullman et al. (2015) and Wundersitz (2014) reported that there were no significant effects of time of week on engagement in handheld talking.

For handheld phone use, Wenners et al. (2013) reported increased engagement on weekdays compared to weekends in an observational study in Massachusetts (US). Similarly, another US-based study in California (Cooper et al., 2012) indicated a significantly lower engagement during the weekend and a higher engagement during weekdays in non-rush hours. A year later, the study was replicated, with Cooper et al. (2013) under similar conditions again reporting an overall lower incidence of handheld phone use during weekends, but this time the difference was not significantly different. Marginal differences were also found by Sullman et al. (2015) in the UK using a logistic regression analysis for weekday and weekend engagement rates in handheld use.

Concerning V/M tasks, a single study (Wenners et al., 2013) reported a significantly higher engagement for V/M tasks (keying/texting) during weekdays compared to weekends. Mixed results were reported in a study taking place in Iran (Sabzevari et al., 2016), where only one of three cities was observed to have a significantly higher prevalence of V/M tasks (manipulating) during weekdays. The remaining studies, all conducted in different countries, reported no significant differences in use, including Fakhrmoosavi et al. (2020), Sullman et al. (2015), Vollrath et al. (2016) and Prat et al. (2015).

Overall, mixed results were obtained for every phone task studied. In the cases where a significant difference was found, results indicated a higher prevalence of engagement during weekdays compared to weekends. It can thus be suggested that the higher rate of engagement is associated with phone use for work-related purposes. It is probable that studies showing a significant difference selected more areas characterised by a concentration of commercial and business location. No strong conclusions can be drawn concerning this feature.

*3.4.2.1. Weather.* Weather conditions and visibility were considered across different studies. An observational study conducted in three other Mexican cities by Vera-López et al. (2013) found no significant association between weather and general mobile phone engagement using logistic regression. In contrast, based on naturalistic data from the U.S., Sharda et al. (2019) concluded that lower visibility levels (i.e., snow or rain) were associated with a lower likelihood of mobile phone use while driving by applying structural equation modelling.

The effect of the weather was also evaluated in relation to different phone functionalities. For instance, Precht et al. (2017) found that drivers texted, browsed, or dialled more frequently when there were no adverse weather conditions compared to rainy weather conditions. Similarly, a study by Tivesten & Dozza (2015) indicated that most visual/manual tasks (dialling, texting, and reading) generally occurred under clear weather conditions. Overall, it appears that drivers tend to decrease their use of mobile phone devices and be more attentive to the road while driving under poor weather conditions and performing more demanding visual/manual tasks. As visual/manual tasks are generally considered to be more demanding and of a higher risk, this behaviour may signal a risk-compensatory strategy used by drivers.

A fundamental problem with the literature analysing the effect of weather conditions on mobile phone engagement is the use of naturalistic and observational designs where there is no control of the conditions where data is collected. For example, in the observational studies, the data collected from weather conditions different from clear/dry was less than 10 % of the total number of observations. Likewise, Precht et al. (2017) could not investigate handheld talking under rainy conditions because of the lack of data.

### 3.4.3. Road configuration

*3.4.3.1. Number of lanes.* The impact of the number of lanes on mobile phone engagement while driving was studied in two observational studies. In a study conducted in Mexico, Vera-López et al. (2013) performed a logistic regression analysis to determine if general mobile phone use was significantly different for drivers circulating on 1–2 lane roads compared with 3–5 lane roads. Results indicated that drivers travelling on 3–5 lane roads were indeed more likely to engage in mobile phone use than drivers on 1–2 lane roads. The research conducted by Vollrath et al. (2016) in Germany extended the analysis to several phone functionalities, including hands-free conversations, handheld conversations, and V/M tasks (keying). Results from logistic regression analysis reported no significant effect of the number of lanes on hands-free conversations in any of the three German cities. For handheld conversations, the number of lanes significantly impacted engagement in the cities of Hannover and Berlin. In the case of Berlin, drivers were more active on single-lane roads compared to two-lane roads, while Hannover showed an opposing trend. The number of lanes had a significant effect on V/M tasks only in the city of Hannover, with drivers more frequently active on two-lane roads compared to single-lane roads.

The limited research and inconclusive results warrant the need for further work in relation to this aspect.

*3.4.3.2. Pedestrian Crossings.* A single study by Oviedo-Trespalacios et al. (2019c) considered pedestrian crossings as potential contributors to handheld mobile phone use (make a call, send a text, take a selfie, share a contact). Findings from a high-fidelity simulator experiment indicated that the odds of handheld use were 88 % lower at a pedestrian crossing (no pedestrian traffic) when compared to a reference category consisting of scenarios of similar engagement rates, including signalised intersections during a red light with no vehicle queue, pedestrian crossing with pedestrian traffic, a straight segment with no traffic, etcetera. It is possible that the absence of pedestrians reduces stopping times which, in turn, shortens the window of opportunity in which drivers could engage in a mobile phone task.

*3.4.3.3. Road Classification.* Road networks are composed of various types of roads with different characteristics. Road classifications assist in differentiating groups of roads according to certain homogenous characteristics such as location, speed limit, traffic service, function, traffic volume, location etc. For instance, the Federal Highway Administration in the US categorises roads by functionality into four main categories: interstates, other arterials, collectors, and local roads. While reviewing the included papers, it was evident that many studies considered road classifications as a potential variable influencing mobile phone engagement while driving (Table 5). It is important to keep in mind that road classifications are idiosyncratic to a jurisdiction and often cannot be comparable across studies. In some cases, authors included in their studies, categories such as roundabouts (road geometry) or suburban (location), which are, for analysis purposes, discussed in other sections. In those instances, the studies were included in this section as most categories do not overlap with other sections. Table 5 presents a summary of the studies, including the road classification framework, the granularity of the phone tasks and a brief synopsis of the findings.

Most evidence seemed to suggest that road classification does not have an impact on mobile phone use while driving. The few instances where significant differences were found correspond to activities where the phone is used in handheld mode. In these cases, engagement was prevalent in arterial/collector roads or similar (primary roads, main streets, ring roads) compared to local streets. This result should be regarded as only indicative unless it can be replicated using a standardised road classification across jurisdictions.

*3.4.3.4. Road Division.* A single study examined the relationship between road divisions and mobile phone use while driving. Sharda et al. (2019) found that drivers are more prone to using a mobile phone when travelling on divided highways. The lack of need to take account of oncoming vehicles and fewer distractions associated with having a visual barrier may explain the higher likelihood of engagement on divided highways.

*3.4.3.5. Road Geometry.* During the driving task, drivers can encounter a wide range of road geometry configurations. Road curves allow vehicles to transit gradually between two tangent road segments. The influence of this road geometry configuration on engagement in V/M tasks was evaluated by Tivesten & Dozza (2015). Results indicated that there is a significant effect of drivers waiting to engage in a V/M task until after passing a sharp curve (radius less than 500 m). However, when the radius of the curve is larger (radius between 500–1000 m), the driver's engagement in V/M tasks is not affected. It is reasonable to conclude that the driving demands associated with driving on sharp curves (steering, estimating curvature and speed, adjusting to the presence of oncoming

**Table 5**
Summary of the articles analysing road classifications in relation to mobile phone engagement while driving.

| Author (Year) | Country | Road Classification | Phone Task | Results Summary |
|---|---|---|---|---|
| Alghnam et al. (2018) | Saudi Arabia | Inner roads, highways | General phone use | Mobile phone use was slightly lower on inner roads compared to highways surrounding the city (statistical significance of this difference was not assessed). |
| Huisingh et al. (2015) | US | Local streets, arterial/collector roads | Handheld/hands-free talking, V/M tasks (texting, dialling) | Handheld/hands-free talking: Engagement on arterial/collector streets was more common but not significantly different than engagement in local streets. V/M tasks: V/M tasks were significantly more common in arterial/collector streets when compared to local streets. |
| Funkhouser & Sayer (2012) | US | Surface streets (not a freeway), highways | Handheld/hands-free talking, V/M tasks (all activities expect calls) | Handheld/hands-free talking: Engagement in conversations in surface streets was marginally more likely than on highways. V/M tasks: V/M tasks were not significantly different when comparing surface streets and highways. |
| Parnell et al. (2018) | UK | "A" road (single or dual carriageways), motorways (high speed roads with more than three lanes), roundabouts | Handheld/hands-free talking, V/M tasks (read text) | Handheld/hands-free talking: Willingness to engage was similar on A roads and motorways while willingness to engage was lowest on roundabouts. V/M tasks: There was a trend showing higher willingness to engage on motorways and A roads when compared to roundabouts. |
| Asgharabad et al. (2013) | Iran | Central streets, suburban streets, ring roads | Handheld use | The rate of engagement was significantly higher on ring roads in comparison to all other classifications and was significantly higher in central city streets when compared to suburban streets. |
| Cooper et al. (2012) | US | Surface streets, highways exit ramps | Handheld use | Slightly higher rates in surface streets when compared to highways (exit ramps). |
| Sabzevari et al. (2016) | Iran | Main roads (wider than 6 m), side streets (below 6 m wide). | Handheld talking, V/M (manipulating) | Handheld talking: Differences in engagement were only significant in one out of three cities with a higher prevalence of use in main streets. V/M tasks: Differences in engagement were marginal between road classifications. |
| Wenners et al. (2013) | US | Primary roads (interstate), secondary roads (arterial), local roads (collectors and all other roadways) | Handheld talking, handheld use, V/M tasks (texting) | Handheld talking, handheld use: Significantly higher engagement on primary roads when compared with local roadways. Differences were not significant between the rest of road types. V/M tasks: There were no significant differences between road classifications. |

vehicles, coping with limited sight range) could dissuade drivers from engaging in mobile phone use. Additionally, merging ramps were also considered in relation to handheld use engagement and V/M tasks. Oviedo-Trespalacios et al. (2019c) calculated that the odds of handheld use were 71 % lower along a merging ramp when compared to a reference category consisting of scenarios of similar engagement rates such as signalised intersections during a red light, pedestrian crossing with pedestrians, straight segment with no traffic, etc. In addition, Precht et al. (2017), considering interchanges as an intersection type, found that V/M task occurrences decreased when drivers passed through an interchange compared to drivers on segments not influenced by intersections.

Roundabouts have also been considered in relation to mobile phone engagement while driving. Regarding general handheld use, Oviedo-Trespalacios et al. (2019c) grouped in this category making a call, sending a text, taking a selfie and sharing a contact. Results indicated that the odds of handheld use were 96 % lower at a roundabout when compared to the reference category. For V/M tasks, Tivesten & Dozza (2015) indicated that there is a significant effect of drivers waiting to engage until after passing a roundabout. This is in agreement with findings from Kidd et al. (2016), who reported significantly fewer drivers holding and manipulating mobile phones in roundabouts when compared with straight roads. However, Kidd et al. (2016) indicated that the significance did not extend to engagement in handheld talking when compared with engagement in roundabouts and on straight road sections. This can be explained by the difficulty that drivers have in self-pacing engagement in mobile phone conversations while driving (Oviedo-Trespalacios et al., 2019c). Overall, there is evidence that road geometry configurations can influence a driver's decision to engage in mobile phone use. Findings suggest that driving on sharp curves and roundabouts results in less engagement in V/M tasks. Extending this analysis to other phone functionalities is necessary for a full assessment of the influence of road geometry configurations.

*3.4.3.6. Lead vehicle presence, headway distance, or time headway.* The relationship between the presence of a lead vehicle and V/M tasks has been assessed in relation to engagement and task timing. Tivesten and Dozza (2015) found that the presence of a leading vehicle does not influence the timing of V/M task initiation (dialling, reading, texting). However, the percentage of lead vehicles present in V/M task events seemed to be slightly lower before task initiation than in the 5 s after, which might suggest that drivers

**Table 6**
Summary of the articles analysing speed in relation to mobile phone engagement while driving.

| Author (Year) | Speed Definitions | Phone Task Granularity | Results |
|---|---|---|---|
| Funkhouser & Sayer (2012) | Park, 0 mph and speed bins from 0 mph to 100 mph (5 mph increments). | Handheld/hands-free talking | Drivers were more likely to start the task while stopped or at low speeds than when moving at speeds above 56 km/h (35 mph) |
| Vollrath et al. (2016) | Stationary, moving | Hands-free talking | No differences in engagement when the vehicle was moving versus stationary. |
| Metz et al. (2014) | Standstill, driving below 10 km/h, driving on highways below 110 km/h, driving on highways between 110 and 160 km/h, driving on highways above 160 km/h | Hands-free talking | Drivers spent significantly less time conversing hands-free while driving on highways above 160 km/h. No difference in the proportion of time spent for other scenarios. |
| Pouyakian et al. (2013) | 20, 50, and 80 km/h | Hands/-free talking | Speed had a significant effect on call answering rates. Results showed that as speed increased, answering rates decreased. |
| Fakhrmoosavi et al. (2020) | Speed limit (>50 mph) | Handheld talking | No significant difference in drivers choosing to engage when the speed limit was above 50 mph when compared to lower speeds. |
| Vollrath et al. (2016) | Stationary, moving | Handheld talking | More drivers engaging in handheld talking while moving than when being stationary in Berlin (Germany). Speed was not found to contribute to the frequency of the behaviour in two other cities. |
| Metz et al. (2014) | Standstill, driving below 10 km/h, driving on highways below 110 km/h, driving on highways between 110 and 160 km/h, driving on highways above 160 km/h | Handheld talking | The proportion of time spent talking did not vary across different speeds. |
| Fakhrmoosavi et al. (2020) | Speed limit (>50 mph) | V/M tasks (manipulating) | Drivers were less likely to engage in V/M tasks when speed limits were greater than 80 km/h. |
| Christoph et al. (2019) | Standstill, speed bins from 0 km/h to 120 km/h (10 km/h increments), >130 km/h | V/M tasks (keying, reading) | A higher occurrence than expected of V/M tasks initiated when stationary, while there was a lower occurrence than expected for all other speeds, with no occurrences above 130 km/h |
| Vollrath et al. (2016) | Stationary, moving | V/M tasks (manipulating) | No difference between being stationary and moving on engagement rates for V/M tasks. |
| Tivesten & Dozza (2015) | Reversing, standstill, speed bins from 0.1 km/h to 120 km/h (10 km/h increments), >130 km/h | V/M tasks (dialling, reading, texting, texting/reading) | V/M phone tasks were significantly more likely to be initiated while stationary and less likely at speeds above 120 km/h. |
| Metz et al. (2014) | Standstill, driving below 10 km/h, driving on highways below 110 km/h, driving on highways between 110 and 160 km/h, driving on highways above 160 km/h | V/M tasks (keying, reading, checking) | An increased proportion of time spent keying while stationary and a reduction while driving on highways above 160 km/h. |
| Funkhouser & Sayer (2012) | Park, 0 mph and speed bins from 0 mph to 100 mph (5 mph increments). | V/M tasks (all activities (with visual interaction) except conversations) | Drivers were much more likely to initiate V/M tasks when stopped |

strategically position themselves (e.g., changing lanes, overtaking) before engaging in phone-related tasks. Other features related to the presence of a lead vehicle include headway distance and time headway. Regarding headway distances, Pouyakian et al. (2013) showed that they influence the decision to answer a call. As headway distances reduced, fewer calls were answered. In fact, it was shown that answering calls at 25 and 35 m headway distances was almost 15 times higher than at closer headway distances (15 and 5 m). This was in line with the findings reported by Tivesten and Dozza (2015), who indicated that drivers tend to wait for the lead vehicle to move further ahead, increasing time headway, before initiating a V/M phone task in steady state driving. Overall, lead vehicle presence does not seem to have a significant effect on individuals' phone engagement. However, drivers may be more willing to engage with increased headway distances or wait for a longer time headway before initiating a task.

### 3.4.4. *Dynamic traffic conditions*

*3.4.4.1. Manoeuvres.* Driving manoeuvres describe how a vehicle interacts with the context and moves through traffic. Several studies have explored how particular vehicle actions may favour or disfavour mobile phone engagement while driving. For example, Christoph et al. (2019) reported that changing lanes was performed less often after starting a V/M task with a phone compared to before starting the V/M task. Similarly, Tivesten & Dozza (2015) indicated that line crossings (i.e., overtaking and/or lane changes) were significantly higher before initiating visual/manual tasks than after. Both studies suggest that drivers wait to complete line-crossing manoeuvres before engaging in V/M tasks. This compensating behaviour might be explained by the high demands associated with the execution of lane changes and overtaking manoeuvres (Portouli et al., 2012), which might deter drivers from dividing their attention.

The influence of manoeuvres performed by other vehicles on mobile phone engagements was also examined. Through a simulator study, Teh et al. (2018) studied lane changes performed by neighbouring vehicles. Lane changing conditions were varied by lane change proximity (5, 10, 15, 20, 25 or 30 m in front of the participant) and lane origin of the other vehicle (slow or fast lane). Analysis indicated that both lane change proximity and lane origin had a statistically significant effect on driver decisions to answer a phone, i.e., drivers took longer to answer the call when the lane change occurred at closer proximity. In relation to the lane from which the other vehicle originated, the study found that drivers perceived higher workloads and longer recovery times when the other vehicle came from the slow lane compared to the fast lane. Additionally, lower perceived demand scenarios, such as lane changes originating from fast lanes, were associated with shorter times to answer an incoming call from the initial sound (call acceptance time).

*3.4.4.2. Oncoming Vehicles.* A naturalistic study by Tivesten & Dozza (2015) reported that the presence of an oncoming vehicle did not show a significant effect on the overall propensity to engage in visual/manual tasks. Still, phone tasks were slightly more commonly initiated after an oncoming vehicle has passed, suggesting that drivers delay task initiation until oncoming vehicles have passed, and doing so is a self-regulating strategy.

*3.4.4.3. Speed.* The effect of travelling speed on phone use while driving has received considerable attention in the literature (Table 6). Funkhouser & Sayer (2012) observed that drivers were much more likely to initiate handheld/hands-free conversations while stopped or at low speeds than when moving at speeds above 56 km/h (35 mph). Hands-free and handheld talking were also assessed independently. For hands-free talking, Vollrath et al. (2016) found no differences in engagement when the vehicle was moving versus stationary. In addition, Metz et al. (2014) found no difference in the proportion of time a driver spends in hands-free conversation while at a standstill, driving below 10 km/h or driving on highways below 160 km/h. However, drivers did spend significantly less time conversing hands-free while driving on highways above 160 km/h. It is important to note that this study did not evaluate speed at the time of engagement, and results correspond instead to the proportion of time a driver spent on the secondary activity in each evaluated context. Additionally, Pouyakian et al. (2013) reported a significant effect of speed on phone call answering rates. Results showed that as speed increased, answering rates decreased. At 20 km/h, drivers were 1.5 times more likely to answer calls than at 80 km/h. In the case of handheld talking, mixed findings were reported in relation to the contribution of speed. Vollrath et al. (2016) reported more drivers engaging in handheld phoning while moving than when being stationary in Berlin (Germany). However, this result was not reproduced in the cities of Hannover and Braunschweig, where speed was not found to contribute to the frequency of the behaviour. Metz et al. (2014) found that the proportion of time spent talking did not vary across different speeds. Also, Fakhrmoosavi et al. (2020) reported that there was no significant difference in drivers choosing to engage in handheld talking when the speed limit was above 50 mph when compared to lower speeds.

Different V/M task groupings were also assessed in relation to speed. Vollrath et al., (2016) found no difference between being stationary and moving on engagement rates for V/M tasks (keying) in Germany. In contrast, other studies found patterns of association and significant effects between speed and engagement. Christoph et al. (2019) found a higher occurrence than expected of V/M tasks (keying, reading) initiated when stationary, while there was a lower occurrence than expected for all other speeds, with no occurrences above 130 km/h. Similarly, after visual inspection of the resulting distributions of engagement, Funkhouser & Sayer (2012) reported that drivers were much more likely to initiate V/M tasks (all tasks except conversations) when stopped. Tivesten & Dozza (2015) also reported that V/M phone tasks (dialling, reading, texting) were significantly more likely to be initiated while stationary and less likely at speeds above 120 km/h. This is in line with findings from Fakhrmoosavi et al. (2020), who indicated that drivers were less likely to engage in V/M tasks when speed limits were greater than 80 km/h. Other relevant findings included an enhanced proportion of time spent keying while stationary and a reduction while driving on highways above 160 km/h (Metz et al., 2014).

In general, there is evidence that speed influences mobile phone engagement. However, the effect could be highly dependent on the type of task. In the cases where speed contributed significantly, mobile phone use was more pronounced while stationary or at low speeds. It is reasonable to think that under low-demand conditions (being stopped or driving slowly), drivers are presented with an opportunity to make a planned interaction with the phone or just check any new notifications. This is consistent with previous research explaining that drivers negotiate both mobile phone task demands and driving task demands when making decisions about phone use engagement (Onate-Vega et al., 2020; Oviedo-Trespalacios et al., 2018b).

*3.4.4.4. Traffic Flow Characteristics.* Several studies analysed the impact of traffic flow characteristics on mobile phone use while driving. The measurements used to describe traffic flow conditions varied widely among the selected studies. A summary of the studies, including measurements, definitions and main findings, is provided in Table 7.

Overall, most of the evidence seemed to imply that traffic flow characteristics do not have a significant effect on mobile phone conversations. In contrast, some studies reported a significant effect on V/M tasks, favouring high and low volume/density traffic conditions over moderate volume/density traffic conditions. It is possible that idle time during stop-and-go conditions in high volume/density traffic conditions and low attentional resource demands for low volume/density traffic conditions encourage engagement in V/M activities. However, no definite conclusions can be drawn as there are also studies reporting a non-significant effect and wide variability in phone task grouping and traffic flow measurements' definitions.

### 3.4.5. Geodemographics and Zoning

*3.4.5.1. Location.* Location was usually assessed in relation to urban, rural and suburban areas; however, other classifications were also used (see Table 8). In the instances where the classifications included classes that overlap with other sections (e.g., Christoph et al., 2019; Tivesten & Dozza, 2015), studies were allocated into this section if the majority of categories corresponded to location.

Overall, most of these studies implied that location has no impact on mobile phone engagement frequency or duration. Some of the studies that reported trends did not validate the differences statistically. Patterns of engagement by phone task were not discernible among the studies that reported a significant effect of location on mobile phone engagement.

*3.4.5.2. Population Density.* An observation study by Fakhrmoosavi et al. (2020) included population density as a potential

**Table 7**
Summary of the articles analysing traffic flow characteristics in relation to mobile phone engagement while driving.

| Author (year) | Traffic Flow Characteristic | Definition | Mobile Phone Task | Results |
|---|---|---|---|---|
| Fakhrmoosavi et al. (2020) | Traffic Volume | Number of vehicles travelling per hour in the observed locations. | Handheld talking, V/M tasks (manipulating) | For both handheld talking and V/M tasks, frequency of use significantly increased with traffic volume. |
| Precht et al. (2017) | Traffic Flow Restriction | Smooth: Service Levels A1, A2, B. Moderate: Service Levels C, D. Heavy: Service Levels E, F | Handheld talking, V/M tasks (texting, browsing, dialling) | Handheld talking: Engagement did not differ between the service levels. V/M tasks: Occurrences were more common when driving in heavy traffic compared to smooth traffic and significantly decreased in moderate traffic compared to smooth traffic. |
| Vollrath et al. (2016) | Traffic Volume | Median split to create "low" and "high" traffic volumes based on counting the number of cars in a minute of observation at each location. | Handheld talking, Hands-free talking, V/M tasks (keying) | V/M tasks, handheld talking, and hands-free talking differences were not statistically significant between low and high traffic volumes. |
| Tivesten & Dozza (2015) | Traffic Flow Restriction | Low: Free flow traffic with no speed restrictions caused by surrounding vehicles. Medium: Presence of some speed restrictions. High: Clearly restricted speed but with fairly stable flow. Stop-and-go: Vehicles alternating between stopping and traveling slowly | V/M tasks (dialling, reading, texting) | Most V/M phone tasks occurred under low traffic density conditions. |
| Xiong et al. (2014) | Traffic Density | Sparse traffic: zero or one vehicle observable in forward radar. Moderate: two to four observable vehicles. Dense: more than four observable vehicles | Handheld/hands-free | Hands-free/handheld talking: Engagement was similar for all density levels. |
| Fitch et al. (2015) | Traffic Flow Restriction | Level of service A, level of service B, level of service C-F | General phone use, talking handheld, talking hands-free, V/M tasks (texting), V/M tasks (dialling) | Cell phone use for commercial vehicles was significantly higher in LOS B, when compared to LOS A and LOS C-F. For light vehicles, engagement in LOS B and LOS C-F was significantly greater than in LOS A. Regarding hands-free talking, commercial drivers' engagement was significantly higher in LOS A. Light vehicle drivers engaged significantly more in LOS C-F when compared to LOS A and LOS B. |

**Table 8**
Summary of the articles analysing location in relation to mobile phone engagement while driving.

| Author (Year) | Location | Phone Task Granularity | Results Summary |
|---|---|---|---|
| Rahman et al. (2021) | Urban, rural | Handheld/hands-free talking, V/M tasks (keying) | Mobile phone use was significantly different by location with more drivers engaged in V/M tasks than talking in urban areas, while drivers in rural areas exhibited the reversed behaviour. Further analysis with association rule mining indicated that V/M tasks were more prevalent in urban scenarios while talking was more prevalent in rural scenarios. |
| Wundersitz (2014) | Metropolitan (urban), rural | Handheld talking | No significant differences in engagement were found between rural and urban areas. |
| Arvin et al., (2017) | Urban, rural, suburban | Handheld use, handheld talking, V/M tasks (viewing, texting) | In general, drivers in urban regions used mobile phones in a more frequent manner than those in rural and suburban areas. Logistic regression showed differences were not significant between location and engagement in handheld use. Statistical significance was not assessed for the remaining functionalities. |
| Cooper et al. (2013) | Urban, rural, suburban | Hands-free talking, handheld use | Hands-free Talking: Significantly higher engagement in rural areas than in urban areas. Handheld use: There were no significant differences in engagement between different locations. |
| Cooper et al. (2012) | Urban, rural, suburban | Hands-free talking, handheld use | Handheld use: There were no significant differences in engagement between different locations. Hands-free talking: Drivers use Bluetooth technology in suburban areas more than drivers in other areas. |
| Christoph et al. (2019) | Urban, rural, highways | V/M Tasks (keying, reading) | V/M tasks: Drivers spent less time engaged in keying/reading tasks in rural roads than it was expected and more time than expected in highways. |
| Tivesten & Dozza (2015) | Urban, rural, highways | V/M tasks (Dialling, reading, texting, texting/reading) | V/M tasks were more common in rural roads, followed by motorway/highway roads and urban roads, in that order. However, the difference in engagement was not validated statistically. |
| Metz et al. (2014) | Urban, rural, highways | Handheld talking, hands-free talking, V/M tasks (keying) | There was no change in the proportion of time a driver spends in any of the targeted activities, for both urban and rural areas when compared to other driving scenarios such as highways. |
| Sharda et al. (2019) | SHRP2 dataset (locality) | General phone use | A higher incidence of mobile phone use in business/industrial and residential areas when compared to other categories such as urban, moderate-open residential, bypass, interstate and special zones (church, schools, playgrounds). |

contributor to mobile phone distraction while driving. Results indicated that handheld talking was significantly more likely in areas with a population of fewer than 500 persons per square mile compared to higher-density areas. In contrast, visual manual tasks such as texting were less likely in these areas. A potential explanation is that low-density areas (rural areas) could be associated with longer travel times which create the opportunity for extended phone interactions such as mobile phone conversations.

*3.4.5.3. Real Estate Prices/ Area Average Income Levels.* Real estate prices and area average income levels serve as measurements of the affluence level of a particular area. In some countries, the difference in road infrastructure between high and low-affluence areas can be substantial. An observational study conducted in Saudi Arabia used logistic regression to examine whether driving in an affluent area (real estate average price of $666 or above per m2) or not influences the frequency of general mobile phone use. Alghnam et al. (2018) reported that drivers in affluent areas were less likely to engage in mobile phone use than those travelling in less affluent areas. A second observational study conducted by Fakhrmoosavi et al. (2020) in the US divided mobile phone use by functionalities for analysis. In areas with a higher average income (over $100,000 a year), drivers were more likely to engage in V/M tasks (manipulating). The same trend was observed for handheld talking; however, the difference was not significant. Differences in mobile phone task granularity, income thresholds, and distracted driving legislation could explain the differences between these studies.

### *3.5. Which driving scenarios were analysed in relation to mobile phone engagement?*

This section comprises studies where contextual/environmental features were grouped together to establish scenarios. As a result, findings in these studies represent the effect of a combination of features in relation to engagement without singling out particular effects corresponding to the conforming features.

This section initially summarises the results associated with the study of multiple feature scenarios in relation to mobile phone engagement while driving. The remainder of the section comprises two subsections that discuss road demand scenarios and intersections, considered special case scenarios and therefore discussed separately.

#### *3.5.0.1. Multiple Feature Scenarios*

Scenarios consisting of varying traffic flow directions and speeds were analysed by Pouyakian et al. (2012) to determine the effect on answering calls. One-way and two-way roads moving at 20 km/h, 50 km/h and 80 km/h were considered. Logistic regression analysis showed that the effect of scenarios on answering calls was not statistically significant. A year later, Hancox et al. (2013) put together scenarios combining different traffic flow directions and the number of lanes to determine the effect on answering calls. Again, results indicated no significant effects of one-way 3-lane and 2-way single-lane scenarios on answering calls. A possible explanation for the lack of significant effects of scenarios on the answering call task is the resource demand associated with this secondary task. Answering calls has consistently been perceived as a low-demand activity by drivers. Therefore, it is reasonable to think that drivers are more prone to answer calls regardless of the scenario.

Other scenarios of interest were tested by Metz et al. (2014). The proportion of engagement time in mobile phone use on highways with varying speeds was compared against the time of engagement for drivers while stationary or while driving in urban and rural areas. For hands-free talking and V/M tasks, the proportion of engagement time while driving was significantly reduced for speeds above 160 km/h when compared to other engagement scenarios. Moreover, the proportion of time spent conducting V/M tasks was reported to be significantly higher while stationary when compared to other engagement scenarios. On the other hand, the proportion of time engaged in handheld talking is not reduced or enhanced significantly for any particular scenario.

While Oviedo-Trespalacios et al. (2018a) assessed scenarios with four or more features, these scenarios combined features such as road classification, location, number of lanes, traffic flow characteristics, pedestrian/cyclist presence, and traffic flow direction. Results showed that participants use their mobile devices (conversations and V/M tasks) more often in suburban/single-lane scenarios than in motorway/multiple-lane scenarios.

#### *3.5.0.2. Road Demand/Complexity*

An alternative approach to evaluate scenarios is assigning a complexity or demand level to each grouping of features and determining these levels' effect on mobile phone engagement. Different methods can be used to categorise scenarios into road demand/complexity levels.

Among the reviewed studies, four studies analysed the effect of road demand levels on mobile phone engagement while driving. Hancox et al. (2013) categorised scenarios into three levels of demand (low, medium, and high) based on Fastenmeier's classification (1995), which considers levels of demand for vehicle handling and information processing resources. According to this classification, if both vehicle handling and information processing resources are challenged, the scenario is deemed to be of high demand. If only one of them is challenged, the scenario is categorised as medium demand. If neither is challenged, the scenario is classified as low demand. Once scenarios were classified by participants, engagement was assessed based on participants' ratings of their willingness to initiate mobile phone tasks while watching the scenarios in video clips. Mobile phone tasks included making and answering calls and sending and reading texts. In general, the highest willingness to engage was present in lower-demand scenarios while the lowest willingness to engage was reported for high-demand scenarios. Sending a text was reported as the least likely function under all demand scenarios while answering a call was the most likely. This suggests that drivers perceive sending a text as a high-demand task while answering a call is perceived as a low-demand task. In high-demand scenarios, all activities were not very likely to be performed; however, answering a call and reading a text had a slightly better chance. Authors suggested this behaviour is in accordance with Fuller's model (2005), which proposes that drivers aim to maintain a specific difficulty level and are only willing to perform additional tasks when in possession of additional resources. Therefore, as demand increases, the type of task has little impact since no additional resources are available.

The Fastenmeier classification was also applied by Petzoldt and Schleinitz (2019) to categorise 43 scenarios into low, medium and high complexity. Results indicated that willingness to text decreased as complexity increased. For high complexity scenarios, the indicated willingness to text was 22.3 %, while in medium complexity, it reached 39 %, and in low complexity, it showed a rate of 61.8 %. However, it was noted that willingness to text could vary greatly within scenarios of the same level of complexity.

Tractinsky et al. (2013) analysed the initiation and reception of calls in scenarios with varying numbers of lanes, road geometry characteristics and traffic densities. The resulting three scenarios included a straight two-lane open road without traffic, a four-lane road with heavy traffic (two lanes in each direction), and a two-lane winding road. Scenarios were classified according to complexity into three levels, with the straight two-lane scenario as the easiest, followed by the heavy traffic scenario and the winding road, respectively. The difficulty levels of the three simulated scenarios were pretested in a pilot study without drivers performing any mobile phone tasks. The pilot study provided performance measures and rankings of perceived difficulty that were verified for significant differences using Scheffe post hoc tests and Wilcoxon signed-ranks tests. Results were presented by age group and showed that regardless of road demand, young and experienced drivers answer all calls. The answering rate for older drivers decreases as complexity increases. On the other hand, the number of calls initiated was reduced as age increased. Interestingly, younger drivers made fewer calls in the easy scenarios, while for experienced and elderly drivers, the call initiation rates did not necessarily decrease as complexity increased.

While Oviedo-Trespalacios et al. (2018a) analysed the influence of road demand on engagement in mobile phone use while driving by conducting a random parameter probit model, road demand was characterised by study participants ranging from very easy to very difficult. A total of six scenarios were considered, which varied mainly in location, road classification, traffic flow direction, traffic density, and cyclist/pedestrian presence. Results showed that the likelihood of reporting being likely or very likely to engage in mobile phone use decreases as the perceived drive difficulty increases.

Overall, there is evidence that rates of engagement in mobile phone use vary according to road demand levels. In general, as demand levels increase, engagement rates in mobile phone tasks decrease. However, the magnitude of the effect is mainly dependent on the demand levels of the mobile phone task and the number of spare resources available.

#### *3.5.0.3. Intersections*

Intersections are one of the most common driving scenarios and were discussed widely in relation to mobile phone engagement. As a result, this subsection will solely focus on analysing the impact of intersections on mobile phone use. In intersection scenarios, feature configurations comprised a varying number of traffic lanes, speeds, and signalling modes might converge. Intersections are perhaps the most common scenarios in which drivers are often required to be stopped momentarily. It would be expected that engagement in mobile phone activities would rise given the lower driving demands and the available extra time. For instance, in one of the studies reviewed, which was based on naturalistic data from 10 drivers aged over 65 years, all phone-related activities at intersections were executed while stopped and none while the vehicle was moving (Charlton et al., 2013). Other studies suggested a marked difference in engagement depending on the phone task.

In general, engagement rates in conversations did not seem to be influenced by intersections. Regarding handheld and hands-free conversation combined, several studies concluded that intersections are not places preferred by drivers to initiate engagement. Huisingh et al. (2015) concluded that the frequency of engagement in talking handheld/hands-free does not vary significantly when comparing vehicles stopped and those recorded in the $<$ 25 mph, 25–50 mph, and $>$ 50 mph speed bins. Moreover, Huth et al. (2015) indicated that conversations were more likely to be already underway before the driver reached the intersection than being initiated while the driver was stationary. Similarly, Morgenstern et al. (2020) reported that conversations were initiated and concluded mostly outside the red-light period and that drivers' engagement in conversations while waiting at a red light was significantly lower when compared to texting. When applying association rule mining, a machine learning algorithm to find patterns of use or co-occurrences in data, Rahman et al. (2021) reported no patterns that included intersections and higher prevalence in scenarios such as urban straight continuous segments during off-peak hours and rural segments during peak hours. This finding is in line with Fitch et al. (2015), who reported a significantly higher engagement in hands-free talking in non-junction segments when compared with intersections/merge ramps.

For handheld talking exclusively, Bernstein & Bernstein (2015) and Wenners & Knodler (2014) indicated that the rate of occurrence did not differ significantly between drivers stopped at red lights and drivers upstream from the intersection. This agreed with Precht et al. (2017), who concluded that handheld talking did not differ significantly when comparing drivers stopped at intersections with different control types and drivers uninfluenced by intersections. Similar results were obtained by Fitch et al. (2015), who did not find any significant differences in engagement between intersections/merge ramps and non-junction segments. In addition, Kidd et al. (2016) reported no difference in the likelihood of engagement in handheld talking when comparing being stopped or moving straight through an intersection with driving on a straight road section. The only instance in which a significant effect was reported corresponded to commercial vehicle drivers who preferred non-junction segments over intersections/merge ramps. This can be explained by the higher demands related to moving vehicles of larger proportions through intersections which might prevent the driver from engaging in any other tasks.

There was a noticeable prevalence of engagement in V/M tasks while stopped at intersections. For instance, Precht et al. (2017) found that V/M task occurrence significantly increased while stopped at intersections (traffic light/stop sign) compared to engagement when drivers were not influenced by an intersection. Similarly, Bernstein & Bernstein (2015) and Wenners & Knodler (2014) found that the rate of texting was significantly higher when drivers were stopped at intersections due to a red light compared to drivers upstream from the intersection or moving through the intersection. Based on a logistic regression analysis, Kidd et al. (2016) reported that the likelihood of manipulating the phone at intersections was significantly higher than on straight-road sections. This was in line with Huth et al. (2015), who indicated that V/M tasks had significantly higher chances of initiation at a red traffic light. When using association rule mining to determine scenarios associated with engagement in V/M tasks, Rahman et al. (2021) found no rules associated with segments, suggesting that engagement generally occurs while waiting at red lights. Common rules included intersections in an urban setting during peak hours. Only two studies found evidence to the contrary. Huisingh et al. (2015) reported no significant differences in the frequency of engagement at intersections across speeds for V/M tasks (texting/dialling). Fitch et al. (2015) found no significant difference in engagement for commercial and light vehicle drivers when comparing intersections/merge ramps with non-junction segments.

An interesting finding regarding tasks that only require manual resources (i.e., holding) was reported by Kidd et al. (2016). Results from a logistic regression analysis indicated that the likelihood of holding a phone was greater at straight road sections than at intersections. In addition, the likelihood of holding a phone while moving through an intersection and the likelihood of holding the phone while moving through a straight road section were significantly different. This might indicate that the prevalence of mobile phone use while stopped at intersections is closely related to a visual resource release during the waiting period. Therefore, manual-only tasks will follow similar patterns of engagements to less demanding activities such as conversations.

There is also evidence that suggests that driving through intersections where the traffic control type requires more attention from the driver to the environment may reduce available attention resources and, in turn, diminish mobile phone use. For instance, Wenners & Knodler (2014) indicated that for activities such as talking handheld and texting, the usage rate did not differ significantly between stop-sign-controlled intersections and a different scenario of low mobile phone usage (driving upstream from the intersection). For handheld use, both handheld talking and V/M tasks grouped together, Oviedo-Trespalacios et al. (2019c) indicated that the odds of engaging in mobile phone use at an intersection with stop-sign and cross traffic from the right and a stop-sign intersection with no traffic were respectively 78 % and 94 % lower when compared to a reference category (signalised intersection during a red light with no vehicle queue).

The lack of motion and extra time that seem to favour engagement in mobile phone use at intersections is not present when the driver passes through the intersection without stopping. For these scenarios, the corresponding findings evidenced that the execution of V/M tasks was not higher than in other scenarios. Wenners & Knodler (2014) reported that text messaging occurred at similar rates for drivers who did not stop at intersections and those upstream from the intersection. Tivesten & Dozza (2015) reported no effect of going straight at intersections on V/M task timing. Kidd et al. (2016) indicated no significant difference between the likelihood of engaging in V/M tasks while passing through an intersection and the likelihood of engaging while driving on straight road sections. Similarly, Christoph et al. (2019) indicated that going straight through an intersection did not occur more or less often when comparing the 15 s before engagement with the first five seconds after initiating the V/M task. A study by Precht et al. (2017) reported that V/M task occurrence significantly decreased while driving through an intersection when compared to drivers not influenced by intersections.

Turning left and right at intersections was also studied by several authors. For V/M tasks, Tivesten & Dozza (2015) reported a statistically significant effect of drivers waiting to initiate a V/M phone task until after turning at an intersection. Similar results were reported by Christoph et al. (2019), who stated that turning at an intersection was performed less often after starting the V/M task compared to 15 s before starting the V/M task. These findings agreed with Oviedo-Trespalacios et al. (2019c), who conducted a logistic regression to examine several handheld activities (making a call, sending a text, sharing a contact, taking a selfie) and found that the odds of using a mobile phone while driving during right and left turns at intersections were 92 % and 94 % lower (respectively) when compared to a reference category (signalised intersections during a red light, pedestrian crossing with pedestrian traffic, straight segment with no traffic).

### *3.6. What method was used to explore the relationship between environmental features and mobile phone engagement?*

The reviewed studies implemented a variety of methods to investigate the relationship between the driving context and individuals' mobile phone engagement. Overall, close to 95 % of studies incorporated a component of descriptive and/or inferential statistics for data analysis. In addition, some studies included statistical modelling methods to further explore the relationships between the variables of interest (36.6 %). These studies included methods such as logistic regressions, structural equation models, association rule mining and decision trees.

Statistical modelling methods are tools to develop and test theories for correlation, causal explanation or prediction purposes. A single method can often serve multiple purposes; for example, a linear regression model can be used to quantify the strength of the effect between independent variables and a response variable or to predict future observations of the response variable. When considering the reviewed papers, all selected research papers had a descriptive and/or explanatory modelling goal.

This distinction is vital since articles exploring association among variables often refer to variables with a significant effect as predictors. However, even when models with predictive capabilities were applied, the objective was not to predict future observations but to explore the nature of the relationship among the variables. Adequate terminology is critical for proper statistical modelling and scientific consensus (Shmueli, 2010).

It is also important to consider, when modelling relationship between variables, the potential theoretical confounders when assessing the effect of contextual factors on mobile phone use. Some of the most common confounders considered or adjusted for in modelling were demographic characteristics (e.g., age, gender, etc.) and driving characteristics (e.g., driving experience, type of vehicle, etc.). There is no clear consensus in the literature on the effect of these confounders on mobile phone use; therefore, inclusion is recommended to avoid distortion of true associations between variables. In addition, correlation measures and significance testing alone do not consider factors with a confounding effect. As a result, studies based solely on these methods of analysis require a more in-depth look at their study design to determine how adequately potential confounders were accounted for and the validity of the results, especially when assessing causal relationships.

To the authors' knowledge, there is a relative lack of research on using contextual/environmental features to predict mobile phone engagement while driving. As a result, a knowledge gap is identified. Implementing predictive statistical models or data mining algorithms for predicting mobile phone engagement while driving can provide added value for future research. Given that contextual/environmental features are closely related to tactical driving and in-situ conditions, accurate predictions may uncover when and where mobile phone engagement is more likely to occur.

## 4. Conclusion

The present manuscript presents a systematic review of the literature on the role of environmental/contextual features as determinants of drivers' mobile phone engagement while driving. A total of 41 manuscripts were included in the review following their selection via a rigorous selection methodology. During the review process, we identified that previous research on the topic was conducted using two different levels of detail: the effect of individual features on engagement or by evaluating the effect of scenarios (combining multiple contextual features) on engagement.

The systematic review confirmed the influence of the driving context on mobile phone engagement while driving. As noted in previous research, consideration of tactical self-regulation has been scarce in the literature (Oviedo-Trespalacios, 2017). This systematic review, therefore, contributes to expanding the body of literature by focusing on one of the elements that is more significant at a tactical decision level, the context in which the decision is made. Additionally, existing literature suggests an intention-behaviour gap, where intentions do not always translate into actions, particularly for risky or illegal behaviours that may conflict with an individual's well-being (Gibbons et al., 2004). This review presents evidence that the driving context influences behavioural enactment and presents evidence that the effect of the driving context can provide an explanation for some of the observed variability in drivers' actual behaviour.

The findings of the review about individual features show that the impact of contextual features on engagement, when significant, can be highly dependent on phone task. This could be indicative that overall demands from the driving task, the context and the secondary mobile phone activity play a role in an individual's decision to engage in the behaviour while driving. It is expected that contextual features that impact driving conditions at a higher degree result in increased cognitive and physical demands on the driver and fewer available resources to allocate to secondary tasks. This, in turn, might be detrimental to the simultaneous execution of other secondary high-demand tasks. As evidenced in many of the contextual features assessed, the effects on engagement were more significant for mobile phone tasks with higher resource demands, such as those including handheld functionalities. In these cases, drivers were more likely to engage when there were increased safety margins (i.e., larger headway distances and low speeds/standstill) or the environment was less complex (i.e., lack of roundabouts/merging ramps, straight road segments, divided highways or after completing line crossing manoeuvres). Likewise, the relationship between traffic and engagement in visual-manual interactions on a mobile phone appeared to be parabolic, i.e., more visual-manual interactions were reported where there was less traffic or when there were high traffic conditions (potentially due to stop-and-go traffic). Although road classification did not seem to significantly affect engagement in most studies, those reporting a significant effect indicated a prevalence of use in arterial/collector roads or similar (primary roads, main streets, ring roads) compared to local streets. Surprisingly, it appears that the presence of lead and oncoming vehicles had little impact on engagement in V/M tasks; however, there was evidence that drivers increased safety margins, such as headway distances, before engaging in V/M tasks.

In relation to conversations, results were mainly mixed for most features evaluated. However, some patterns of use are worth noting. Studies focusing on handheld/hands-free talking or solely on hands-free talking reported a trend of higher engagement during afternoon periods compared to morning ones. In the instances where speed showed a significant effect, drivers favoured low speeds or standstill conditions for engagement. In addition, the evaluation of different traffic flow measurements did not seem to yield a significant effect on engagement. Particularly for answering calls, drivers favour larger headway distances and are more comfortable initiating the interaction when other vehicles are not performing line-crossing manoeuvres at a close distance.

Results about location, real estate prices/average income levels, and the number of lanes were mixed and showed no discernible tendencies by task. The effect of day of the week, despite not showing any patterns by phone task, showed that mobile phone use was more prevalent during weekdays. Regarding weather, it appears that drivers favour clear weather conditions over poor weather conditions with low visibility (e.g., rain and fog) when using mobile phones.

Regarding scenarios, the findings show that engagement decreases with a pronounced effect on higher-demand phone tasks as complexity increases. Following this line, scenarios that included intersections evidenced that stopping conditions favour engagement in tasks that have both visual and manual interactions with the phone's interface. This suggests that releasing visual and manual resources while stopped at red lights encourages engagement. For other intersection scenarios with shorter or absence of stopping times or where traffic control requires a higher attentional engagement from the driver (i.e., stop signs), engagement rates in visual/manual tasks do not tend to increase.

## 5. Limitations and future directions

The present review identifies limitations, and future research directions for the distracted driving research field. A key lesson is that consistent and well-defined groupings of mobile phone task functionalities considering human factors (e.g. cognitive processes, physical ergonomics, workload perception, automatic behaviours, task duration, etc.) are necessary to improve analysis quality and comparability of the research field. Given that evidence showed that the decision to engage in most cases is highly dependent on total resource demand, it is advisable to group phone functionalities based on demand similarities. Evaluating the impact of contextual features by grouping together tasks requiring higher physical and cognitive resource demands, such as handheld talking, with lower demand activities, such as hands-free talking, might mask the actual effect of one or both functionalities. Similarly, studies grouping V/M tasks with varying demand levels (i.e., a study defining V/M tasks as texting versus a study defining V/M tasks as texting and holding the phone) might result in contrasting results when evaluating the same contextual feature. This common categorisation can be further enhanced by incorporating other considerations that might affect drivers' perceived expected demand of the task. For instance, these additional considerations can include task duration and the distinction of engagement as the result of an automatic response, an incoming interaction or the individuals' decision to initiate the task themselves.

It might also be possible to adhere this categorisation of tasks to existing constructs or theories dealing with attention allocation, resource demands and cross-interference while multi-tasking. These theories are often classified into three categories: filter, general resource capacity, and multiple resource theories (Epling, 2017). While different in their explanations of how interference arises, adhering to one of them within a driving distraction context can help to better understand the role of secondary task demand as part of the overall task demand while multitasking.

Another important consistency issue hindering comparability and preventing the identification of engagement patterns is the discrepancy in the definitions of contextual features. While differences in features such as road classifications are expected due to the different jurisdictions where data collection took place, more congruous definitions should be expected from other features. For instance, the definition of traffic density varied widely among papers. In some cases, the definition was more in line with a traffic volume measure rather than a traffic density measure. In addition, to comply with SAE Recommended Practice J2944 terminology, authors should use "distance gap", "time gap", or simply "gap" when referring to headway distances and time headways (Green, 2013).

Regarding demographic characteristics, the studies included in this review mainly represented driving conditions in Europe and North America. From the articles reviewed, the distribution of gender was evenly distributed or male predominant, and a minimal share of the studies focused solely on women. Regarding age distribution, the focus of research efforts targets primarily young and middle-aged drivers. The impact of contextual features on mobile phone use by elderly drivers has not received much attention from researchers.

It is important to observe that neither correlation analysis nor regression demonstrates causality; rather, they indicate the co-occurrence of variations between variables. Therefore, even when effects are significant, it does not imply a cause-and-effect relationship between context variables and mobile phone use. The scope of this systematic review is to provide a scholarly synthesis of the literature identifying patterns related to significant effects of contextual factors on mobile phone use. As such, the main focus of the systematic review is on research outcomes. A methodological review should be conducted for an in-depth assessment of the quality of the studies (i.e., data collection method, experiment design, confounders, hypotheses testing statistics, analysis methods etc.) and its adequacy in relation to the analysis goal. This methodological review can provide further insights into the patterns identified in the current literature review and establish causal linkages among variables in a more robust way.

In addition, the systematic review noted a research gap regarding the utilisation of the driving context to predict mobile phone engagement while driving. Evaluating any improvements in the predictive power of models with the inclusion of contextual variables could be a valuable addition to the current literature on the topic.

Lastly, the systematic literature review covers studies published up to the year 2020. This leaves a gap in the reviewed literature from 2020 to the publication date. As a result, additional research efforts are needed to assess the literature from 2020 onwards.

## CRediT authorship contribution statement

**Sandra Cuentas-Hernandez:** Conceptualization, Formal analysis, Investigation, Methodology. **Xiaomeng Li:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Mark J King:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Ioni Lewis:** Conceptualization, Methodology, Supervision, Writing – review & editing. **Oscar Oviedo-Trespalacios:** Conceptualization, Methodology, Supervision, Writing – review & editing.

## Declaration of competing interest

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

## Data availability

Data will be made available on request.

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## Appendices

*Appendix A. Systematic classification of selected articles*

| Author(s) | Year | Country | Sample Characteristics | Data Collection Method | Context Features | Device Mode | Phone Task/ Subtask | Methods |
|---|---|---|---|---|---|---|---|---|
| Pouyakian et al. | 2012 | Iran | n = 42; gender = 100 % male; age = M:26.2 years, SD:3.03 years | Video Clips | Scenario (traffic flow direction, speed) | Adaptation/ simulator | Hands-free talking (answer calls) | Descriptive/ Inferential statistics, logistic regression |
| Sullman | 2012 | UK | n = 17168; gender = 56.6 % male, 43.4 % female; age=<30 years 20.7 %, 30–50 years 56.5 %,>50 years 22.8 % | Observational | Time of day | Handheld | Handheld use (handheld talking, holding, keying) | Descriptive/ Inferential statistics |
| Cooper et al. | 2012 | USA | n = 5413; gender = 58.6 % male, 41.4.0 % female; age = 25—69 years 88.2 %, 16–24 years 8.7 %, > 70 years 3.1 % | Observational (intersection-based) | Location, time of day, time of week, road type | Handheld, hands-free | Handheld use (holding a phone to the ear, manipulating a phone, handheld talking), hands-free talking | Descriptive/ Inferential statistics |

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| Author(s) | Year | Country | Sample Characteristics | Data Collection Method | Context Features | Device Mode | Phone Task/ Subtask | Methods |
|---|---|---|---|---|---|---|---|---|
| Funkhouser & Sayer | 2012 | USA | n = 108; gender = evenly divided; age = three age groups: younger (20–30 years), middle-aged (40–50 years), older (60—70 years) | Naturalistic | Speed, time of day, road classification, lighting conditions | Handheld, hands-free | Handheld/ hands-free talking, V/M tasks (all activities (with visual interaction) except conversations) | Descriptive/ Inferential statistics |
| Cooper et al. | 2013 | USA | n = 5774; gender = 54.0 % female; age = 25—69 years 87.2 %, 16–24 years 7.6 %, > 70 years 5.2 % | Observational (intersection-based) | Location, time of day, time of week | Handheld, hands-free | Handheld use (holding a phone to the ear, manipulating a phone, handheld talking), hands-free talking | Descriptive/ Inferential statistics |
| Pouyakian et al. | 2013 | Iran | n = 42; gender = 100 % male; age = M:26.2 years, SD:3.03 years | Video Clips | Scenario (traffic flow direction, number of lanes), speed, headway distance | Adaptation/ simulator | Hands-free talking (answer calls) | Descriptive/ Inferential statistics, logistic regression |
| Hancox et al. | 2013 | UK | n = 20; gender = 20 % female, 80 % male; age = M:32 years, R:23–47 years | Video Clips/ think aloud | Road demand | Handheld, hands-free | Hands-free talking (answer a call, make a call), V/M tasks (read a text, send a text) | Descriptive/ Inferential statistics |
| Tractinsky et al. | 2013 | Israel | Dataset 1: n = 38; age = 16 young drivers (M:18, SD:0.44), 18 experienced drivers (M:26.4, SD:1.92); Study 2: n = 54; age = 18 experienced drivers (M:26.4, SD:1.76), 18 novice drivers (M:18.3, SD:0.74), 18 older drivers (M:69.8, SD:4.2) | Simulator | Road Demand (based on road geometry, lane number, traffic flow characteristics, traffic flow direction) | Adaptation/ simulator | Hands-free talking (answer calls, make calls) | Descriptive/ Inferential statistics |
| Vera-López et al. | 2013 | Mexico | n = 7940; gender = 76.64 % male | Observational (intersection-based) | Weather, number of lanes, time of week, time of day | Handheld, hands-free | General phone use (handheld/ hands-free talking, keying) | Logistic regression |
| Charlton et al. | 2013 | Australia | n = 10; gender = 60 %male, 40 % female; age = M:74.1 years, SD: 5.76 years | Naturalistic (intersection-based) | Scenario (Speed, road geometry) | – | General phone use | Descriptive/ Inferential statistics |
| Toole et al. | 2013 | USA | n = 100; gender = 95 % male, 5 % female; age = M:44.5 years, SD=12.20 years | Naturalistic | Time of day | Handheld, hands-free | General phone use (V/M tasks (dialling, texting), handheld talking, hands-free talking) | Descriptive/ Inferential statistics, GLMM |
| Wenners et al. | 2013 | USA | n = 17667; gender = 55.4 % males, 44.6 % females; age = 84.9 % adults (20–64 years), 10.0 % elders | Observational (intersection-based) | Time of day, time of week, road classification | Handheld | Handheld use, handheld talking, V/M tasks (keying/ texting) | Descriptive/ Inferential statistics |

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| Author(s) | Year | Country | Sample Characteristics | Data Collection Method | Context Features | Device Mode | Phone Task/ Subtask | Methods |
|---|---|---|---|---|---|---|---|---|
| | | | (65 + years), 5.1 % teens (16–19 years) | | | | | |
| Asgharabad et al. | 2013 | Iran | n = 30773; gender = 93 % male, 7 % female; age=<30 years 20.2 %, 30–50 years 68 %, >50 years 11.8 % | Observational | Time of day, road classification | Handheld | Handheld use | Descriptive/ Inferential statistics |
| Wundersitz | 2014 | Australia | n = 11524; gender = 55.6 % male, 44.4 % female | Observational (intersection-based) | Location, time of day, time of week | Handheld | Handheld talking | Descriptive/ Inferential statistics |
| Metz et al. | 2014 | Germany | n = 49; gender = 6.1 % female; age = M:43.8 years, SD:10.1 years | Naturalistic | Speed, location, scenario (road classification, speed) | Handheld, hands-free | Handheld talking, hands-free talking, V/M tasks (keying, reading, checking) | Descriptive/ Inferential statistics |
| Wenners & Knodler | 2014 | USA | n = 2784 | Observational | Road geometry, scenario (road, geometry, intersection control,), scenario (speed, road geometry, intersection control) | Handheld | Handheld talking, V/M tasks (keying) | Descriptive/ Inferential statistics |
| Xiong et al. | 2014 | USA | n = 108; age = equally distributed into younger (20–30 years), middle aged (40–50 years), older (60–70 years) | Naturalistic | Time of day, traffic flow characteristics | Handheld, Hands-free | Handheld/ hands-free talking, V/M tasks (all activities except conversations) | Descriptive/ Inferential statistics |
| Prat et al. | 2015 | Spain | n = 6578; gender = 68.2 % males, 31.6 % female; age=<30:1036, 30–50:3324, >50: 2217 | Observational | Time of week, time of day | Handheld | Handheld talking, V/M tasks (texting/ keying) | Descriptive/ Inferential statistics |
| Sullman et al. | 2015 | UK | n = 10984 | Observational (intersection-based with only a single site not within 100 m of a controlled intersection) | Time of week, time of day | Handheld, hands-free | General phone use, handheld use (talking, texting/ keying), hands-free talking, handheld talking, V/M tasks (texting, keying) | Descriptive/ Inferential statistics, logistic regression |
| Huisingh et al. | 2015 | USA | n = 3265; gender = 49.8 % female; age = 30–50 years 54.7 % | Observational (intersection-based) | Road classification, scenario (speed, road geometry) | Handheld, hands-free | Handheld/ hands-free talking, V/M tasks (keying) | Descriptive/ Inferential statistics |
| Tivesten & Dozza | 2015 | Sweden | n = 103; gender = 57 % male, 43 % female; age = M:45.3 years, SD: 10.8 years | Naturalistic | Lighting conditions, lead vehicle presence, oncoming vehicle presence, location, traffic flow | Handheld | V/M tasks (dialling, reading, texting, texting/ reading) | Descriptive/ Inferential statistics |

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| Author(s) | Year | Country | Sample Characteristics | Data Collection Method | Context Features | Device Mode | Phone Task/ Subtask | Methods |
|---|---|---|---|---|---|---|---|---|
| | | | | | characteristics, weather, time headway, speed, manoeuvre, road geometry, scenario (mane over, road geometry) | | | |
| Huth et al. | 2015 | France | n = 248; gender = 43.5 % female, 56.5 % male; age = 30–50 years 52.8 %, >50 years 34.7 %, <30 years 12.5 % | Observational (intersection-based) | Scenario (speed, road geometry, intersection control) | Handheld, hands free | Handheld/ hands-free talking, V/M tasks (all activities except calls) | Descriptive/ Inferential statistics |
| Fitch et al. | 2015 | USA | Dataset 1: n = 202; gender = 97 % male, 3 % female; Dataset 2: n = 109; gender = 60.6 % male, 39.4 % female | Naturalistic | Traffic flow characteristics, road geometry, scenario (traffic flow characteristics, road geometry) | Handheld, hands-free | General phone use, handheld talking, hands-free talking, V/M tasks (texting), V/M tasks (dialling) | Descriptive/ Inferential statistics |
| Berstein & Berstein | 2015 | USA | n = 2000; gender = 55 % female, 45 % male (subset) | Observational (intersection based) | Scenario (speed, road geometry, intersection control) | Handheld | Handheld talking, V/M tasks (manipulating) | Descriptive/ Inferential statistics |
| Cheema et al. | 2014 | Qatar | n = 2011; gender = 93.73 % male, 6.27 % female | Observational | Time of day | Handheld | Handheld use | Descriptive/ Inferential statistics |
| Vollrath et al. | 2016 | Germany | n = 11837; gender = 62 % male, 38 % female; age = young drivers 19 %, middle aged drivers 70 %, older drivers 11 % | Observational | Number of lanes, speed, time of day, time of week, traffic flow characteristics | Handheld, hands-free | Handheld talking, hands-free talking, V/M tasks (manipulating) | Descriptive/ Inferential statistics, logistic regression |
| Sabzevari et al. | 2016 | Iran | n = 7979; gender = 94,7% male, 5.3 % female; age=<30 years 32.6 %, 30–50 years 46.5 %, >50 years 20.9 % | Observational | Time of week, time of day, road classification | Handheld | Handheld talking, V/M task (manipulating) | Descriptive/ Inferential statistics |
| Kidd et al. | 2016 | USA | n = 16556; gender = 60.3 % male, 39.7 % female; age = 20–59 years 84.3 %, <20 years 4.1 %, >60 years 11.6 % | Observational | Road geometry, time of day, scenario (speed, road geometry) | Handheld | Handheld talking, V/M tasks (holding), V/M tasks (manipulating) | Descriptive/ Inferential statistics, logistic regression |
| Teh et al. | 2018 | UK | n = 24; gender = 58.3 % males, 41.6 % female; age = M:32.2 years, SD: 6.05 years | Simulator | Manoeuvre | Adaptation/ Simulator | Hands-free talking (answer calls) | Descriptive/ Inferential statistics |
| Arvin et al. | 2017 | Iran | n = 1794; gender = 83.96 % male, 16.04 % female; age = | Observational | Location, time of day | Handheld | Handheld use, handheld talking, V/M | Descriptive/ Inferential statistics, |

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| Author(s) | Year | Country | Sample Characteristics | Data Collection Method | Context Features | Device Mode | Phone Task/ Subtask | Methods |
|---|---|---|---|---|---|---|---|---|
| | | | 25–60 years 51.06 %, 18–25 years 40.92 %, >60 years 8.02 % | | | | tasks (viewing, keying) | logistic regression |
| Precht et al. | 2017 | USA | n = 38; gender = 52.6 % male, 47.4 % female, age = 16–24 years 34.2 %, 25–34 years 26.3 %, 35–69 years 15.8 % | Naturalistic | Weather, lighting conditions, traffic flow characteristic, road geometry, scenario (road geometry, intersection control) | Handheld | Handheld talking, V/M tasks (texting/ dialling/ browsing) | Generalized linear mixed model (GLMM) |
| Oviedo-Trespalacios et al. | 2018a | Australia | n = 447; gender = 66.2 % female, 33.8 % male; age = M:29.62 years, SD:11.61 years | Video Clips/ questionnaire | Scenario (road classification, location, number of lanes, traffic flow characteristics, traffic flow direction, pedestrian/ cyclist presence), road demand | Handheld, hands-free | General phone use, handheld/ hands-free talking, V/M tasks (texting) | Descriptive/ Inferential statistics, random parameters probit model |
| Alghnam et al. | 2018 | Saudi Arabia | n = 1700 | Observational | Real estate prices, road classification | – | General phone use | Descriptive/ Inferential statistics, logistic regression |
| Parnell et al. | 2018 | UK | n = 12; gender = 50 % male, 50 % female, age = M:39.75 years, SD: 11.8 years | Simulator, naturalistic, think aloud | Road classification | Handheld, hands-free | Handheld/ hands-free talking (make a call), V/M tasks (read text) | Descriptive/ Inferential statistics |
| Petzoldt & Schleinitz | 2019 | Germany | n = 41; gender = 53,7% male, 46.3 % female; age = M:32.7 years, R:19–63 years | Video clips/ think aloud | Road demand | Handheld | V/M tasks (texting) | Descriptive/ Inferential statistics |
| Christoph et al. | 2019 | Netherlands | n = 28; gender = 50 % female, 50 % male; age = M:44.5 years, SD:12.9 years, R:26–70 years | Naturalistic | Speed, location, manoeuvre, scenario (road geometry, speed) | Handheld | V/M tasks (keying, reading) | Descriptive/ Inferential statistics |
| Sharda et al. | 2019 | USA | n = 2074; gender = equal split; age = R:16–98 years, about 25 % 20–24 years and about one-fifth of drivers in the study are 65 years or over | Naturalistic | Road division, location, weather | – | General phone use (texting, holding, listening, location, browsing, operating, dialling, handheld, viewing.) | Structural equation modelling |
| Oviedo-Trespalacios et al. | 2019c | Australia | n = 35; gender = 63 % male; age = M:22.9 years, SD:4 years | Simulator | Road geometry, road classification, pedestrian crossing, scenario (road geometry, intersection control, cross-traffic direction), | Handheld | Handheld use (make a call, send a text, share contact, take a selfie) | Descriptive/ Inferential statistics, logistic regression |

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| Author(s) | Year | Country | Sample Characteristics | Data Collection Method | Context Features | Device Mode | Phone Task/ Subtask | Methods |
|---|---|---|---|---|---|---|---|---|
| | | | | | scenario (road geometry, intersection control, traffic flow characteristics), scenario (road geometry, manoeuvre), scenario (road geometry, intersection control, queue presence), scenario (road geometry, traffic flow characteristics) | | | |
| Fakhrmoosavi et al. | 2020 | USA | n = 179769; gender = 59 % female, 41 % male: age = 16–29 years 23.5 %, 30–59 years 63.4 %, >60 years 13.1 % | Observational | Time of day, time of week, speed limit, traffic flow characteristic, population density, income level | Handheld | Handheld talking, V/M tasks (manipulating) | Descriptive/ Inferential statistics, random effects logit model |
| Rahman et al. | 2021 | USA | n = 3727 | Observational | Road geometry, time of day, location, scenario (road geometry, location, time of day) | Handheld, hands-free | General phone use, handheld/ hands-free talking, V/M tasks (keying) | Descriptive/ Inferential statistics, association rule mining |
| Morgenstern et al. | 2020 | Netherlands, Germany, Poland, UK, France | n = 159; gender = 50.9 % male, 49.1 % female; age = M:44 years, SD:13.2 years | Naturalistic (intersection based) | Scenario (road geometry, speed, intersection control) | Handheld, hands-free | Handheld/ hands-free talking, V/M tasks (keying/ browsing) | Descriptive/ Inferential statistics |

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