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# Is distraction on the road associated with maladaptive mobile phone use? A systematic review

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ABSTRACT

Maladaptive Mobile Phone Use (MMPU) (also known as Smartphone Addiction, Nomophobia, Fear of Missing Out, or Problematic Mobile Phone Use) is a growing mental health problem. However, the health and safety consequences of MMPU remain unexplored in many real-life contexts. A potential setting where MMPU may have some negative repercussions is on the road. It is well established that road users (e.g., drivers, motorcyclists, pedestrians, and cyclists) increasingly injure themselves or others due to distractions such as phone use while on the road. Emerging research suggests that MMPU is a possible determinant of this risky behaviour. Therefore, it is essential to investigate the relationship between MMPU and mobile phone use behaviour on the road, as it could help guide and improve interventions aimed at increasing road safety. This systematic review investigated the relationship between maladaptive mobile phone use and mobile phone use behaviour on the road in terms of attitudes and risk perception, intention, phone use engagement, performance changes, and safety outcomes. A total of 44 studies were identified with 47 unique samples of road users, of which 68.1% (32/47) were comprised of drivers, 19.1% (9/47) were pedestrians, 8.5% (4/47) were unspecified road users, and there was one group of motorcyclists and cyclists. Our findings confirmed that MMPU is related to risky behaviour on the roads. In the 29 studies considering observed or self-reported behaviour, 90.9% (30/33) found that road users who scored higher in MMPU are more likely to use their phones on the road as cyclists, drivers, motorcyclists, and pedestrians. Of the nine studies that analysed performance changes, 55.6% (5/9) showed evidence that MMPU changes the performance of road users engaging in mobile phone use, meaning that there is evidence suggesting that MMPU determines the level of impairment. Of the nine studies that analysed the safety-related-outcomes, 66.7% (6/9) found that the higher the MMPU score, the more likely road users are to experience safety–critical traffic events. This review contributes to the literature by showing a pathway between the negative health consequences of MMPU and road trauma. We also identified that the quality of the studies was generally low due to study design and blinding aspects. This field of research also lacks standard practices as researchers avoid using established and well-validated questionnaires, often creating new ones to measure MMPU. This hinders the generalisability of the findings and raises questions about the construct validity and external validity of MMPU. The usefulness of future research would be enhanced by a consistent methodological approach using the same scales based on standard behavioural definitions. The cross-disciplinary nature of MMPU effects means that transport and road safety professionals need to work with healthcare professionals and technology organisations to understand and address MMPU as a contributing factor to road crashes.

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## 1. Introduction

### 1.1. The problem of distraction on the road

Mobile phones have substantially changed our lives, and their use has increased during the past decade, including use in risky situations such as on the road (Huemer et al., 2018; Oviedo-Trespalacios et al., 2019a). All road users must pay attention when travelling on roads and react to unexpected hazards (Davis et al., 2019; Fuller et al., 2008; Vaezipour et al., 2022). Phone use among road users can impair attention, creating safety risks (Davis et al., 2019; Fuller et al., 2008; Onate-Vega et al., 2020). Indeed, almost all types of road users (i.e., cyclists, drivers, motorcyclists, and pedestrians) are at increased risk of crashes or injuries due to distractions caused by phone use (Li et al., 2020; Nguyen-Phuoc et al., 2020a b, c; Stavrinos et al., 2018; Yazdani et al., 2019).

All road users are at risk of distracted driving and distraction-related injuries. In driving, existing evidence suggests that 61% of a sample of Australian drivers (n = 484) engaged in risky mobile phone use, such as texting and browsing when driving (Oviedo-Trespalacios et al., 2017). In the United Kingdom, 29% of a sample of drivers reported engaging in phone calls, 30% reading text messages, and 22% sending texts on at least a daily basis (n = 314) (Sullman et al., 2018). In Colombia, 78% of a sample of young drivers (n = 392) engaged in a mobile phone at least occasionally when driving (Oviedo-Trespalacios and Scott-Parker, 2017). Such widespread use of mobile phones while driving can have detrimental effects on driving performance, such as increased reaction time and impaired vehicle control (Oviedo-Trespalacios et al., 2016; Bastos et al., 2020). Naturalistic study findings which capture driver behaviour in the context of their everyday lives show that the likelihood of crashing increases nearly 3.6 times when using a mobile phone (n = 3,542) (Dingus et al., 2016). For motorcyclists, self-reported studies found that 74% of a sample of university students in Vietnam (n = 665) used mobile phones while riding a motorcycle (Truong et al., 2018), while 75% of motorcyclists in Indonesia (n = 500) used mobile phones (Widyanti et al., 2020). In Malaysia, an observational study showed that 0.2% of motorcyclists (n = 72,377) were using a mobile phone while approaching or at a signalised intersection (Rusli et al., 2020). Motorcyclists talking on mobile phones are found to miss twice as many traffic signals, are more likely to swerve into the next lane (46%), tailgate (23%), have close calls (18%), and run red lights (10%) (n = 1,578) (Beck et al., 2007). The likelihood of a crash/fall due to texting while riding increased by 2.2 times (n = 665) (Truong et al., 2019).

Mobile phone use is also reported as an issue among vulnerable road users such as pedestrians and cyclists. Up to 40% of pedestrians (n = 363) are distracted by their mobile phones when crossing the road (Lennon et al., 2017) and are not looking or checking before crossing (at either signalised or unsignalised intersections) (Horberry et al., 2019). Pedestrians interacting with their phones usually wait for longer (Byington & Schwebel, 2013), miss more opportunities to cross safely (Byington & Schwebel, 2013), and have an increased rate of collisions (Simmons et al., 2020). However, some authors assert that the risk of phone use among pedestrians remains unclear (Ralph & Girardeau, 2020). In the case of cycling, cyclists have often been observed using their phones, but crash-related research on distraction among cyclists has been limited. A study found that mobile phone calls (64.9%) are reported as a distractor more often than text messages (46.4%) among cyclists (n = 1,064) (Useche et al., 2018). In Groningen, an observational video recording study found that 2.2% of cyclists were observed talking on their phones, and 0.6% were text messaging or entering a phone number (n = 2,138) (De Waard et al., 2010). According to a retrospective questionnaire study involving cyclists who reported having a collision with their bicycle, 2.2% of cyclists were listening to music during the collision (n = 2,138) (De Waard et al., 2010). A cross-sectional study stated that 17.7% of distracted cyclists (n = 1974) experienced auditory distractions (earbuds and headphones) (Wolfe et al., 2016). Operating a smartphone coincided with reduced visual detection, reduced visual perception, delayed response time, reduced speed, decreased peripheral vision performance, and increased risk and mental effort ratings (De Waard et al., 2010). Given the range of potential negative effects of mobile phone distraction on the performance of road users, it is essential to understand factors that might increase mobile phone use, including socio-psychological factors. This systematic review will examine the association between maladaptive mobile phone use and phone use behaviour while sharing the road.

### 1.2. Maladaptive mobile phone use: The concept and theoretical underpinnings

Maladaptive mobile phone use (MMPU) is generally defined as excessive use of phones that interferes with work and social interactions (Billieux et al., 2015) or results in negative consequences for individuals (Akin et al., 2014). MMPU is a heterogeneous and multi-faceted behaviour (Billieux et al., 2015), and there is no clear consensus about its definition. Some studies refer to MMPU as a behavioural addiction. However, the adequacy of the addiction terminology is still debatable as there is no clear evidence of severe psychological and physical consequences found in established addictions such as gambling and substance abuse (Billieux et al., 2015; De-Sola Gutiérrez et al., 2016; Panova and Carbonell, 2018). In this review, MMPU is considered as an umbrella term that covers phenomena such as problematic mobile phone use, smartphone addiction, nomophobia, Fear of Missing Out (FoMO), mobile phone involvement, cell phone overuse, mobile phone dependency, habitual phone use, possession attachment to phone, compulsive mobile phone checking, texting dependency, and texting automaticity. Although there is a current lack of a widely agreed conceptualisation of MPPU, the phenomenon is relevant for health and wellbeing research because of its potentially harmful consequences (Sohn et al., 2019; Tao et al., 2016).

Billieux et al. (2015) developed the pathway model of Problematic Mobile Phone Use (PMPU) that highlights three types of problematic use: addictive patterns of use (e.g., addiction symptoms, reassurance behaviours), antisocial patterns of use (e.g., prohibited use), and risky patterns of use (e.g., phone use while driving). As explained by Billieux et al. (2015), the pathway model of PMPU suggests that MMPU plays a direct role in risky patterns of use, such as on-road behaviour. Although some studies have been published showing empirical evidence of the relationship between MMPU and road user behaviour (Nguyen-Phuoc et al., 2020b; Oviedo-Trespalacios et al., 2019), the generalisability and replicability of this association have not been determined. This is important as understanding risky patterns of use among mobile phone users can further confirm the theoretical underpinnings of MMPU itself. Arguably, establishing this understanding could also be beneficial for road safety. MMPU can offer critical information about the determinants of risky behaviours, such as phone use while on the road and new opportunities for interventions.

### 1.3. Maladaptive mobile phone use and road safety

The relationship between MMPU and on-road behaviours has been reported in road safety research worldwide. According to Oviedo-Trespalacios et al. (2019a), when car drivers present high levels of problematic phone use, they also report more frequent handheld and hands-free mobile phone use when driving. Additionally, MMPU has been identified to directly affect the frequency of mobile phone use while riding a motorcycle (Nguyen-Phuoc et al., 2020b) and can also be associated with drivers' dangerous phone use (Lannoy et al., 2020). Smartphone addiction studies in road safety have also become more common, even though the term "addiction" concerning mobile phone use is contested. Previous research that assumes that addiction is a valid term for maladaptive mobile phone use has found a direct relationship between mobile phone addiction and phone use while in a potentially dangerous situation such as driving (Kita and Luria, 2018). Phone addiction is also associated with total collisions, falling/slipping, and bumps (Kim et al., 2017).

Emerging road safety research has started to explore new constructs such as Fear of Missing Out (FoMO) and no-mobile-phone-phobia (Nomophobia) to identify determinants of phone use among road users. FoMO is a psychosocial construct described as the persevering desire to share others' rewarding experiences. Importantly, FOMO has been linked to both negative affectivity and increased severity of problematic mobile phone use (Elhai et al., 2018; Wolniewicz et al., 2018). FoMO can be associated with distracted walking, the tendency to engage in virtual social interactions while walking, and dangerous traffic incidents (Appel et al., 2019). Also, it had the most significant relative contribution in a study modelling problematic mobile phone use severity (Elhai et al., 2020). Nomophobia is the fear and anxiety associated with being without a mobile phone (Bhattacharya et al., 2019). Nomophobia influences drivers: the larger the nomophobia scores, the more likely drivers are to use their phone while driving (Kaviani et al., 2020a). Additionally, the longer a person spends on their smartphones, the stronger the associated phone use while driving (Kaviani et al., 2020b).

## 2. Research gap and research aim

The increasing number of studies examining MMPU link it to the on-road behaviour of people, which highlights the relevance of carefully investigating this concept to help prevent distraction on the roads. However, the existing research appears dispersed and lacks systematic synthesis, limiting our ability to understand the relationship between MMPU and on-road behaviour fully. This is an essential yet challenging undertaking due to limited consensus on the conceptualisation of MMPU for the wide range of road users. Therefore, there is a need to systematically analyse the published literature on the relationship between MMPU and road behaviour across different road users to establish evidence on how it may result in risks to consumer road safety. The present study aims to fill this gap by exploring the evidence about the association between MMPU and mobile phone use behaviour. Although MMPU can be conceptualised as a unitary phenomenon, previous reviews have reported a wide range of operationalisations. Therefore, the second aim of our research is to investigate how MMPU and road user behaviour have been operationalised in the existing literature. This includes looking at cognitive aspects (attitudes (i.e., attitudes and belief), risk perception (i.e., distraction perception, perceived crash risk, safety awareness, perceived safety), and intention), phone use engagement (prior/past behaviour and observed behaviour), and safety-related road user performance (performance changes and safety outcomes) to understand the association between MMPU (i.e., in daily life) and mobile phone use behaviour while on the road (Fig. 1). These aspects are considered to be theoretically relevant for distracted driving behaviour (Gauld et al., 2014; Oviedo-Trespalacios et al., 2019).

## 3. Methods

A Systematic Classification Scheme (SCS) was developed to guide a systematic review and to enable an assessment. Articles were searched according to the search strategy described in Section 3.1 and then reviewed and organised using the SCS.

### 3.1. Systematic classification Scheme (SCS)

Based on the background outlined above, an SCS was developed comprised of the following questions:

1. What categories of road users were considered (i.e., cyclists, drivers, motorcyclists, pedestrians, or scooter riders)?
2. What variations in the study design and demographic characteristics of the participants were found? (e.g., country, sample size, age, sex, and year).
3. What variations in the measurement scales of MMPU (definition, original psychometric performance, and psychometric performance in reviewed paper) were used?
4. What associations between MMPU and mobile phone use behaviour while on the road (i.e., attitudes, risk perception, intention, behaviour, performance changes, and safety outcomes) were considered?

### 3.2. Search strategy

The terms used in this search strategy (Table 1) were adapted from two papers with some additional terms (Lopez-Fernandez et al., 2015; Stavrinos et al., 2018). For road users, the defined terms concerned cyclists, drivers, motorcyclists, pedestrians, and scooter riders. The searches considered all published articles archived in the following databases: PsycINFO, Scopus, PubMed, MEDLINE, Embase, Web of Science, and ProQuest. In addition, backward and forward citation searching was also conducted for all papers identified through database searching. Time restrictions were not implemented, but only papers published before 31 August 2022 and in English were considered. The inclusion criteria were original peer-reviewed scientific articles, including conference papers and short papers but excluding reviews. Two additional conditions needed to be met for inclusion: (1) Inclusion of participants with information about potential maladaptive relationships with their mobile phones in their daily lives; (2) Participants with information about their mobile phone use while on the road, including cyclists, drivers, motorcyclists, pedestrians, and scooter riders. All studies containing exposure to MMPU in risky road situations were

**Table 1**
Search strategy topics.

| Topic | Subject topic areas | Adapted from |
|---|---|---|
| Mobile phone | phone* or "cell*phone*" or "mobile phone*" or smartphone* or "handheld device*" or "electronic device*" | Lopez-Fernandez et al. (2015); Stavrinos et al. (2018) |
| Maladaptive mobile phone use (MMPU) | addict* or problematic or pathol* or excessive* or distract* or inatten* or involvement or dependenc* or nomophobia or "fear of missing out" or "possession attachment" or compulsive or overuse | Lopez-Fernandez et al. (2015); Stavrinos et al. (2018) |
| Road users | pedestrian or walk* or driv* or cycl* or motorcycl* or scooter or transport* or vehicle* or bicycl* | Stavrinos et al. (2018) |


**Fig. 1.** A framework of mobile phone use behaviour related to road safety used in this review.

included.

### 3.3. Systematic review

The protocol of this systematic review was registered through PROSPERO (https://www.crd.york.ac.uk/PROSPERO/) with the registered number CRD42021259275. The study was designed using pre-established criteria based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) protocol (Shamseer et al., 2015). Endnote version 20 was used to manage records throughout this review, and Microsoft Excel was used for data extraction. Articles were extracted into Endnote, and duplicates were removed by one team member (FIR). Title and abstract screening were conducted by FIR and verified by another team member (OOT). After screening, the full texts of studies included were screened, reviewed, and confirmed (FIR & OOT). Once completed, the other team members reviewed and confirmed the included/excluded studies (OOT, AT, MK). Any disagreement was discussed between all four team members at any of these stages.

Papers were selected from two sources, databases and citation searching (Fig. 2). The initial 12,133 identified records resulted from seven databases. After removing duplicates, 6,382 papers were independently screened based on title/abstracts, resulting in 166 articles assessed in full text. These papers were evaluated for their eligibility by accessing and reviewing full texts; 35 were retained. Based on these 35 papers, backward and forward citation searching were conducted, resulting in nine additional documents being included in the review. The following data were extracted from the total of 44 papers: year of publication, authors, country, sample size, study design, statistical analyses, age and gender of the sample, type of road user, type of MMPU, association study (relationship between MMPU in daily life and mobile phone use behaviour while on the road), data/research context (MMPU and road context), and key findings. This review used the Effective Public Health Practice Project's (EPHPP) Quality Assessment Tool for Quantitative Studies to evaluate the methodological quality of the eligible studies (Thomas et al., 2004). All included studies were assessed by two authors, and the rest of the authors were consulted to reach a consensus for resolving any conflicts in decisions.

## 4. Results and discussion

This section is presented in four parts based on critical themes of identified evidence. First, the type of road users and then the approach used to study their behaviour are presented. This is followed by results and discussion of the road users and behavioural indicators of the included studies. The third part describes the validated measurement scales used to study MMPU. The last section will present the quality assessment and associations between MMPU and road user behaviour (i.e., attitude and risk perception, intention, phone use engagement, performance changes, and safety outcomes).

### 4.1. Characteristics of the studies

A total of 44 studies published between 2012 and 2022 were eligible for inclusion in the review. Only the study published by Przybylski et al. (2013) reported data from two countries (the United Kingdom and the USA), making the total studies 45. Those studies comprised 15 studies from Australia (33.3%), 11 studies from each: the USA (24.4%) and Asia (24.4%), Europe reported seven studies (15.6%), and one study was from Africa. Based on the study design, most studies (38/44) used a

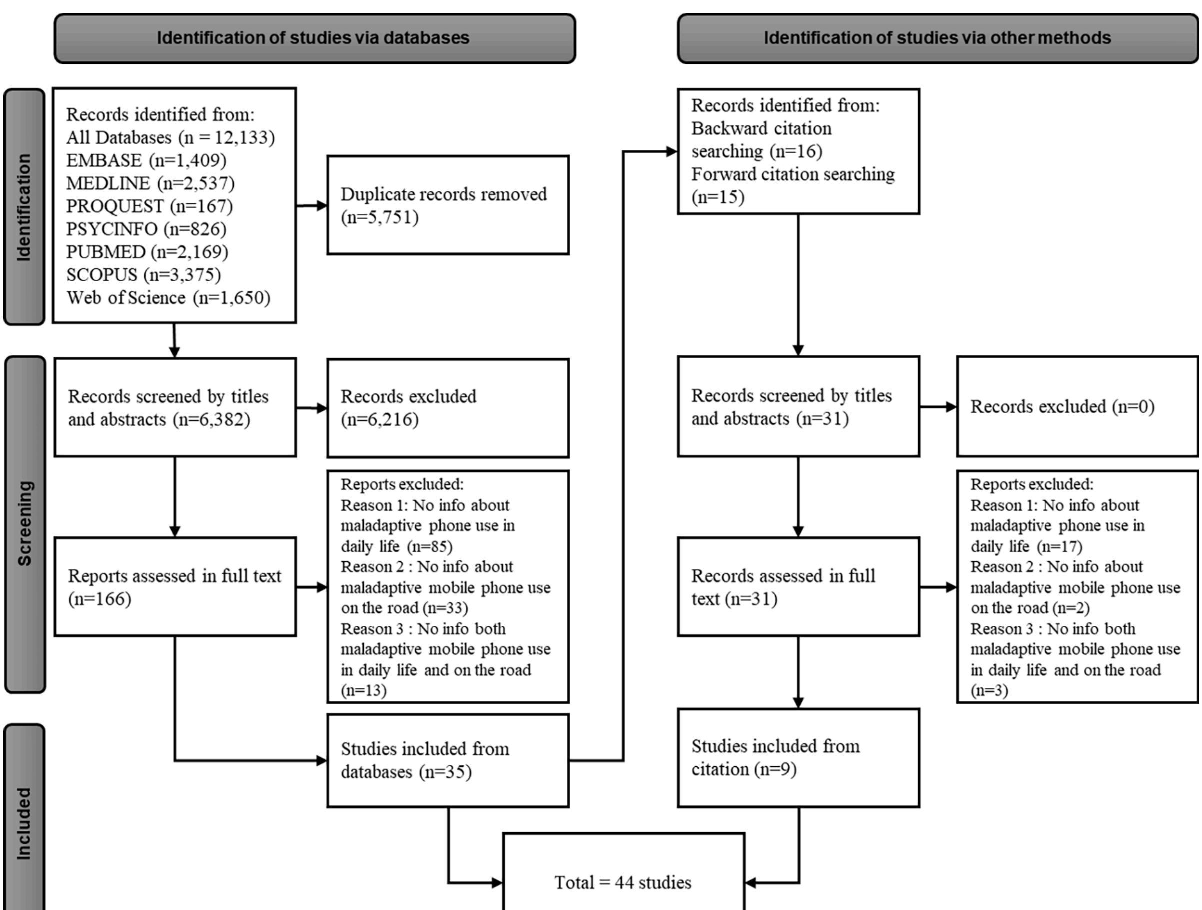


**Fig. 2.** Systematic review flowchart.

cross-sectional design (86.4%), five studies used an experimental design (11.4%), and only one study used an observational design (2.3%) (Table 2). The experimental studies were conducted using a driving simulator (Chee et al., 2021; Kass et al., 2016; Matias et al., 2021; Van Dam et al., 2020) and walking a treadmill (Mourra et al., 2020). The demographic characteristics of the studies are summarised in Table 2. The age of the participants ranged from 16.5 to 80 years, and the samples in 26 (59%) of the studies were mainly females.

The results demonstrate some biases and limitations in this field of research. The participants are primarily from high-income countries (79.5 %) (i.e., Australia, Canada, France, Germany, Israel, Italy, Korea, United States, Saudi Arabia, Switzerland, and United Kingdom) (The World Bank, 2022). The remainder were conducted in upper/middle-income or lower/middle-income countries. Findings from high-income countries may not accurately represent the potential associations in upper-middle or lower/middle-income countries. A comparatively large proportion of the population might not actively use mobile phones on roads due to high infringement costs or security risks (Pew Research Center, 2019). Most studies used cross-sectional designs involving a one-time measurement of exposure and outcome, which prevented us from establishing causal relationships (Bird, 2018). This study design is also prone to recall errors or social desirability bias, so we must be careful not to draw firm conclusions if the patterns across multiple studies appear to be conflicting (Bird, 2018). As most of the participants in the reviewed studies were females, gender differences could bias the findings. Gender differences may influence findings in self-awareness such that females tend to be more self-aware and self-report mobile phone use more openly (Kwon et al., 2013a).

### 4.2. Road users and behavioural indicators considered

A total of 44 papers were identified with 47 unique samples of road users, of which 68 % (32/47) were comprised of drivers, 19.1 % (9/47) were pedestrians, 10.6 % (5/47) were unspecified road users, and there was one group each of motorcyclists and cyclists. One study involved both drivers and motorcyclists (Nguyen-Phuoc et al., 2020b), one study

**Table 2**
Demographic characteristics of the studies.

| Country | Study Design | Demographic characteristics of the participants | | | | References |
|---|---|---|---|---|---|---|
| | | n | Age (years) (Mean; Standard Deviation) | Sex (%) | | |
| | | | | Male | Female | |
| Australia | Self-reported | 612 | 17–24 (NA) | 30 | 70 | Brown et al. (2021) |
| Australia | Experiment | 127 | 18–25 (19.76; 1.63) | 20 | 80 | Chee et al. (2021) |
| Australia | Self-reported | 154 | 17–25 (20.66;1.91) | 27 | 73 | Eren and Gauld (2022) |
| Australia | Self-reported | 171 | 17–25 (20; 2.4) | 21.64 | 73.68 | Gauld et al. (2014) |
| Australia | Self-reported | 114 | 17–25 (NA) | 22.81 | 77.19 | Gauld et al. (2017) |
| Australia | Self-reported | 2,838 | 18–60+ (NA) | 47.10 | 52.90 | Kaviani et al. (2020a) |
| Australia | Self-reported | 2,774 | 18–60+ (NA) | 47 | 53 | Kaviani et al. (2020b) |
| Australia | Self-reported | 2,773 | 18–60+ (NA) | 47 | 53 | Kaviani et al. (2022) |
| Australia | Self-reported | 990 | 18–84 (51.2; 15.7) | 31.4 | 68.6 | Koppel et al. (2022) |
| Australia | Self-reported | 363 | 17–65 (26.9; 11.2) | 27 | 73 | Lennon et al. 2017 |
| Australia | Self-reported | 170 | 18–66 (28.11; 12.04) | 27.60 | 71.20 | Moore and Brown (2019) |
| Australia | Self-reported | 709 | 18–83 (NA) | 51.50 | 48.50 | Oviedo-Trespalacios et al. (2019b) |
| Australia | Self-reported | 526 | 18–25 (21.53; 2.38) | 61.79 | 38.21 | Oxtoby et al. (2019) |
| Australia | Self-reported | 853 | 17–25 (19.89; 2.36) | 25.70 | 74.30 | Sullivan et al. (2021) |
| Australia | Self-reported | 196 | 17–24 (20.02; 2.05) | 53.57 | 46.43 | White et al. (2012) |
| Canada | Experiment | 48 | 18–46 (25.5; 5.5) | 41.67 | 58.33 | Mourra et al. (2020) |
| China | Self-reported | 387 | 17–60 (NA) | 56.60 | 43.40 | Hou et al. (2021) |
| China | Self-reported | 425 | 18–50 (NA) | 48.7 | 51.3 | Hou et al. (2022) |
| China | Self-reported | 405 | 17–26 (NA) | 65.93 | 34.07 | Jiang et al. (2017) |
| China | Self-reported | 603 | NA (26.92; 7.19) | 60.40 | 39.60 | Jiang et al. (2019) |
| China | Self-reported | 14,221 | (15.12; 1.89) | 47.20 | 52.80 | Tao et al. (2016) |
| France | Experiment | 29 | 17–26 (20; 2) | 24 | 76 | Matias et al. (2021) |
| Germany | Self-reported | 272 | 17–80 (37.87; 13.66) | 45.60 | 54.40 | Appel et al. (2019) |
| Iran | Self-reported | 400 | 18–65 (35.63; 8.72) | 77 | 23 | Shokri et al. (2018) |
| Israel | Observation | 221 | 17–22 (19.3; 1.71) | 64.70 | 35.30 | Kita & Luria (2018) |
| Italy | Self-reported | 1,130 | 18+ (23; 3.2) | 20 | 80 | Perilli et al. (2021) |
| Korea | Self-reported | 608 | Addicted users (22.54; 2.05) Normal users (23.01; 2.32) | 30.10 | 69.90 | Kim et al. (2017) |
| Korea | Self-reported | 948 | 20–50 (NA) | 69 | 31 | Yeo and Park (2021) |
| Nigeria | Self-reported | 406 | 18–50+ (NA) | 70.20 | 29.80 | Adeyemi (2021) |
| Saudi Arabia | Self-reported | 1,581 | 17–27 (NA) | 55.30 | 44.70 | Alkhateeb et al. (2020) |
| Switzerland | Self-reported | 95 | 18–42 (22.09; 3.57) | 6.30 | 93.70 | Lannoy et al. (2020) |
| Ukraine | Self-reported | 220 | 19–70 (35.5; 10.54) | 81.80 | 18.20 | Hill et al. (2019) |
| UK/USA | Self-reported | 62 | 18–33 (NA) | 23 | 77 | Przybylski et al. (2013) |
| USA | Experiment | 45 | >18 (NA) | NA | NA | Kass et al. (2016) |
| USA | Self-reported | 468 | 18–74 (35.11; 12.24) | 55 | 45 | Liese et al. (2019) |
| USA | Self-reported | 244 | 18–75 (NA) | 31.6 | 68.4 | Merlo et al. (2013) |
| USA | Self-reported | 94 | >16.5 (NA) | NA | NA | Mirman et al. (2017) |
| USA | Self-reported | 270 | NA (19.43; 2.58) | 40.37 | 59.63 | O'Connor et al. (2017) |
| USA | Self-reported | 925 | NA (28.90; 12.32) | 43 | 57 | Panek et al. (2015) |
| USA | Self-reported | 432 | NA (28.26; 8.28) | 62 | 38 | Steelman et al. (2012) |
| USA | Self-reported | 515 | Male: (21; 4.1) Female: (20.1; 2.30) | 40 | 60 | Struckman-Johnson et al. (2015) |
| USA | Experiment | 37 | NA (21; 3.63) | 29.73 | 70.27 | Van Dam et al. (2020) |
| USA | Self-reported | 974–1,006 | 17–28 (NA) | NA | NA | Weller et al. (2013) |
| Vietnam | Self-reported | 857 | 18–45 (NA) | 50–75.6 | 24.4–50 | Nguyen-Phuoc et al., (2020b) |

n: Sample; NA: Not Available.

involved both drivers and pedestrians (Panek et al., 2015), and one study involved both pedestrians and unspecified road users (Tao et al., 2016). Another five studies were categorized as unspecified road users because the authors did not specify the respondents' characteristics, whether as cyclist, driver, motorcyclist, pedestrian, or passenger (Kim et al., 2017; Liese et al., 2019; Perilli et al., 2021; Steelman et al., 2012; Tao et al., 2016).

Among 47 studies with unique samples, 33 explored aspects of phone use engagement (70.2 %) involving cyclists, drivers, motorcyclists, pedestrians, and unspecified road users. Only studies involving drivers and pedestrians discussed all five aspects of mobile phone use behaviour: attitude and risk perception, intention, phone use engagement, performance changes, and safety outcomes. One cyclist study explored attitude and risk perception, intention, and phone use engagement (Jiang et al., 2019). One study involving motorcyclists examined attitudes and phone use engagement while using a mobile phone when riding a motorcycle (Nguyen-Phuoc et al., 2020b). Regarding unspecified road users, five studies discussed phone use engagement and safety outcomes. See Table 3 for details.

### 4.3. Maladaptive mobile phone use measurement

The concept of MMPU has been approached from different theoretical paradigms, which has resulted in a wide range of scales used to measure this latent construct across other groups. To this day, researchers have continued developing or adapting existing scales as there is no consensus in the literature regarding the best way to measure MMPU (see Lopez-Fernandez et al., 2015; De-Sola Gutiérrez et al., 2016; Harris et al., 2020 for comprehensive reviews related to MMPU scales). According to Lopez-Fernandez et al. (2015), there are two groups of scales: generalised or specific-task scales. Generalised MMPU scales measure phone use activities such as texting, talking/calling, browsing, sending emails, etc. In contrast, specific-task MMPU scales only measure specific phone use activities such as texting (Lopez-Fernandez et al., 2015).

Regarding MMPU in the road safety context, the current review presents information about the psychometric properties of the scales used in the forty-four papers included in this review. The MMPU scales used are outlined in Table 4 and Table 5. We found that 26 scales have been applied in the road safety context (23 generalised MMPU and three specific-task MMPU). However, few of them have been extensively used.

**Table 3**
Characteristics of the studies.

| Road User | Attitude and Risk Perception | Intention | Phone use Engagement | Performance Changes | Safety Outcomes | Authors & Year |
|---|---|---|---|---|---|---|
| **Cyclists** | S | S | S | – | – | Jiang et al. (2019) |
| **Driver** | – | – | – | – | S | Adeyemi (2021) |
| | – | – | S | – | – | Alkhateeb et al. (2020) |
| | – | – | S | – | – | Brown et al. (2021) |
| | – | – | – | E | E | Chee et al. (2021) |
| | S | S | S | – | – | Eren and Gauld (2022) |
| | S | S | S | – | – | Gauld et al. (2014) |
| | S | S | – | S | – | Gauld et al. (2017) |
| | – | – | S | – | – | Hill et al. (2019) |
| | – | – | – | E | E | Kass et al. (2016) |
| | – | – | S | – | – | Kaviani et al. (2020a) |
| | – | – | S | – | – | Kaviani et al. (2020b) |
| | – | – | S | – | – | Kaviani et al. (2022) |
| | – | – | O | – | – | Kita & Luria (2018) |
| | – | – | S | S | – | Koppel et al. (2022) |
| | – | – | – | S | – | Lannoy et al. (2020) |
| | – | – | – | E | – | Matias et al. (2021) |
| | – | – | S | – | – | Merlo et al. (2013) |
| | S | – | S | – | – | Mirman et al. (2017) |
| | – | – | S | – | – | Moore and Brown (2019) |
| | S | – | S | – | – | Nguyen-Phuoc et al. (2020b) |
| | – | – | S | – | S | O'Connor et al. (2017) |
| | – | – | S | – | – | Oviedo-Trespalacios et al. (2019b) |
| | – | – | S | – | – | Oxtoby et al. (2019) |
| | – | – | S | – | – | Panek et al. (2015) |
| | – | – | S | – | – | Przybylski et al. (2013) |
| | S | – | – | – | – | Shokri et al. (2018) |
| | S | – | S | – | – | Struckman-Johnson et al. (2015) |
| | – | – | S | – | – | Sullivan et al. (2021) |
| | – | – | – | E | – | Van Dam et al. (2020) |
| | S | – | S | – | – | Weller et al. (2013) |
| | S | S | – | – | – | White et al. (2012) |
| | – | – | S | – | – | Yeo and Park (2021) |
| **Motorcyclists** | S | – | S | – | – | Nguyen-Phuoc et al. (2020b) |
| **Pedestrians** | – | – | S | – | S | Appel et al. (2019) |
| | S | S | S | – | – | Hou et al. (2021) |
| | S | – | S | – | – | Hou et al. (2022) |
| | S | S | S | – | – | Jiang et al. (2017) |
| | – | S | – | – | – | Lennon et al. (2017) |
| | – | – | E | E | – | Mourra et al. (2020) |
| | – | – | S | – | – | Panek et al. (2015) |
| | – | – | – | – | S | Tao et al. (2016) |
| **Unspecified** | – | – | – | – | S | Kim et al. (2017) |
| | – | – | – | – | S | Liese et al. (2019) |
| | – | – | S | – | – | Perilli et al. (2021) |
| | – | – | S | – | – | Steelman et al. (2012) |
| | – | – | – | – | S | Tao et al. (2016) |

Note: E = Experiment; O = Observation; S = Self-reported.

**Table 4**
The scale used to measure MMPU (Generalised).

| No. | Scale | Definition | Original psychometric performance | Psychometric performance in reviewed papers | Citation |
|---|---|---|---|---|---|
| 1 | **Mobile Phone Problem Use Scale (MPPUS-27)** | This scale was initially designed by Bianchi and Phillips (2005). It conceptualises MMPU as a construct that can measure addiction-related symptoms such as tolerance, escape from other problems, withdrawal, craving, and negative life consequences of the mobile phone. | **Sample size:** 195 **Number of items & Scale:** 27 (Likert 1–10) **Overall score (M; SD):** 80.5; 34.5 **Factors:** (1) MPPUS **Cronbach α** = 0.93 | **Sample size**: 94 (47 parent-adolescent) **Number of items & Scale:** 27 (Likert 1–10) **An overall score (M; SD)**:Parents (M; SD) : 73.11; 30.93 Adolescents (M; SD) :120.04: 39.37 **Factors:** (1) MPPUS **Cronbach** $\alpha_{parents}$: 0.89; $\alpha_{adolescent}$: 0.90 | Mirman et al. (2017) |
| | | | | **Sample size**: 709 **Number of items & Scale:** 26 (Likert 1–10) **An overall score (M; SD)**: Male (M; SD) : 58.80; 39.07 Female (M; SD) : 72.23; 41.36 **Factors:** (1) MPPUS **Cronbach α** = 0.954 | Oviedo-Trespalacios et al. (2019b) |
| 2 | **Mobile Phone Problem Use Scale (MPPUS-10)** | MPPUS-10 is a brief version of the MPPUS. The authors who developed the brief version (Foerster et al., 2015) conceptualise MMPU as a construct that can be measured in terms of addiction-related symptoms such as loss of control, withdrawal, negative consequences, craving, and peer dependence. | **Sample size**: 412 **Number of items & Scale**: 10 (Likert 1–10) **Overall score** (M; SD): 28.2; 15.6 **Factors**: (1) MPPUS **Cronbach α** = 0.85 | **Sample size**: Motorcycle riders (529); Car drivers (328) **Number of items & Scale**: 10 (Likert 1–10) **An overall score (M; SD)**: NA **Factors:** (1) MPPUS **Cronbach α** = 0.836 to 0.916 | Nguyen-Phuoc et al. (2020b) |
| | | | | **Sample size:** 1,154 **Number of items & Scale:** 10 (Likert 1–10) **An overall score (M; SD):** NA **Factors:** (1) MPPUS **Cronbach α** = 0.86 | Eren and Gauld (2022) |
| 3 | **Mobile Phone Dependence Questionnaire (MPDQ)** | This measurement was developed by Toda et al. (2006). It conceptualises MMPU as the association between the intensity of phone use and health-related lifestyle, such as smoking habits for males. | **Sample size**: 275 **Number of item & Scale**: 20 (Likert 0–3) & Dichotomous) **An overall score (M; SD)**: 32.4; 9.5 **Factors**: 6 (NA) **Cronbach α** = 0.86 | **Sample size**: 45 **Number of items & Scale**: 20 (Likert 1–4) **An overall score (M; SD)**: High & Low MPD **Factors**: Mobile phone dependence **Cronbach α** = NA | Kass et al. (2016) |
| | | | | **Sample size**: 37 **Number of items & Scale**: 20 (Likert 1–5) **An overall score (M; SD)**: 66.2; NA **Factors**: Mobile phone dependence **Cronbach α** = 0.89 | Van Dam et al. (2020) |
| 4 | **Problematic Mobile Phone Use Questionnaire (PMPUQ)** | This measurement was developed by Billieux et al. (2008). It conceptualises MMPU through four facets: prohibited use, dangerous use, dependence, and financial problems. | **Sample size**: 339 **Number of items & Scale:** 30 (Likert 1–4) **Overall score (M; SD):** Factor (1) 7.68; 2.56; (2) 8.52; 3.19; (3) 12.75; 4.53; (4) 21.92; 6.93 **Factors:** (1) Prohibited use; (2) Dangerous use; (3) Dependence; and (4) Financial problems. **Cronbach α** = 0.65; 0.73; 0.84; and 0.85 respectively | **Sample size**: 95 **Number of items & Scale:** 6 (Likert 1–4) **Overall score (M; SD):** (1) 7.68; 2.56; (2) 8.52; 3.19; (3) 12.75; 4.53; (4) 21.92; 6.93 **Factors:** (1) Dangerous use; (2) Dependence **Cronbach α** = 0.70 and 0.82 | Lannoy et al. (2020) |
| 5 | **Problematic Mobile Phone Use Questionnaire-Revised (PMPUQ-R)** | This measurement was an updated version of PMPUQ by Billieux et al. (2008) and was developed by Kuss et al. (2018). The financial problem scale was excluded because it is no longer considered an MMPU. | **Sample size**: 512 **Number of items & Scale**: 16 (Likert 1–4) **An overall score (M; SD)**: NA **Factors**: (1) Dependence; (2) Prohibited use/Antisocial smartphone use, and (3) Dangerous driving **Cronbach α** = 0.86 | **Sample size**: 2,838 **Number of items & Scale**: 16 (Likert 1–4) **An overall score (M; SD)**: NA (Absence (0.8 %); mild (37.3 %), moderate (48.7 %); and severe (13.2 %)) **Factors**: (1) Dependent use; (2) Prohibited use; and (3) Dangerous use. **Cronbach α** = 0.86 | Kaviani et al. (2020a) |
| 6 | **Mobile Phone Involvement Questionnaire (MPIQ)** | This scale was initially developed by Walsh et al. (2010). The scale conceptualises MMPU based on behavioural addiction, which includes symptoms such as cognitive and | **Sample size**: 946 **Number of items & Scale**: 8 (Likert 1–7) **Overall score (M; SD)**: (3.46; 1.1) **Factors:** (1) Mobile phone | **Sample size**: 612 **Number of items & Scale**: 8 (Likert 1–7) **An overall score (M; SD)**: 3.74; 1.25 **Factors:** (1) Mobile phone | Brown et al. (2021) |

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**Table 4** (*continued*)

| No. | Scale | Definition | Original psychometric performance | Psychometric performance in reviewed papers | Citation |
|---|---|---|---|---|---|
| | | behavioural salience, withdrawal and loss of control. It was initially developed by Walsh et al. (2010). | involvement<br>**Cronbach α** = 0.78 | involvement<br>**Cronbach α** = 0.86 | |
| | | | | **Sample size**: 171<br>**Number of items & Scale:** 8 (Likert 1–7)<br>**An overall score (M; SD)**: 4.04; 1.18<br>**Factors:** (1) Mobile phone involvement<br>**Cronbach α** = 0.87 | Gauld et al. (2014) |
| | | | | **Sample size**: 114<br>**Number of items & Scale:** 8 (Likert 1–7)<br>**Overall score (M; SD)**: 3.99; 1.15<br>**Factors**: (1) Mobile phone involvement<br>**Cronbach α** = 0.85 | Gauld et al. (2017) |
| | | | | **Sample size:** 220<br>**Number of items & Scale**: 8 (Likert 1–7)<br>**An overall score (M; SD):** 22; 10*<br>**Factors**: (1) Mobile phone involvement<br>**Cronbach α** = 0.81 | Hill et al. (2019) |
| | | | | **Sample size**: 387<br>**Number of items & Scale:** 3 (Likert 1–5)<br>**Overall score (M; SD)**: 2.899; 0.884<br>**Factors:** (1) Mobile phone involvement<br>**Cronbach α** = 0.849 | Hou et al. (2021) |
| | | | | **Sample size**: 405<br>**Number of items & Scale:** 8 (Likert 1–5)<br>**Overall score (M; SD)**: 3.06; 0.698<br>**Factors:** (1) Mobile phone involvement<br>**Cronbach α** = 0.801 | Jiang et al. (2017) |
| | | | | **Sample size**: 603<br>**Number of items & Scale**: 8 (NA)<br>**Overall score (M; SD)**: (1) 2.78; 1.052; (2) 2.74; 0.983; (3) 2.63; 0.972; (4) 2.60; 0.931; (5) 2.41; 0.908; (6) 2.72; 0.920; (7) 2.69; 0.981; (8) 2.62; 0.865<br>**Factors:** (1) Mobile phone addiction<br>**Cronbach α** = 0.890<br>Note: The authors did not use the term mobile phone involvement but did not justify it. The items were rewritten and adapted. Initially, there were nine items, but the final was eight items. | Jiang et al. (2019) |
| | | | | **Sample size**: 363<br>**Number of items & Scale:** 8 (Likert 1–7)<br>**An overall score (M; SD)**: 3.68; 1.36<br>**Factors:** (1) Mobile phone involvement<br>**Cronbach α** = 0.91 | Lennon et al. (2017) |
| | | | | **Sample size**: 853<br>**Number of items & Scale:** 8 (Likert 1–7)<br>**An overall score (M; SD)**: 4.08; 1.07<br>**Factors:** (1) Mobile phone involvement<br>**Cronbach α** = 0.82 | Sullivan et al. (2021) |
| 7 | | | | **Sample size**: 196<br>**Number of items & Scale:** 8 (Likert 1–7)<br>**An overall score (M; SD)**: 3.53; 1.18<br>**Factors:** (1) Mobile phone involvement<br>**Cronbach α** = 0.78 | White et al. (2012) |

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**Table 4** (*continued*)

| No. | Scale | Definition | Original psychometric performance | Psychometric performance in reviewed papers | Citation |
|---|---|---|---|---|---|
| | **Compulsive mobile phone checking** | The measurement was developed by Steelman et al. (2012) based on the Cell Phone Attachment Scale (Alexander et al., 2007). The scale conceptualises problematic phone use as compulsive behavioural action such as continuously checking the phone even though there is no call, message, or alert, including at night, and the difficulty of controlling the spending time on the phone. | **Sample size**: 432<br>**Number of items & Scale**: 10 (Likert 1–7)<br>**An overall score (M; SD)**: 4.84; 1.17<br>**Factors**: (1) Compulsive Mobile Checking<br>**Cronbach α** = 0.91 | | Steelman et al. (2012) |
| 8 | **Fear of Missing Out (FoMO)** | This measurement conceptualizes MMPU with participants' general experiences, such as fears, worries, and anxieties concerning being in (or out of) touch with the events, experiences, and conversations across the extended social circles through mobile phone use. This scale was developed by Przybylski et al. (2013). | **Sample size**: 1,013<br>**Number of items & Scale**: 10 (Likert 1–5)<br>**Overall score (M; SD)**: 2.56; 0.82<br>**Factors**: (1) Fear of Missing Out (FoMO)<br>**Cronbach α** = 0.87 | **Sample size**: 87<br>**Number of items & Scale**: 10 (Likert 1–5)<br>**An overall score (M; SD)**: 2.37; 0.84<br>**Factors**: (1) Fear of Missing Out<br>**Cronbach α** = 0.89 | Przybylski et al. (2013) |
| | | | | **Sample size**: 272<br>**Number of items & Scale**: 10 (Likert 1–5)<br>**An overall score (M; SD)**: 2.09; 0.55<br>**Factors**: (1) Fear of Missing Out<br>**Cronbach α** = 0.74 | Appel et al. (2019) |
| | | | | **Sample size**: 612<br>**Number of items & Scale**: 10 (Likert 1–5)<br>**An overall score (M; SD)**: 2.53; 0.87<br>**Factors**: (1) Fear of Missing Out<br>**Cronbach α** = 0.88 | Brown et al. (2021) |
| | | | | **Sample size:** 425<br>**Number of items & Scale:** 5 (Likert 1–5)<br>**An overall score (M; SD):** NA<br>**Factors:** (1) Fear of Missing Out<br>**Cronbach α** = NA | Hou et al. (2022) |
| | | | | **Sample size:** 29<br>**Number of items & Scale:** 10 (Likert 1–5)<br>**An overall score (M; SD):** NA<br>**Factors:** (1) Fear of Missing Out<br>**Cronbach α** = NA | Matias et al. (2021) |
| 9 | **Cell Phone Overuse Scale (CPOS) II** | CPOS II was developed by O'Connor et al. (2017) by eliminating redundant items and maximising the psychometric properties of CPOS I (O'Connor et al., 2017). This scale conceptualises MMPU by considering the frequency of behaviours (i.e., the anticipation of incoming calls, emotional reaction, time impact) that may represent problematic phone use. | **Sample size**: 383<br>**Number of items & Scale**: 21 (Likert 1–6)<br>**An overall score (M; SD)**: NA<br>**Factors**: (1) Anticipation of incoming calls; (2) Cell phone interference with daily life activities; (3) Strong emotional reaction to the cell phone; and (4) Recognized problematic cell phone use.<br>**Cronbach α** = NA | **Sample size**: 270<br>**Number of items & Scale**: 13 (Likert 1–5)<br>**An overall score (M; SD)**: NA<br>**Factors**: (1) Emotional; (2) Time impact; and (3) Anticipation.<br>**Cronbach α** = 0.87 | O'Connor et al. (2017) |
| 10 | **Smartphone Addiction Scale (SAS)** | This scale conceptualises MMPU as smartphone addiction based on the Korean self-diagnostic program for Internet addiction (K-scale) and the smartphone's features. It was initially developed by Kwon et al. (2013a). | **Sample size**: 540<br>**Number of items & Scale**: 33 (Likert 1–6)<br>**An overall score (M; SD)**: NA<br>**Factors**: (1) Daily-life disturbance; (2) Positive anticipation; (3) Withdrawal; (4) Cyberspace-oriented relationship; (5) Overuse; and (6) Tolerance.<br>**Cronbach α** = 0.967 | **Sample size**: 1,581<br>**Number of items & Scale**: 33 (1–6)<br>**An overall score (M; SD)**: NA<br>**Factors**: NA<br>**Cronbach α** = 0.967 | Alkhateeb et al. (2020) |
| 11 | **Smartphone Addiction Scale-Short Version (SAS-SV)** | This scale investigates the measurement of MMPU with the revised and short version of the smartphone addiction scale and proves its validity in adolescents. In addition, it suggested cutting off the values by gender to determine smartphone addiction and elaborate on the characteristics of smartphone usage in adolescents. It was developed by Kwon et al. (2013b). | **Sample size**: 540<br>**Number of items & Scale**: 10 (Likert 1–6)<br>**An overall score (M; SD)**: 25.26; 10.78<br>**Factors**: Smartphone Addiction<br>**Cronbach α** = 0.911 | **Sample size**: 221<br>**Number of items & Scale**: 8 (Likert 1–5)<br>**An overall score (M; SD)**: 2.68; 0.72<br>**Factors**: (1) Smartphone Addiction<br>**Cronbach α** = 0.79 | Kita & Luria (2018) |
| 12 | **Self-rating Questionnaire for Adolescent Problematic** | It was initially developed by Tao et al. (2013). (The original paper is in Chinese, only the abstract is provided in English). This scale conceptualises | **Sample size**: 2,376<br>**Number of items & Scale**: 13 (NA)<br>**An overall score (M; SD)**: NA<br>**Factors**: (1) Withdrawal symptoms; | **Sample size**: 14,221<br>**Number of items & Scale**: 13 (Likert 1–5)<br>**An overall score (M; SD)**: NA | Tao et al. (2016) |

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Table 4 (*continued*)

| No. | Scale | Definition | Original psychometric performance | Psychometric performance in reviewed papers | Citation |
|---|---|---|---|---|---|
| | **Mobile Phone Use (SQAPMPU)** | MMPU by covering three dimensions: withdrawal symptoms, physical and mental health effects, and craving. This scale was developed for adolescents. | (2) Effect of physical and mental health; and (3) Craving. **Cronbach α** = 0.87 | **Factors**: (1) Withdrawal symptoms; (2) Effect of physical and mental health; and (3) Craving. **Cronbach α** = 0.94 | |
| 13 | **Perceived possession attachment to phone** | This measurement was developed by Weller et al. (2013) and only consisted of five items that conceptualise MMPU as a perceived attachment to one's phone. | **Sample size**: 1,006 **Number of items & Scale**: 5 (Likert 1–5) **An overall score (M; SD)**: NA **Factors**: (1) Attachment to phones **Cronbach α** = 0.81 | | Weller et al. (2013) |
| 14 | **Smartphone Addiction Proneness Scale for Youth (SAPS)** | This study conceptualises MMPU as smartphone addiction considering disturbance of adaptive functions, virtual life orientation, withdrawal, and tolerance. It was initially developed by Kim et al. (2014). | **Sample size**: 795 **Number of items & Scale**: 15 (Likert 1–4) **Overall score (M; SD)**: 2.53; 0.87 **Factors**: (1) Disturbance of adaptive functions; (2) Virtual life orientation; (3) Withdrawal; and (4) Tolerance. **Cronbach α** = 0.88 | **Sample size**: 608 **Number of items & Scale**: 15 (Likert 1–4) **An overall score (M; SD)**: NA **Factors**: (1) Tolerance; (2) Withdrawal (3) Virtual life orientation; and (4) Disturbance of adaptive functions. **Cronbach α** = 0.691-0.873 | Kim et al. (2017) |
| | | | | **Sample size**: 48 **Number of items & Scale**: 15 (Likert 1–4) **An overall score (M; SD)**: 35.6; 9.9 **Factors**: SAPS **Cronbach α** = NA | Mourra et al. (2020) |
| 15 | **Phone Attachment and Dependence Inventory (PADI)** | This scale conceptualises MMPU as the degree of dependence on one's smartphone and the attachment of the emotional aspects of smartphone use. It was initially developed by Ward et al. (2017). | **Sample size**: 275 **Number of items & Scale**: 11 (Likert 1–5) **An overall score (M; SD)**: NA **Factors**: (1) Phone dependence; (2) Emotional Attachment **Cronbach α** = 0.89 and 0.79 | **Sample size**: 127 **Number of items & Scale**: 11 (Likert 1–5) **An overall score (M; SD)**: NA **Factors**: (1) Phone dependence; (2) Emotional Attachment **Cronbach α** = 0.79; 0.89 | Chee et al. (2021) |
| 16 | **Nomophobia Questionnaire (NMP-Q)** | Nomophobia (no mobile phone phobia) conceptualises MMPU as the fear of being unable to interact between people and mobile information and communication technologies, primarily through smartphones, as maladaptive phone use. It involves four factors: not being able to communicate, losing connectedness, not being able to access, and giving up convenience. It was initially developed by Yildirim and Correia (2015). | **Sample size**: 300 **Number of items & Scale**: 20 (Likert 1–7) **An overall score (M; SD)**: NA **Factors**: (1) Not being able to communicate; (2) Losing connectedness; (3) Not being able to access; and (4) Giving up convenience. **Cronbach α** = 0.945 | **Sample size**: 2,838 **Number of items & Scale**: 20 (Likert 1–7) **An overall score (M; SD)**: 69.4; 25.1 **Factors**: (1) Not being able to communicate; (2) Losing connectedness; (3) Not being able to access; and (4) Giving up convenience. **Cronbach α** = 0.955 | Kaviani et al. (2020a) |
| | | | | **Sample size**: 2,774 **Number of items & Scale**: 20 (Likert 1–7) **An overall score (M; SD)**: 69.13; 25.05 **Factors**: (1) Not being able to communicate; (2) Losing connectedness; (3) Not being able to access; and (4) Giving up convenience. **Cronbach α** = NA | Kaviani et al. (2020b) |
| | | | | **Sample size**: 2,773 **Number of items & Scale**: 20 (Likert 1–7) **An overall score (M; SD)**: 69; 25.1 **Factors**: (1) Not being able to communicate; (2) Losing connectedness; (3) Not being able to access; and (4) Giving up convenience. **Cronbach α** = 0.96 | Kaviani et al. (2022) |
| | | | | **Sample size**: 990 **Number of items & Scale**: 20 (Likert 1–7) **An overall score (M; SD)**: 72.4; 26.5 **Factors**: (1) Not being able to communicate; (2) Losing connectedness; (3) Not being able to access; and (4) Giving up convenience. **Cronbach α** = 0.96 | Koppel et al. (2022) |
| 17 | **Dependence Test of Mobile Phone (DTMP)** | This scale was developed based on dependence criteria of the Diagnostic and Statistical Manual for Mental | **Sample size**: 2,833 **Number of items & Scale**: 22 (Likert 1–7) | **Sample size**: 1,130 **Number of items & Scale**: 17 (Likert 0–4) | Perilli et al. (2021) |

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**Table 4** (*continued*)

| No. | Scale | Definition | Original psychometric performance | Psychometric performance in reviewed papers | Citation |
|---|---|---|---|---|---|
| | | Disorders-Fourth Edition-Text Revision (DSM-IV-TR). It was initially created by Choliz (2012). | **An overall score (M; SD):**<br>**Factors**: (1) Abstinence; (2) Lack control/problems; and (3) Tolerance/ Interference.<br>**Cronbach α** = 0.94 | **An overall score (M; SD)**: 26; 10<br>**Factors**: NA<br>**Cronbach α** = NA | |
| 18 | **Cell Phone Dependence Scale (CPD)** | This scale conceptualises MMPU as the importance of cell phone availability by considering anxiety without a phone and dependent on a phone. It was developed by Gaster et al. (No Year) for the study of Struckman-Johnson et al. (2015). | **Sample size**: 515<br>**Number of items & Scale**: 12 (Likert 1–5)<br>**An overall score (M; SD)**:Men (38.31; 8.84); Females (41.26; 9.06)<br>**Factors**: (1) Anxious without a cell phone; (2) Dependent on cell phone<br>**Cronbach α** = 0.87 and α = 0.77 | | Struckman-Johnson et al. (2015) |
| 19 | **Addictive tendency** | This scale conceptualises MMPU as addictive inclinations to use cell phones by examining tendencies, disputes with different operations, and loss of rein, which are severely associated with addictive behaviour. This is developed by Shokri et al. (2018). | **Sample size**: 400<br>**Number of items & Scale**: 7 (Likert 1–5)<br>**An overall score (M; SD)**: NA<br>**Factors**: (1) Addictive tendency<br>**Cronbach α** = 0.78 | | Shokri et al. (2018) |
| 20 | **Habitual Use of the Phone Scale (HUPS)** | This scale conceptualises problematic phone use as a person's habitual tendencies to use their phone, and it does not explicitly mention pathologies of phone use. It was developed by Oxtoby et al. (2019) and adapted from various standardised scales of phone use. | **Sample size**: 526<br>**Number of items & Scale**: 3 (Likert 1–5)<br>**An overall score (M; SD)**: 9.05; 2.63<br>**Factors**: (1) Habitual phone use<br>**Cronbach α** = 0.8 | | Oxtoby et al. (2019) |
| 21 | **Smartphone Addiction Survey-Short Version (SAS-SV)** | The scale conceptualises problematic phone use behaviour as symptoms of addiction, withdrawal, and tolerance, and this was created based on previous smartphone addiction measurement scales. This was developed by Adeyemi (2021). | **Sample size**: 406<br>**Number of items & Scale**: 10 (Likert 1–5)<br>**An overall score (M; SD)**: NA<br>**Factors**: Mobile phone addiction proneness<br>**Cronbach α** = 0.79 | | Adeyemi (2021) |
| 22 | **Smartphone dependency** | This scale was developed by Yeo and Park (2021) rooted in Korean Children and Youth Panel Survey. The scale conceptualised problematic phone use as dependency on a smartphone, nervousness without a smartphone, and feeling bored and isolated. | **Sample size**: 948<br>**Number of items & Scale**: 7 (Likert 1–5)<br>**An overall score (M; SD)**: NA<br>**Factors**: (1) Smartphone dependency<br>**Cronbach α** = 0.91 | | Yeo and Park (2021) |
| 23 | **Problematic Use of Mobile Phones (PUMP) Scale** | This scale conceptualises MMPU as excessive phone use considering tolerance, withdrawal, a longer time than intended, great deal of time spent, craving, activities given up or reduced, use despite physical or psychological problems, failure to fulfil role obligations, use in physically hazardous situations, and use despite social or interpersonal problems. This scale was developed by Merlo et al. (2013). | **Sample size**: 244<br>**Number of items & Scale**: 20 (Likert 1–5)<br>**An overall score (M; SD)**: NA<br>**Factors**: (1) PUMP<br>**Cronbach α** = 0.94 | | Merlo et al. (2013) |

*Overall the mean of the sum; M = Mean; NA = Not Available; SD = Standard Deviation.

This large number of scales is highly problematic as it is unclear whether they measure the same construct due to a lack of convergent validity studies (Fayers and Machin, 2016).

The wide range of scales prevents us from *meta*-analysing the findings to establish confidence in a relationship between MMPU and on-road behaviour. In this review, we analysed the scales used and provided relevant information so that researchers wishing to work in this field could have a framework of references when making their methodological decisions. According to Lopez-Fernandez et al. (2015), to develop a reasonable scale, it is necessary to confirm its validity, translate and adapt it to other cultures, and propose clear and valid classification and cut-off points to estimate the incidence and prevalence of MMPU. We did not find much information about how the scales were adapted for the culture of the studied population, even though some authors modified some scales.

The first recognised scholars to study the relationship with an MMPU scale in the context of road user behaviour were White et al. (2012), who used the Mobile Phone Involvement Questionnaire (MPIQ) developed by Walsh et al. (2010). The MPIQ measures behavioural addiction, which includes symptoms such as cognitive and behavioural salience, withdrawal, and loss of control (Walsh et al., 2010). The MPIQ has become the most used scale and has been implemented and tested in terms of its psychometric properties in ten studies (Brown et al., 2021; Gauld et al., 2014; Gauld et al., 2017; Hill et al., 2019; Hou et al., 2021; Jiang et al., 2017; Jiang et al., 2019; Lennon et al., 2017; Sullivan et al., 2021; White et al., 2012).

Another notable feature of research on MMPU and road safety is that the Mobile Phone Problem Use Scale (MPPUS), considered the gold standard as a measure, is not the most used in the reviewed articles. Only four studies used this scale to explore distracted driving behaviour-MMPU interactions (Eren and Gauld, 2022; Mirman et al., 2017; Nguyen-Phuoc et al., 2020b; Oviedo-Trespalacios et al., 2019), and

**Table 5**
The scale used to measure MMPU (Specific-task).

| No. | Scale | Definition | Psychometric performance | Citation |
|---|---|---|---|---|
| 1 | **Texting Automaticity** | This scale conceptualises texting automaticity as a texting behaviour (starting a text, sending a text, checking a text, and reading a text) without thinking, meaning to do it, and without realising that they do it and cannot stop doing it efficiently. The measurement was developed by Gardner et al. (2012) and is part of the Self-Report Behavioural Automaticity Index (SRBAI). | **Sample size**: 925<br>**Number of items & Scale**: 4 (Likert 1–5)<br>**An overall score (M; SD)**: NA<br>**Factors**: (1) Automaticity<br>**Cronbach α** = 0.95 (texting while driving) and α = 0.94 (texting while walking) | Panek et al. (2015) |
| | | | **Sample size**: 170<br>**Number of items & Scale**:4 (Likert 1–5)<br>**An overall score (M; SD)**: 2.09; 0.97<br>**Factors**: (1) Automaticity<br>**Cronbach α** = 0.85 | Moore and Brown (2019) |
| 2 | **Self-Perception of Text-message Dependency Scale (STDS)** | This scale conceptualises dependency on text messaging as a phone problem that involves emotional reaction to receiving or not receiving a text, relationship maintenance via text, and excessive use of texting. This scale was developed by Liese et al. (2019). | **Sample size**: 468<br>**Number of items & Scale**: 15 (Likert 1–5)<br>**An overall score (M; SD)**: 38.23; 11.02<br>**Factors**: (1) Emotional reaction to receiving (or not receiving) a text; (2) Relationship maintenance via text; and (3) Excessive use of texting.<br>**Cronbach α** = 0.90 | Liese et al. (2019) |
| 3 | **The DSM-5-based scale of texting addiction** | This scale was adapted from the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), which introduced behavioural addiction, with gambling disorder as the sole category and modified the criteria to reflect similar behaviours regarding MMPU for the task-specific measure. It conceptualises MMPU as a texting addiction where people feel bothered, irritable, and restless due to the inability to stop texting and do illegal texting while driving. | **Sample size**: 468<br>**Number of items & Scale**: 11 (Likert 1–5)<br>**An overall Score (M; SD)**: 1.42; 1.81<br>**Factors**: DSM-5 texting addiction<br>**Cronbach α:** NA | |

M = Mean; NA = Not Available; SD = Standard Deviation.

MMPU-attitude & belief interaction (Nguyen-Phuoc et al., 2020b). If we rank scales solely on their internal consistency coefficients (reliability), the Smartphone Addiction Scale (Kwon et al., 2013a) with α = 0.967 would be at the top of the list. However, in psychometrics, it is recommended to use multiple scales to increase validity, but this was rarely done in the reviewed studies. Indeed, only three studies used two MMPU scales (Brown et al., 2021; Kaviani et al., 2020a; Liese et al., 2019), while the others only used one MMPU scale.

### *4.4. Association between MMPU and mobile phone use on the roads*

The study of associations is presented in six sub-sections. The first section presents the quality assessment of the studies. The second and third sections represent cognitive aspects of the behaviour, from the attitude and risk perception to the intention of engaging in phone use while on the road. Section four is related to road users' behaviour (i.e., phone use engagement). And the last two sections discuss safety-related context (i.e., performance changes and safety outcomes) on the road.

#### *4.4.1. Quality assessment*

According to the Effective Public Health Practice Project (EPHPP) guideline (Thomas et al., 2004), the findings showed that all studies were methodologically weak. No studies were rated methodologically moderate or vigorous because no randomised control trials or cohort studies were identified. Meta-analyses of the quantitative data were not possible due to the heterogeneity of the data and the low-quality design of included studies. Therefore, the association between MMPU in daily life and phone use behaviour while on the road is summarised narratively and should be considered with caution.

#### *4.4.2. Attitude and risk perception*

Attitudes and beliefs reflect a person's favourable or unfavourable evaluation of performing a behaviour. Nearly 81.8% (9/11) of the studies showed that higher MMPU scores were associated with more (favourable) attitudes and beliefs regarding mobile phone use while on the road. This finding was consistent across cyclists (Jiang et al., 2019), drivers (Eren and Gauld, 2022; Gauld et al., 2014, 2017; Nguyen-Phuoc et al., 2020b; White et al., 2012), motorcyclists (Nguyen-Phuoc et al., 2020b), and pedestrians (Hou et al., 2021; Jiang et al., 2017). Notably, 72.7% (8/11) of research considering attitudes and beliefs followed the Theory of Planned Behaviour (TPB). However, some studies developed their attitudes and beliefs construct, such as Nguyen-Phuoc et al. (2020b), which considered attitudes and beliefs associated with safety while using the phone when riding and driving.

Most studies showed that higher MMPU scores among participants (i.e., higher level of behavioural and cognitive association with the phones) resulted in reduced perceptions of risk concerning the negative consequences of using mobile phones while on the road (i.e., road crashes or injuries). This finding was supported by 60% (3 out of 5 studies) that analysed risk perception when cycling (Jiang et al., 2019) and driving (Struckman-Johnson et al., 2015; Weller et al., 2013). This result was in line with Oviedo-Trespalacios et al. (2017), who found that drivers who stated the effects of mobile phone distraction were minor and seemed sceptical about any impairment were more likely to report using their mobile phones at any moment. Two studies showed no evidence to support the findings that higher MMPU scores will reduce perceived risk while driving (Mirman et al., 2017) and crossing the street (Hou et al., 2022). A potential explanation is that it might be a function of the specific items on the MMPU scale and their emphasis on phone use's social consequences and benefits. Some studies considered the perceived safety of phone use while on the road. The research conducted by Jiang et al. (2017) found that higher MMPU scores were associated with lower safety awareness (i.e., Using a mobile phone while crossing would not cause an accident"). However, in the study by Hou et al. (2021), this was not significant by asking the questions: "I think to cross a street while walking using a mobile phone would be very unsafe" and "When I cross together with my friends, if they were using mobile phones while crossing the street, then I will stop them". See more details in Table 6.

#### *4.4.3. Intention*

Intention is understood as individual motivation and is influenced by an individual's attitudes. Some psychosocial factors (i.e., subjective norms, perceived behavioural control) are part of the Theory of Planned

**Table 6**
Association study between MMPU and attitude and risk perception.

| Road user | Study | Construct | Results | | Direction | Global Rating EPHPP |
|---|---|---|---|---|---|---|
| | | | Qualitative | Quantitative | | |
| Cyclists | Jiang et al. (2019) | Attitude | Mobile phone addiction was positively associated with (favourable) attitudes towards using phones while cycling. | r = 0.262; p <.01 | ↑ | ●○○ |
| | | Distraction perception | Mobile phone addiction was negatively associated with the distraction perception of phone use while cycling. | r = -0.284; p <.01 | ↓ | ●○○ |
| Drivers | Eren and Gauld (2022) | Attitude | Problematic mobile phone usage was positively associated with (favourable) attitudes toward concealed responses while driving. | r = 0.22; p <.001 | ↑ | ●○○ |
| | Gauld et al. (2014) | Attitude | Mobile phone involvement was positively associated with (favourable) attitudes toward concealing texting while driving. | r = 0.27; p <.001 | ↑ | ●○○ |
| | Gauld et al. (2017) | Attitude | Mobile phone involvement was positively associated with (favourable) attitudes toward initiating texting while driving. | r = 0.16; p <.05 | ↑ | ●○○ |
| | | | Mobile phone involvement was not associated with (favourable) attitudes toward monitoring/reading text while driving. | r = 0.12 | NS | ●○○ |
| | | | Mobile phone involvement was positively associated with (favourable) attitudes towards responding to texting while driving. | r = 0.16; p <.05 | ↑ | ●○○ |
| | Mirman et al. (2017) | Risk perception | Mobile phone problem use scale (parent) was not associated with risk perception (parent) while driving. | r = -0.147 | NS | ●○○ |
| | | | Mobile phone problem use scale (parent) was not associated with risk perception (teen) while driving. | r = 0.238 | NS | ●○○ |
| | | | Mobile phone problem use scale (teen) was not associated with risk perception (parent) while driving. | r = 0.105 | NS | ●○○ |
| | | | Mobile phone problem use scale (teen) was not associated with risk perception (teen) while driving. | r = -0.035 | NS | ●○○ |
| | Nguyen-Phuoc et al. (2020b) | Attitude & beliefs | Problematic mobile phone use was positively associated with (favourable) attitudes and beliefs about using phones while driving. | β = 0.353; p <.01 | ↑ | ●○○ |
| | Shokri et al. (2018) | Attitude | The addictive tendency was not associated with (favourable) attitude while driving (note: the regression is inverse (attitude is not a predictor of addictive tendency). | r = -0.07; p <.001 β = 0.64 | NS | ●○○ |
| | Struckman-Johnson et al. (2015) | Perceived crash risk | Cell phone dependence was negatively associated with perceived crash risk while driving for males. | Males: r = -0.261; p <.01 | ↓ | ●○○ |
| | | | Cell phone dependence was not associated with perceived crash risk while driving for males. | Females: r = -0.019 (NS) | NS | ●○○ |
| | | Attitude & beliefs | Cell phone dependence was not associated with confidence in driving for females. | Male: r = 0.020 (NS) | NS | ●○○ |
| | | | Cell phone dependence was negatively associated with confidence in driving for females. | Females: r = -0.092; p <.05 | ↓ | ●○○ |
| | Weller et al. (2013) | Risk perception | Perceived possession attachment to a phone was negatively associated with risk perception of phone use while driving. | r = -0.17; p <.001 | ↓ | ●○○ |
| | White et al. (2012) | Attitude | Mobile phone involvement was positively associated with (favourable) attitude toward using phones while driving. | r = 0.16; p <.05 | ↑ | ●○○ |
| Motorcyclists | Nguyen-Phuoc et al. (2020b) | Attitude & beliefs | Problematic mobile phone use was positively associated with (favourable) attitudes and beliefs. | β = 0.225; p <.01 | ↑ | ●○○ |
| Pedestrians | Hou et al. (2021) | Attitude | Mobile phone involvement was positively associated with (favourable) attitudes toward using phones while crossing the street. | r = 0.153; p <.001 | ↑ | ●○○ |
| | | Safety awareness | Mobile phone involvement was not associated with safety awareness while walking. | r = -0.016 | NS | ●○○ |
| | Hou et al. (2022) | Risk perception | Fear of Missing Out (FoMO) was not associated with the risk perception of the probability of using phones while crossing the street. | r = 0.06 | NS | ●○○ |
| | Jiang et al. (2017) | Attitude & beliefs | Mobile phone involvement was positively associated with (favourable) attitudes and beliefs about using phones while crossing (positive belief, i.e., use time effectively and negative belief, i.e., being distracted). | r = 0.164; p <.01 | ↑ | ●○○ |
| | | Perceived safety | Mobile phone involvement was positively associated with the perceived safety of using phones while walking. | r = 0.101; p <.01 | ↑ | ●○○ |

r = correlation; CI = confidence interval; NS = non-significant; β = standardised coefficient of beta; NA = not available; p = p value.

Behaviour (Ajzen, 1991). From eight studies that analysed intention, 87.5% (7/8) showed that with higher MMPU scores, road users are more likely to use mobile phones while on the road. This finding was supported by several scholars in cycling (Jiang et al., 2019), driving (Eren and Gauld, 2022; Gauld et al., 2014; White et al., 2012), and road crossing (Hou et al., 2021; Jiang et al., 2017; Lennon et al., 2017). No study explored the association between MMPU and intention of phone use while riding a motorcycle or other road users. Lennon et al. (2017) reported that mobile phone involvement increased the intention to use the phone while driving for all participants regardless of age, and younger pedestrians had a stronger intention to do so than other ages. However, Gauld et al. (2017) reported that mobile phone involvement was not associated with the intent to initiate (starting a communication), monitoring/reading (checking a mobile phone/reading a text), and respond to texting (replying to a communication) while driving. Intention is usually studied by considering the other variables described in the TPB. Consequently, when analysing the impact of MMPU on intention, the authors of the present study also included the effect of other variables. Most relationships between MMPU and intention tested across different studies were significant after controlling for the other

**Table 7**
Association study between MMPU and Intention.

| Road user | Study | Results | | Direction | Global Rating EPHPP |
|---|---|---|---|---|---|
| | | Qualitative | Quantitative | | |
| Cyclists | Jiang et al. (2019) | Mobile phone addiction was positively associated with the behavioural intention of phone use while cycling. | r = 0.477; p <.01<br>β = 0.479; p <.05 | ↑ | ●○○ |
| Drivers | Eren and Gauld (2022) | Problematic mobile phone usage was positively associated with the intention of concealing responding while driving. | r = 0.33; p <.001<br>β = 0.16; p <.001 | ↑ | ●○○ |
| | Gauld et al. (2014) | Mobile phone involvement was positively associated with the intention to conceal texting while driving. | r = 0.41; p <.01<br>β = 0.18; p <.001 | ↑ | ●○○ |
| | Gauld et al. (2017) | Mobile phone involvement was not associated with the intention to initiate texting while driving. | r = 0.12 (NS)<br>β = -0.09 (NS) | NS | ●○○ |
| | | Mobile phone involvement was not associated with the intention of monitoring/reading text while driving. | r = 0.27; p <.01<br>β = 0.03 (NS) | NS | ●○○ |
| | | Mobile phone involvement was not associated with the intention to respond to texting while driving. | r = 0.19; p <.05<br>β = -0.02 (NS) | NS | ●○○ |
| | White et al. (2012) | Mobile phone involvement was positively associated with the intention to use a phone while driving. | r = 0.21; p <.01<br>B = 0.14; p <.01 | ↑ | ●○○ |
| Pedestrians | Hou et al. (2021) | Mobile phone involvement was positively associated with the intention of using phones while crossing the street. | r = 0.284; p <.001 | ↑ | ●○○ |
| | Jiang et al. (2017) | Mobile phone involvement was positively associated with the intention of using phones while crossing the street. | r = 0.382; p <.01<br>β = 0.245; p <.001 | ↑ | ●○○ |
| | Lennon et al. (2017) | Mobile phone involvement was positively associated with the intention of using phones while crossing the street. | Age 18–65 y.: β = 0.18; p <.001; | ↑ | ●○○ |
| | | Mobile phone involvement was positively associated with the intention of using phones while crossing the street. | Age 18–30 y.: β = 0.17; p <.01 | ↑ | ●○○ |

r = correlation; OR = odd ratio; CI = confidence interval; NS = non-significant; β = standardised coefficient of beta; NA = not available; p = p value.

TPB variables, such as attitudes, perceived behavioural control, and social norms. This shows that the link between MMPU and intention is quite marked beyond traditional psychosocial factors. See more details in Table 7.

### 4.4.4. *Phone use engagement*

The findings showed that 90.9% (30/33) of studies that considered phone use engagement found that road users who scored higher on MMPU are more likely to engage with phone use while on the road. In driving, 87% (20/23) studies confirmed a relationship between MMPU and drivers (Alkhateeb et al., 2020; Brown et al., 2021; Eren and Gauld, 2022; Kaviani et al., 2020a,b, 2022; Kita and Luria, 2018; Koppel et al., 2022; Merlo et al., 2013; Mirman et al., 2017; Moore and Brown, 2019; Nguyen-Phuoc et al., 2020b; O'Connor et al., 2017; Oviedo-Trespalacios et al., 2019; Oxtoby et al., 2019; Panek et al., 2015; Przybylski et al., 2013; Sullivan et al., 2021; Weller et al., 2013; Yeo and Park, 2021). In contrast, several scholars found conflicting results (Gauld et al., 2014; Hill et al., 2019; Struckman-Johnson et al., 2015).

Oviedo-Trespalacios et al. (2019b) reported that problem users use more handheld and hands-free mobile phones while driving than casual, habitual, and regular users. Struckman-Johnson et al. (2015) mentioned that mobile phone dependence was in the top two variables associated with men's and women's texting while driving. It is also important to note that only one of three factors, "anticipation of incoming calls or messages", was associated with higher phone use in the car (O'Connor et al., 2017). The other two factors (i.e., the impact of time spent on the phone and the emotional aspect) were not associated with phone use while driving (O'Connor et al., 2017). A potential interpretation is that individuals who experience greater anticipation of incoming calls and messages feel a compulsive need to check their phones more often (O'Connor et al., 2017).

For pedestrians, all included studies agreed that higher MMPU is associated with more phone use while crossing the street or walking (Appel et al., 2019; Hou et al., 2021; Hou et al., 2022; Jiang et al., 2017; Mourra et al., 2020; Panek et al., 2015). Virtual social interactions while walking might happen because people dislike solitary walking along roads and try to fulfil the desire always to be connected to other people (Przybylski et al., 2013). The same results were also found for cyclists and motorcyclists; higher MMPU is associated with being more likely to use a phone while cycling (Jiang et al., 2019) and riding a motorcycle (Nguyen-Phuoc et al., 2020b). Two studies involving unspecified road users also showed similar results (Perilli et al., 2021; Steelman et al., 2012). See more detail in Table 8.

### 4.4.5. *Performance changes*

Road users with higher MMPU are believed to be more likely to experience performance changes. However, our review indicates limited evidence exploring this association (Table 9). The findings showed that 55.5% (5/9) of studies identified performance changes associated with MMPU (Chee et al., 2021; Gauld et al., 2017; Koppel et al., 2022; Matias et al., 2021; Struckman-Johnson et al., 2015).

In the driving context, self-reported studies such as Gauld et al. (2017) demonstrated a positive association between greater mobile phone involvement and self-reported cognitive capture during tasks such as initiating, monitoring/reading, and responding to interactive social media on the phone while driving. Some of the questions used to investigate cognitive capture were: "How often have you found yourself suddenly focused on your smartphone rather than on the road when driving?" and "How often have you accidentally failed to carry out a routine driving task (e., missed a turn, forgotten to indicate, forgotten to change gear." A recent cross-sectional study showed that Nomophobia appears to be associated with an increase in risky driving behaviours as measured in the Driver Behaviour Questionnaire (DBQ) (Koppel et al., 2022). Whilst the correlation appears moderate, it is important to note that Nomophobia influences lapses during driving the most. Violations are the least associated behaviour. This could be because slips and lapses are involuntary errors associated with the ability to suppress potentially distracting stimuli while driving (e.g., a ringing phone or a digital roadside advertising sign). However, the self-reported evidence of performance changes due to MMPU is contradictory. A study found that perceived texting distractibility is negatively associated with mobile phone dependence while driving for males but not females (Struckman-Johnson et al., 2015). A potential explanation for this is that males could have a lower impression of being distracted by texting while driving because of norms of masculinity that determine fearlessness and downplaying of danger (Struckman-Johnson et al., 2015). Other self-reported studies, such as Lannoy et al. (2020), did not show a relationship between MMPU and performance changes (See Table 9).

Two studies using a driving simulator did not predict the association between MMPU and performance changes (Kass et al., 2016; Van Dam et al., 2020). In the driving simulator experiments, the performance changes were measured through the number of traffic law violations committed (i.e., combined stop sign and traffic light violations), mean speed, the number of centreline crossings (i.e., crossing the double yellow line to the left), and road edge excursions (i.e., leaving the roadway to the right) (Kass et al., 2016). Some reasons why the experiment may not have had the expected result are participants may have deduced that the notification on the phone was part of the experiment (i.e., students use their phones more for text messaging and some features available on the phone than they do for receiving a call), technology malfunction impacting the collection of eye-tracking data, and maybe due to lack of statistical power (Kass et al., 2016). While another study indicated that drivers with MMPU did not affect their situational awareness when they were distracted by a text message that they could not respond to (Van Dam et al., 2020). This could be because the driver cannot predict when such a text message distraction will occur and thus cannot self-regulate their behaviour to limit the effect of the distraction.

Regarding pedestrians, only one study that used a walking treadmill showed that smartphone addiction proneness was not influenced by more missed stimuli (to measure task-switching delays) and accuracy (i.e., the successful response percentage) in the direction of the task while walking (Mourra et al., 2020). A stimulus was "missed" if, after the auditory cue, the participant did not lift their head before the motivation disappeared (Mourra et al., 2020). Interestingly, the smartphone addiction proneness scores were positively correlated with the frequency of texting while walking (Mourra et al., 2020). The findings indicated that pedestrians with high MMPU scores were more prone to distractions while walking (Mourra et al., 2020).

In cycling, no study found a relationship between MMPU and performance changes. Importantly, this does not mean using a mobile phone while cycling does not represent risks, as the research has been limited. Texting, calling or playing a game on a mobile phone's touch screen while cycling can impair the performance, i.e., speed, lane position, reaction and brake time, and peripheral visual detection (De Waard et al., 2014). In summary, the impact of MMPU on performance changes still needs further research.

#### 4.4.6. Safety outcomes

Generally, the higher the MMPU score, the more likely road users are to experience safety–critical traffic events (i.e., falling, slipping, bumps/collisions, moving violations, road traffic injuries, and motor vehicle crashes). This is due to their inability to recognise potentially dangerous or unsafe conditions. This finding was supported by 66.7% (6/9) of studies that analysed safety outcomes such as in drivers (Adeyemi, 2021), pedestrians (Appel et al., 2019; Tao et al., 2016), and unspecified road users (Kim et al., 2017; Liese et al., 2019; Tao et al., 2016). All the studies used self-report methods to measure crashes, so there is a survival bias as all road users involved in the collision did not experience fatal injuries (see Table 10).

In driving, Adeyemi (2021) stated mobile phone addiction proneness increased the likelihood of road collisions by 2.64 times. However, other scholars found that MMPU was not associated with collisions (i.e., contact with other vehicles, objects, or people) (Kass et al., 2016). In addition, MMPU also was not associated with the risk of motor vehicle crashes (from minor "car remained fully functional after an accident, no repair work required" to totalled accident "damages to the car were beyond repair") (O'Connor et al., 2017). A potential explanation for these findings could be recalling errors among participants.

When MMPU scores are higher, pedestrians are more likely to be distracted and prone to safety–critical traffic events (Appel et al., 2019; Tao et al., 2016). Middle and high school students who reported MMPU were more likely (3.56 times) to experience pedestrian collisions (colliding with someone or something or being knocked into by other people or hit by something else, such as vehicles, buildings, or trees) and to experience falls (3.91 times) while walking (Tao et al., 2016). Additionally, Appel et al. (2019) stated that Fear of Missing Out (FoMO) predicted dangerous incidents due to phone use while walking in traffic.

Some studies did not specify which road users were involved in phone use-related safety outcomes (Kim et al., 2017; Liese et al., 2019; Tao et al., 2016). A study reported that the likelihood of traffic collision due to MMPU increased by 3.76 times and bumps/collisions by 1.83 times, falling/slipping by 2.08 times, and being trapped in the subway by 2.85 times (Kim et al., 2017). Another study reported that problematic mobile phone use increased the likelihood of road traffic injuries by 3.93 times (middle school students) and 3.23 times (high school students); and falls by 3.91 times (middle school students) and 2.91 times (high school students) (Tao et al., 2016). In addition, Liese et al. (2019) reported participants with motor vehicle crashes had higher scores on the self-perception of text-message dependency scale (STDS) and DSM-5 texting addiction than those who did not report such incidents.

Reports of harmful physical consequences associated with MMPU have been limited (Panova and Carbonell, 2018). However, the present review addressed this critical gap in the literature. The reviewed articles generally showed that addiction or MMPU could result in negative physical consequences in the form of potential road-crash-related injuries among drivers (Adeyemi, 2021), pedestrians (Appel et al., 2019; Tao et al., 2016), and unspecified road users (Kim et al., 2017; Liese et al., 2019; Tao et al., 2016). Users presenting MMPU might be more prone to collision due to multitasking or dual performance decrements (Weksler & Weksler, 2012; Oviedo-Trespalacios et al., 2019b). This is particularly serious on the road, where activities such as driving, walking, and cycling require high levels of attention and effective decision-making to be safe. The present review shows that MMPU might impair road users' behaviour and decision-making.

## 5. Limitations and future research

A limitation of this research is that only some types of road users were considered. The present review identified papers reporting on the relationship between MMPU and the behaviour on the road of drivers, pedestrians, motorcyclists, and cyclists. Nonetheless, many other road users could be using their phones on the road, increasing their risk. For example, an observational study in Germany found that 0.4% of e-scooter riders were holding a phone while riding a scooter (n = 253) (Huemer et al., 2022). A study in the United States found that 4% of skateboarders looked at mobile phones (n = 100) (Fang and Handy, 2017). It is likely that the patterns linking MMPU and phone use identified in this paper also apply to e-scooter and skateboard riders. However, further research is needed to confirm this. It is also important to acknowledge that special groups of road users, such as those travelling for or because of work (e.g., delivery riders, commuters, fleet drivers, etc.), often use their phones (Costantini et al., 2022; Nguyen-Phuoc et al., 2020a, c; Oviedo-Trespalacios et al., 2020, 2022). Research is needed to understand how job demands might interact with MMPU and influence mobile phone use while on the road.

The heterogeneity in the studies reviewed prevented us from conducting a meta-analysis. We tried to group studies to conduct meta-analyses, but the total maximum number of studies in the categories was only three (in one case) (Gauld et al., 2014; Gauld et al., 2017; White et al., 2012). This particular case concerned MMPU and attitude towards using phones while driving. While all three studies used the Mobile Phone Involvement scale (Walsh et al., 2010), they utilised different response variables. Gauld et al. (2014) used a question related to texting in a concealed manner (harmful = 1, to harmless = 7), and in further research, Gauld et al. (2017) asked participants what they

**Table 8**
Association study between MMPU and phone use engagement.

| Road user | Study | Results | | Direction | Global Rating EPHPP |
|---|---|---|---|---|---|
| | | Qualitative | Quantitative | | |
| Cyclists | Jiang et al. (2019) | Mobile phone addiction was positively associated with the behaviour of phone use while cycling. | β = 0.29; p <.05 | ↑ | ●○○ |
| Drivers | Alkhateeb et al. (2020) | Participants reported a high score of smartphone addiction spent more time engaged in mobile phone use while driving. | r is correlated, but it is not available; p <.001 | ↑ | ●○○ |
| | Brown et al. (2020) | Fear of Missing Out (FoMO) was positively associated with texting while driving (send). | r = 0.09; p <.05<br>β = 0.09; p <.05 | ↑ | ●○○ |
| | | Fear of Missing Out (FoMO) was not associated with texting while driving (read). | r = 0.06<br>β = 0.06 | NS | ●○○ |
| | | Mobile phone involvement was positively associated with texting while driving (send) | r = 0.25; p <.001<br>β = 0.22; p <.001 | ↑ | ●○○ |
| | | Mobile phone involvement was positively associated with texting while driving (read). | r = 0.27; p <.001<br>β = 0.27; p <.001 | ↑ | ●○○ |
| | Eren and Gauld (2022) | Problematic mobile phone usage was positively associated with concealed responding to a smartphone while driving. | r = 0.42; p <.001 | ↑ | ●○○ |
| | Gauld et al. (2014) | Mobile phone involvement was not associated with the probability of enacting the behaviour of concealed texting while driving. | r = 0.31; p <.001<br>B = 0.04 (β is not available) | NS | ●○○ |
| | Hill et al. (2019) | Mobile phone involvement was not associated with texting while driving. | Initial model<br>OR = 1.02; 95 %CI = 0.99–1.05; p <.14<br>Parsimonious model<br>OR = 1.03; 95 %CI = 1.00–1.06; p <.06 | NS | ●○○ |
| | Kaviani et al. (2020a) | Severe nomophobia was positively associated with engaging in dangerous, problematic mobile phone use while driving 14 times more likely than absent nomophobia. | OR = 14.00; 95 % CI = 5.21–37.41 | ↑ | ●○○ |
| | Kaviani et al. (2020b) | Nomophobia (the factor of not being able to communicate) was not associated with the likelihood of engaging in illegal phone use while driving. | OR = 1.00; 95 %CI = 0.99–1.01 | NS | ●○○ |
| | | Nomophobia (the factor of losing connectedness) was not associated with the likelihood of engaging in illegal phone use while driving. | OR = 1.02; 95 %CI = 0.99–1.04 | NS | ●○○ |
| | | Nomophobia (the factor of access to information) was positively associated with the likelihood of engaging in illegal phone use while driving. | OR = 1.06; 95 %CI = 1.04–1.09 | ↑ | ●○○ |
| | | Nomophobia (the factor of giving up convenience) was not associated with the likelihood of engaging in illegal phone use while driving. | OR = 1.02; 95 %CI = 0.99–1.04 | NS | ●○○ |
| | Kaviani et al. (2022) | Compared to participants with severe nomophobia, participants with absent, mild, and moderate nomophobia were less likely to engage in illegal phone use while driving. | Absence:<br>OR = 0.15; 95 %CI = 0.034-0.68<br>Mild:<br>OR = 0.31; 95 %CI = 0.24-0.41<br>Moderate:<br>OR = 0.55; 95 %CI = 0.43-0.71 | ↑ | ●○○ |
| | Kita & Luria (2018) | Smartphone addiction was positively associated with phone use while driving. | r = 0.233; p <.01 | ↑ | ●○○ |
| | Koppel et al. (2022) | Nomophobia was positively associated with engagement in technology while driving. | r = 0.208; p <.01<br>β = 0.13; p <.001 | ↑ | ●○○ |
| | Merlo et al. (2013) | Problematic use of mobile phones was positively associated with talking on the phone while driving. | r = 0.411; p <.001 | ↑ | ●○○ |
| | | Problematic use of mobile phones was positively associated with writing text messages or emails while driving. | r = 0.612; p <.001 | ↑ | ●○○ |
| | Mirman et al. (2017) | Mobile phone problem usage scale was positively associated with the frequency of mobile phone use while driving. | Estimate: 0.0083; p <.0001 | ↑ | ●○○ |
| | Moore and Brown (2019) | Habitual texting was positively associated with texting while driving. | r = 0.26; p <.01<br>B = 0.27; p <.05 | ↑ | ●○○ |
| | Nguyen-Phuoc et al. (2020b) | Problematic mobile phone use was positively associated with the frequency of mobile phone use while driving. | β = 0.299; p <.01 | ↑ | ●○○ |
| | O'Connor et al. (2017) | Compulsive cell phone use (anticipation of incoming calls) was positively associated with higher reported in-vehicle cell phone use while driving. | B = 0.22; p <.03 | ↑ | ●○○ |
| | | Compulsive cell phone use (emotional) was not associated with higher reported in-vehicle cell phone use while driving. | B = -0.14 | NS | ●○○ |
| | | Compulsive cell phone use (time impact) was not associated with higher reported in-vehicle cell phone use while driving. | B = 0.04 | NS | ●○○ |
| | Oviedo-Trespalacios et al. (2019b) | Mobile phone problem use scale was positively associated with handheld and hands-free mobile phone use while driving. Problem users engaged in more handheld and hands-free mobile use while driving than casual, habitual, and regular users. | Handheld use: F(3, 705) = 62.50; p <.001<br>Hands-free use: F(3, 705) = 10.80; p <.001 | ↑ | ●○○ |
| | Oxtoby et al. (2019) | For males, habitual phone use was positively associated with phone use in the car. | Male: r = 0.381; p <.001<br>β = 0.188; p <.001 | ↑ | ●○○ |

(continued on next page)

**Table 8** (*continued*)

| Road user | Study | Results | | Direction | Global Rating EPHPP |
|---|---|---|---|---|---|
| | | **Qualitative** | **Quantitative** | | |
| | | For females, habitual phone use was not associated with phone use in the car. | Female: r = 0.169 (NS)<br>β = 0.042; p <.616 (NS) | NS | ●○○ |
| | Panek et al. (2015) | Texting automaticity was positively associated with dangerous texting behaviour while driving. | β = 0.14; p <.001 | ↑ | ●○○ |
| | Przybylski et al. (2013) | Fear of Missing Out (FoMO) was positively associated with distracted driving (more frequent use of mobile communications technology). | β = 0.28; p <.029 | ↑ | ●○○ |
| | Struckman-Johnson et al. (2015) | Cell phone dependency was not associated with texting levels while driving. | Male: r = 0.435; p <.001<br>β = 0.286 (NS)<br>Female: r = 0.338; p <.001<br>β = 0.254 (NS) | NS | ●○○ |
| | Sullivan et al. (2021) | Mobile phone involvement was positively associated with initiating mobile phone use while driving. | r = 0.20; p <.001<br>β = 0.16; p <.001 | ↑ | ●○○ |
| | | Mobile phone involvement was positively associated with monitoring mobile phone use while driving. | r = 0.25; p <.001<br>β = 0.22; p <.001 | ↑ | ●○○ |
| | | Mobile phone involvement was positively associated with responding to mobile phone use while driving. | r = 0.30; p <.001<br>β = 0.27; p <.001 | ↑ | ●○○ |
| | | Mobile phone involvement was positively associated with total mobile phone use while driving (initiating, monitoring, and responding). | r = 0.30; p <.001<br>β = 0.26; p <.001 | ↑ | ●○○ |
| | Weller et al. (2013) | Perceived possession attachment to a phone was positively associated with the proportion of cell phone use on trips (talking while driving). | β = 0.15; p <.01<br>r = 0.19; p <.01 | ↑ | ●○○ |
| | | Perceived possession attachment to a phone was positively associated with the proportion of cell phone use on trips (texting while driving). | β = 0.19; p <.01<br>r = 0.26; p <.01 | ↑ | ●○○ |
| | | Perceived possession attachment to the phone was positively associated with drivers who used an app on the phone while driving. | β = 0.25; p <.01 | ↑ | ●○○ |
| | | Perceived possession attachment to the phone was positively associated with drivers who used the internet on the phone while driving. | β = 0.16; p <.01 | ↑ | ●○○ |
| | Yeo & Park (2021) | Smartphone dependency was positively associated with talking/calling phone use while driving. | β = 0.310; p <.000 | ↑ | ●○○ |
| | | Smartphone dependency was positively associated with manipulating phone use while driving. | β = 0.502; p <.000 | ↑ | ●○○ |
| Motorcyclists | Nguyen-Phuoc et al. (2020b) | Problematic mobile phone use was positively associated with the frequency of mobile phone use while riding a motorcycle. | β = 0.217; p <.01 | ↑ | ●○○ |
| Pedestrians | Appel et al. (2019) | Fear of Missing Out (FoMO) was positively associated with distracted walking. | r = 0.341; p <.001<br>β = 0.16; p <.004 | ↑ | ●○○ |
| | | Fear of Missing Out (FoMO) was positively associated with the frequency of engaging in virtual social interactions (reading and writing emails, using messengers, using social media) while walking or waiting in traffic lights or crossing the street. | r = 0.269; p <.001<br>β = 0.16; p <.01 | ↑ | ●○○ |
| | Hou et al. (2021) | Mobile phone involvement was positively associated with phone use while crossing the street. | r = 0.205; p <.01<br>β = 0.437; p <.01; OR = 1.549 | ↑ | ●○○ |
| | Hou et al. (2022) | Fear of Missing Out (FoMO) was positively associated with the behaviour of using a phone while crossing the street | r = 0.22; p <.01<br>β = 0.26; p <.001 | ↑ | ●○○ |
| | Jiang et al. (2017) | Mobile phone involvement was positively associated with prior behaviour of mobile phone use while crossing the street. | r = 0.265; p <.01<br>β = 0.152; p <.001 | ↑ | ●○○ |
| | Mourra et al. (2020) | Smartphone addiction proneness was positively associated with the frequency of texting while walking. | r = 0.49; p <.001 | ↑ | ●○○ |
| | | Smartphone addiction proneness was positively associated with the frequency of playing a game on a smartphone while walking. | r = 0.38; p <.007 | ↑ | ●○○ |
| | Panek et al. (2015) | Texting automaticity was positively associated with texting while walking. | β = 0.36; p <.001 | ↑ | ●○○ |
| Unspecified | Perilli et al. (2021) | Mobile phone dependence test was positively associated with dangerous use of phones while on the road (e.g., driving, cycling, walking) | OR = 1.9; p <.001; 95 % CI = 1.4–2.6 | ↑ | ●○○ |
| | Steelman et al. (2012) | Compulsive mobile phone checking was positively associated with dangerous mobile phone usage while driving motor vehicles. | r = 0.23; p <.001<br>β = 0.17; p <.05 | ↑ | ●○○ |

r = correlation; OR = odd ratio; CI = confidence interval; NS = non-significant; B = unstandardised coefficient of beta (population); β = standardised coefficient of beta; NA = not available; p = p value.

thought about initiating phone use while driving (good = 1, to bad = 7), and White et al. (2012) investigated whether using phone while driving would be considered good (extremely unlikely = 1, to extremely likely = 7). These questions describe independent behaviours with different motivations that prevent us from conducting a meta-analysis. Other cases include the intention to use a phone while driving. Only two studies considered the impact of Mobile Phone Involvement on the intention to use phones while driving (White et al., 2012; Gauld et al. 2014). Regarding phone use engagement, only two studies used the FoMO scale (Brown et al., 2021; Przybylski et al., 2013) and the Mobile Phone Involvement scale (Brown et al., 2021; Sullivan et al., 2021). For pedestrians, only two studies used the Mobile Phone Involvement scales towards intention to use a phone while crossing the street (Jiang et al., 2017; Lennon et al., 2017) and towards phone use engagement while crossing a street (Hou et al., 2021; Jiang et al., 2017). While there are three articles on nomophobia and phone use while driving (Kaviani et al., 2020a; Kaviani et al., 2020b; Kaviani et al., 2022), the reported data came from one study. As can be seen, the small number of studies analysing the same construct and outcome prevent us from generalising findings.

The present review highlights the urgency to have better and standard research . In addition, we do not have sufficient information to

**Table 9**
Association Study between MMPU and Performance Changes.

| Road user | Study | Results: Qualitative | Results: Quantitative | Direction | Global Rating EPHPP |
|---|---|---|---|---|---|
| Drivers | Chee et al. (2021) | Phone dependence moderated the effect of phone presence on speeding. | F(2,114) = 3.21, p =.038 | ↑ | ●○○ |
| | | Phone emotional attachment did not affect speeding. | NS | NS | ●○○ |
| | Gauld et al. (2017) | Mobile phone involvement was positively associated with initiating cognitive capture while driving. | r = 0.34; p <.001<br>β = 0.17; p <.001 | ↑ | ●○○ |
| | | Mobile phone involvement was positively correlated with monitoring/reading cognitive capture while driving. | r = 0.34; p <.001<br>β = 0.29; p <.01 | ↑ | ●○○ |
| | | Mobile phone involvement was positively associated with responding to cognitive capture while driving. | r = 0.34; p <.001<br>β = 0.17; p <.01 | ↑ | ●○○ |
| | Kass et al. (2016) | Drivers with high mobile phone dependence had no difference (centerline crossings) than those with low mobile dependence drivers (scenario runs 1 to 2). | F(1, 41) = 5.89; p <.05 | NS | ●○○ |
| | | Drivers with high mobile phone dependence had no difference (mean speed) from low mobile dependence drivers. | F(1, 41) = 8.33; p <.01 | NS | ●○○ |
| | | Drivers with high mobile phone dependence had no difference (traffic violations) from low mobile dependence drivers. | F(1, 41) = 2.63; p =.11 | NS | ●○○ |
| | | Drivers with high mobile phone dependence had no difference (road edge excursions) from the control group. | F(1, 41) = 3.03; p =.09 | NS | ●○○ |
| | Koppel et al. (2022) | Nomophobia was positively associated with errors while driving. | r = 0.274; p <.01 | ↑ | ●○○ |
| | | Nomophobia was positively associated with lapses while driving. | r = 0.319; p <.01 | ↑ | ●○○ |
| | | Nomophobia was positively associated with violations while driving. | r = 0.190; p <.01 | ↑ | ●○○ |
| | | Nomophobia was positively associated with aggressive violations while driving. | r = 0.196; p <.01 | ↑ | ●○○ |
| | | Nomophobia was positively associated with aberrant driving behaviours (composite of error, lapses, and violations). | β = 0.10; p <.01 | ↑ | ●○○ |
| | Lannoy et al. (2020) | Mobile phone dependence was not associated with dangerous phone use while driving. | r = 0.18; p <.05 (NS)<br>β = 0.06 | NS | ●○○ |
| | Matias et al. (2021) | Fear of Missing Out was positively associated with driving visual search tasks in difficult situations (i.e., high-fog density). | r = 0.48 | ↑ | ●○○ |
| | Struckman-Johnson et al. (2015) | Cell phone dependence was negatively associated with perceived texting distractibility while driving for males. | Males: r = -0.240; p <.01 | ↓ | ●○○ |
| | | Cell phone dependence was not associated with perceived texting distractibility while driving for females. | Females: r = -0.026 (NS) | NS | ●○○ |
| | Van Dam et al. (2020) | Mobile phone dependency had no difference with the effect on drivers' situational awareness when they were distracted by a text message that they could not respond to. | NA | NS | ●○○ |
| Pedestrians | Mourra et al. (2020) | Smartphone addiction proneness could not predict missed stimuli in the direction task while walking. | b = 0.034, t(138) = 2.06; p =.041 | NS | ●○○ |
| | | Smartphone addiction proneness could not predict accuracy in the task direction while walking. | b = -0.00087, t(138) = -0.58; p =.565 | NS | ●○○ |

r = correlation; OR = odd ratio; CI = confidence interval; NS = non-significant; b = unstandardised coefficient of beta (sample); β = standardised coefficient of beta; NA = not available; p = p value; F = F distribution.

inform healthcare practice about the implications for prevention and the risks on the road for road users with high MMPU. We acknowledge that self-reported measurements are not always the best and make it difficult to develop policies and guidelines to support safe mobility for all road users. Future research in this area must explore and demonstrate the theoretical underpinnings of the MMPU on-road behaviour relationship. There is still much work in this field related to the limitation of its concepts, measurement scale, and methodologies. We need consistency in research; consistent well-validated scales and clear behavioural definitions should be used. Also, research methods oriented to establish a causality link between MMPU and on-road behaviour are needed. Therefore, to further study the impact of MMPU on road user behaviour, future research may conduct investigations using observational methods and objective measures of MMPU (i.e., apps which monitor the frequency of use) and longitudinal designs. The evidence of the impact of MMPU on on-road behaviour also highlights that there is scope to use MMPU-specific intervention to improve road safety, as they most likely will have a spill-over effect on on-road behaviour.

## 6. Conclusion

Mobile phone use on the road is currently considered one of the most prominent road safety issues. This review systematically analysed evidence on MMPU related to road user behaviour. A total of 44 studies were included for consideration. Our synthesis confirmed that MMPU is associated with user behaviour on the roads. 90.9% (30/33) of studies considering observed or self-reported behaviour found that road users with high MMPU scores are more likely to use their phones on the road. For both motorists (i.e., car drivers and motorcyclists) and vulnerable road users (i.e., cyclists and pedestrians), phone use on the roads can be dangerous and often illegal (Lennon et al., 2017; Nguyen-Phuoc et al., 2020b; Oviedo-Trespalacios et al., 2019). The association between MMPU and on-road behaviour found in this study provides evidence that MMPU is a determinant of distraction on the road and brings new opportunities for developing evidence-based interventions. For example, practitioners can support road safety by directly addressing MMPU, as lower MMPU will result in less phone use on the road.

Although a few studies showed limited evidence that MMPU decreases the performance of road users engaged in distraction, the majority identified a potential link between MMPU and safety–critical traffic events, i.e., falling, slipping, bumps/collisions, moving violations, road traffic injuries, and motor vehicle crash. These findings suggest that MMPU is a risk factor for road safety. This has important implications for policy because if we want to prevent health-compromising behaviours

**Table 10**
Association study between MMPU and Safety Outcomes.

| Road user | Study | Results | | Direction | Global Rating EPHPP |
|---|---|---|---|---|---|
| | | Qualitative | Quantitative | | |
| Drivers | Adeyemi (2021) | Drivers classified as prone to mobile phone addiction proneness had 2.64 times more likely to have phone-related road accidents. | OR = 2.64; 95 %CI = 1.37–5.07 | ↑ | ●○○ |
| | Chee et al. (2021) | Phone emotional attachment did not affect collisions. | NS | NS | ●○○ |
| | Kass et al. (2016) | Drivers with high mobile phone dependence had no difference (collision) from low mobile phone dependence drivers. | F(1, 41) = 3.86; p =.056 | NS | ●○○ |
| | O'Connor et al. (2017) | Compulsive cell phone use was not associated with a previous motor vehicle crash risk. | Anticipation: B = -0.12<br>Emotional: B = -0.17<br>Time Impact: B = 0.10 | NS | ●○○ |
| Pedestrians | Appel et al. (2019) | Fear of Missing Out (FoMO) was positively associated with dangerous incidents due to phone use while walking in traffic. | r = 0.228; p <.001<br>Exp (B) = 1.60; 95 % CI = 1.13–2.27); p =.009 | ↑ | ●○○ |
| | Tao et al. (2016) | Problematic mobile phone use increased the likelihood of pedestrian collisions by 3.56 (middle and high school students). | Middle school students<br>OR = 3.56; 95 % CI = 3.05–4.15<br>High school students<br>OR = 3.56; 95 % CI = 2.47–3.19 | ↑ | ●○○ |
| | | Problematic mobile phone use increased the likelihood of falls while walking by 3.91 (middle and high school students). | Middle school students<br>OR = 3.91; 95 % CI = 3.25–4.71<br>High school students<br>OR = 3.91; 95 % CI = 2.49–3.40 | ↑ | ●○○ |
| Unspecified | Liese et al. (2019) | Road users who reported more symptoms on the DSM-5 scale reported experiencing motor vehicle accidents in the past year than those who did not report. | F(1, 463) = 4.10; p =.044 | ↑ | ●○○ |
| | | Road users who reported higher scores on the Self-perception of Text-message Dependency Scale (STDS) reported moving violations than those who did not report. | Emotional reaction [F(1, 463) = 5.50; p =.019];<br>Excessive use [F(1, 463) = 4.04; p =.045];Relationship maintenance [F (1, 463) = 4.95; p =.027] | ↑ | ●○○ |
| | | Road users reported higher scores on the DSM-5 scale texting addiction reported a moving violation than those who did not report. | F(1, 463) = 9.21; p =.003 | ↑ | ●○○ |
| | Kim et al. (2017) | Smartphone addiction increased the likelihood of traffic accidents by 3.76 times. | OR = 3.76; 95 % CI = 0.85–16.72 | ↑ | ●○○ |
| | | Smartphone addiction increased the likelihood of falling/slipping by 2.08 times. | r = 0.13; p =.001<br>OR = 2.08; 95 % CI = 1.10–3.91 | ↑ | ●○○ |
| | | Smartphone addiction increased the likelihood of bumps/collisions by 1.83 times. | r = 0.15; p <.0003<br>OR = 1.83; 95 % CI = 1.16–2.87 | ↑ | ●○○ |
| | | Smartphone addiction increased the likelihood of being trapped in the subway by 2.85 times. | OR = 2.85; 95 % CI = 0.59–13.76 | ↑ | ●○○ |
| | Tao et al. (2016) | Problematic mobile phone use increased the likelihood of road traffic injuries by 3.23–3.93 times. | Middle school students<br>OR = 3.93; 95 % CI = 3.01–5.12<br>High school students<br>OR = 3.23; 95 % CI = 2.61–4.00 | ↑ | ●○○ |
| | | Problematic mobile phone use increased the likelihood of unintentional injuries such as falls by 2.91–3.91 times. | Middle school students<br>OR = 3.91; 95 % CI = 3.25–4.71<br>High school students<br>OR = 2.91; 95 % CI = 2.49–3.40 | ↑ | ●○○ |

r = correlation; OR = odd ratio; CI = confidence interval; NS = non-significant; β = standardised coefficient; NA = not available; p = p value; F = F distribution.

on the road, such as distracted driving or walking, we need to address the underlying mental issues of the road users such as MMPU. Most of the existing interventions to manage distracted driving are based on the social, technology, and traffic policy aspects. At the same time, very little attention has been given to the cognitive issues that drive these risky behaviours (Regan and Oviedo-Trespalacios, 2022).

The findings of the present systematic review suggest that addressing the psychological determinants of phone use while driving, such as MMPU, is necessary to prevent phone use on the road. A key lesson is that road safety stakeholders should not focus only on external factors to the road user, such as penalties and policy, but consider the intrinsic factors that influence phone use on the road. MMPU is a mental health and psychological phenomenon that requires a psychological approach to design effective solutions (Sohn et al., 2019). For example, MMPU can adversely affect attentional and sensory brain networks (Li et al., 2021). Also, MMPU is associated with reduced self-control and increased risk-taking behaviour (Dou et al., 2020). Importantly, this implies that interventions that seek to improve an individual's decision-making and self-regulation (e.g., education programs (Rowden & Watson, 2014) and enforcement (Bates et al., 2016; Rowden and Watson, 2014)) might be less effective among individuals experiencing significant MMPU. Indeed, Billieux et al. (2015) showed that MMPU leads to an extraversion pathway in the form of dependence-like symptoms and excessive phone use driven by a strong and constant desire to socialize with others. This desire to socialise with others while on the road, a context that requires concentration and sound decision-making to avoid unexpected hazards, can result in safety risks. Importantly, this finding also creates new opportunities for preventing distraction on the road. For example, using psycho-informatics methods to diagnose and treat MMPU could be an effective tool to prevent phone use on the road as they address MMPU directly (see Montag et al., 2015 for more information). The transport and road safety disciplines must work with healthcare professionals and technology organisations to understand and address the impact of MMPU on the road.

In conclusion, this review highlights that there is a way that MMPU can result in adverse health consequences related to critical safety outcomes (i.e., traffic injuries, pedestrian collision, falling/slipping, and being trapped in the subway). This finding confirms the MMPU framework by Billieux et al. (2015), which describes the association between MMPU and road trauma. MMPU also significantly affects cognition, which is a determinant of behaviour. Road safety researchers need to carefully consider variables (i.e., attitude, risk perception, and intention) when using psychosocial frameworks as an addition. It is also necessary for transport and road safety professionals to work with healthcare professionals and technology organisations as part of prevention initiatives targeting distraction on the road.

## 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

No data was used for the research described in the article.

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